United States Department of Agriculture
Forest Service
Nez Perce -Clearwater National Forests
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File Code: 1920; 1560
Date: October 13, 2023

Honorable Shannon Wheeler
Chairman
Nez Perce Tribal Executive Committee (NPTEC)
P.O. Box 305
Lapwai, ID 83540

Dear Chairman Wheeler,

Thank you for your hospitality and for the conversation at our meeting with the Nez Perce Tribal Executive Committee on September 26th, 2023. I appreciate the open dialogue which gave us a better understanding of the work we have left to do on the revised Forest Plan for the Nez Perce-Clearwater National Forests from the Nez Perce Tribe's perspective. I look forward to our upcoming meeting with NPTEC on October 24th.

Following our September meeting I have gained a better appreciation for the Tribe's position regarding standards in relation to tribal treaty rights. While the 2012 planning rule forms a regulatory framework that differs from your perspective and from previous Forest Service rules, we respect your viewpoint and I believe we can continue to work together to find a collaborative solution.

As I have remarked in the past, future projects will be developed to move towards desired conditions. Using a co-stewardship framework, it is my hope that we will be developing projects together that move landscapes towards our joint desired conditions. When developing projects in this manner, ensuring constraints are met at the end of project development should be a mere formality as we will have already built projects that meet our mutual needs, including providing for treaty reserved rights and meeting our treaty obligations. This up-front collaboration to build a program that meets desired conditions will help insure we also address trade-offs at the Forest-scale.

The revised plan, as of this week, includes 45 goals, 199 desired conditions, 51 objectives, 122 guidelines and 68 standards to guide sustainable and integrated resource management. As described in 36 CFR §219.15, consistency with **all** plan components, not just standards, is an important, and mandatory, part of project development. "A project must contribute to the maintenance or attainment of one or more goals, objectives or desired conditions and does not foreclose the opportunity to maintain or achieve any goal, desired condition or objectives, over the long term." Thus, my expectation is that from the initial development of a project, an action that does not meet our obligation to provide access to treaty reserved resources for the Tribe to practice their treaty rights on the Forest, would not be permitted to continue to be developed or the project would be modified to be consistent with our obligation to provide access to treaty reserved resources. Our team has focused most of our time in developing desired conditions that will achieve the end-state we want to see on the landscape. Many of these desired conditions have been developed in collaboration and in consultation with the Tribe. For instance, one of our desired conditions that was developed collaboratively with the Tribe, FW-DC-WTR-03 demonstrates our commitment to recovery of aquatic ecosystems "Aquatic habitats contribute to ecological conditions capable of supporting self-sustaining populations of native species and diverse plant, invertebrate, and vertebrate aquatic and riparian-dependent species. Aquatic habitats are key contributors to for the recovery of threatened and endangered fish species and provide important habitat components for all native aquatic species." Another example of how desired conditions will guide our work in the future is FW-DC-WLMU-06, which states "Habitat conditions maintain or improve elk habitat use and provide nutritional resources sufficient to support productive elk populations. The amount and distribution of early seral nutritional resources are consistent with the desired conditions in the Forestlands and Meadows, Grasslands, and Shrublands sections. Elk habitat quality is not degraded by invasive plant species." Any proposed project that impaired our ability to provide for quality fish or wildlife habitat in the future, at the Forest scale, would be inconsistent with these desired conditions and therefore not allowed to proceed. We also have objectives that aim to actively restore ecological resources, such as soil and riparian habitats, as well as objectives that enhance treaty reserved resources and facilitate tribal access to them. Precluding attainment of these objectives would also be inconsistent with the plan.

As we then apply the project constraints to a proposed project at the end of project development, the legal framework becomes for standards: "The project or activity complies with applicable standards", and for guidelines "the project or activity: (i) complies with applicable guidelines as set out in the plan; or (ii) is designed in a way that is as effective in achieving the purpose of the applicable guidelines."

We asked your staff to provide specific guidelines they recommend to be standards. Two were brought forward to our attention. We reanalyzed these two guidelines and determined that if those guidelines were standards, it is likely that critical restoration projects proposed by the Tribe and others would not be able to move forward, and if these plan components would have been standards in the past, at least two projects proposed and implemented by Tribe would not have been able to proceed without a plan amendment. This exemplifies the need for some flexibility in certain situations- especially when the planned project is a benefit to the environment or is an affirmative action to benefit and improve tribal treaty rights. We have since had an opportunity to have conversation with your staff regarding our concerns with converting these two guidelines to standards. We still are concerned that critical aquatic restoration work, proposed by the Tribe and by the Forest Service, including three current planning projects (Packer Meadows, Crooked River, planned work at Musselshell Meadows) would not be able to proceed without a forest plan amendment should we make the conversion.

At the same time, I asked my staff to take another hard look at the guidelines in the plan. Each guideline has been scrutinized many times before, however, after hearing how you articulated your concerns in our government-to-government meeting last month, the Revision team and I went through the exercise again, trying to look at through a lens more similar to yours. As a result of that exercise, I am proposing ten guidelines be re-written as standards, see Appendix 1.

I look forward to your review of this proposal. We will also continue to evaluate any specific guidelines brought forward for inclusion as a standard and welcome conversation regarding trade-offs of any potential modification. We are also awaiting further input from your staff on the desired conditions in the Tribal Trust Responsibility section as well as direction from you regarding additional plan components for special areas on the Forest that have significant cultural value. We endeavor to include perspectives and related plan components from the October 2022 workshop with Nez Perce Tribal gatherers and elders, Gathering Perspectives of Our Homelands, after the objection period.

Regarding Tribal Trust Responsibility Standard 01, I was able to talk to our Regional Office of General Counsel (OGC) attorney and Washington Office OGC attorney who specializes in Treaty Right law. She will be contacting Mike Lopez directly to set up a call with your Office of Legal Counsel (OLC), herself and a WO-OGC attorney with expertise in Planning. I am hopeful that our respective attorneys can have a discussion and provide us with counsel on the legal framework of the standard and potential paths forward. I understand the wording of the plan component in the draft FEIS version is not satisfactory to you. It was intended to recognize that no matter the project, there are likely to be small and temporary impacts to treaty reserved resources and may impact access for limited periods or at a limited scale. For example, our collaborative aquatic restoration projects have short term negative impacts on fish, access, and water quality for the long-term benefit. Similarly, we are unable to continue using the wording of the 1987 plans, as you requested, as they do not meet our plan component definitions under the 2012 planning rule. We have used much of the 1987 plan standard language verbatim in the forest wide goal FW-GL-TT-03 as that it aligns well with how the regulations define goal plan components. I am looking forward to hearing the attorneys' perspectives on verbiage options for you and I to consider.

In your comment letter on the DEIS sent on April 20, 2020, you indicated that the language of FW-TT-STD-01, "Agency actions that are detrimental to the protection and preservation of Native American religious and cultural sites, practices and treaty rights shall not be authorized", was acceptable to you. If NPTEC still concludes this wording, coupled with the other existing goals, desired conditions, and objectives (see Appendix 2), is satisfactory, perhaps we could use this language as a start for future permutations. We are also proposing one new standard and one new guideline for your consideration regarding special forest products as they relate to access to treaty reserved resources, see appendix 2.

Finally, I wanted to provide some perspective that you requested at our meeting with you regarding how our timber harvest levels correlate to healthy forests. Timber harvest, on the Nez Perce-Clearwater is one of several tools that is used to create healthy forests that are resilient to climate change. Several studies, including a study done by the Nature Conservancy (Landscape Assessment) and a study done as part of this planning process (Natural Range of Variability modelling) show the magnitude of the problem. Our Forests are over-dense due to fire suppression over the last hundred years. Ecosystems once managed by yourself to be in a natural state are now highly departed from that healthy balance. We have heard many times from NPTEC members, tribal members, and staff that the Tribe is concerned with the health of the Forest and is noticing the amount of dead and dying trees. Nearly one-third of the Forest in the managed front country is in an unhealthy condition. On 80% of the Forest, the tool we have to return ecosystems to be within a healthy balance is fire--both natural and planned ignitions. We recognize that the Nez Perce having been putting fire on the landscape since time immemorial and we hope to collaborate more with you on these types of projects. On 20% of the Forest, in Management Area 3, we have additional tools such as timber harvest and mechanical thinning. These tools are necessary to have greater control in areas near private land and communities and they also provide jobs and income to local communities. We have carefully crafted a land management plan that ensures timber harvest, and other mechanical tools, will be done thoughtfully and only where impacts won't keep us from meeting our legal, moral, and ethical obligations both to the Tribe and to the US people. The proposed Plan would move our forested ecosystems towards into the desired condition range in 35 to 40 years. In order to do this, we would need about 60,000 acres of disturbance each year to move our forests towards a healthy condition. Of those 60,000 acres a year, up to 10,000 acres may be completed through timber harvest; the remainder would be achieved with natural or planned fire. The timber harvest is limited geographically to about 20 percent of the Forest and within that, it is subject to all of the goals, desired conditions, guidelines and standards in the Revised Forest Plan. The result of this restoration work is a timber harvest volume of up to 190 million board feet as a byproduct of moving towards our desired conditions—a byproduct that also helps sustain economies and communities and provides sustainable building solutions. To insure integration, as the vegetation restoration work increases, so too does the aquatic restoration levels. We hope that the Nez Perce Tribe continues to partner with us in this important restoration work through our Good Neighbor Authority and other Agreements.

As we work to manage our forests to be resilient to the effects of climate change- timber harvest will be a critical part of any holistic adaptation strategy. Best available scientific information clearly demonstrates that reducing tree density is a very important part of creating resilient forests. The Intertribal Timber Council has gathered a lot of information on this topic and also recommends reducing densities and overstory canopy to prepare our forests for a changing climate. As described above, fire is the tool we use to increase resilience and address the wildfire crisis on most of the landscapes across the Forests. However, wildfire cannot be used on a large scale everywhere and thus on 20% of the landscape in the front country, timber harvest must be used in combination with fire to reduce impacts to communities and protect sensitive ecosystems. As an example, the linear fuels break projects currently being proposed are strategically placed areas utilizing mechanical harvest that will protect communities from future fire ignitions—but in order to create resilient ecosystems and fully use fire in the future, these mechanical fuels breaks are necessary to protect communities.

I look forward to having continued conversations on all these points. We will be prepared on October 24th to discuss each of these topics in more detail and look forward to your feedback. Thank you again for the generous amount of time your staff and NPTEC have spent working with the Forest since 2012 in development of this revised plan. I am confident we will achieve a mutually beneficial result that demonstrates our commitment to meet our tribal trust obligations and honor the past, present, and future culture of the Nez Perce.

Sincerely,

CHERYL F. PROBERT
Forest Supervisor

Attachments:
Appendix 1- Proposed Guidelines to Standards
Appendix 2- Tribal Trust Resources Excerpt from revised plan

cc: Mike Lopez, OLC; Aaron Miles, Sr., Director, DNRM; Dave Johnson, Director, DFRM

Appendix 1 – Potential Guidelines to Convert to Standards

Plan Component	Plan Component Text
FW-GDL-RMZ-04	Aerial application of chemical retardant, foam, or other fire chemicals and petroleum should be avoided in mapped aerial retardant avoidance areas in order to minimize impacts to the RMZ and aquatic resources.
FW-GDL-RMZ-05	To minimize adverse effects to the Endangered Species Act listed species, riparian areas, aquatic habitat, and riparian dependent species, new incident bases, camps, helibases, helispots, staging areas, and other centers for incident activities should be located outside of riparian management zones. When no practical alternative exists, measures to maintain, restore, and enhance riparian areas, stream habitat, and riparian dependent species should be used.
FW-GDL-RMZ-06	To minimize sediment delivery and adverse effects to stream channels, construction of machine fireline in riparian management zones should be avoided, except where needed to cross streams or to save human life.
FW-GDL-ARINF-11	Culverts and bridges in fish-bearing and perennial streams should allow for passage of fish and other aquatic and riparian dependent species through the establishment of banks inside or beneath the crossing structure and mimicking the natural channel features, unless precluded by site characteristics such as bedrock or high channel gradient.
FW-GDL-AREM-03	To maintain water quality and to prevent biological, chemical, or industrial pollutants from being delivered to water bodies, mineral exploration, processing, and extraction projects, except for suction dredging, should not have direct water flow paths to streams, lakes, or wetlands. Projects should install barriers between streams, lakes, wetlands, or groundwater dependent ecosystems and construction-related pollutant hazards such as sumps, processing pits, fuel storage, latrines, adits and shafts, underground workings, open pits, overburden, development rock and waste rock dumps, tailings impoundments, leach pads, mills, and process water ponds or natural pollutant hazards such as acidity, metals, sulfate, cyanide, or nitrate or a combination of the preceding.
FW-GDL-AREM-04	Mineral operations should minimize adverse effects to aquatic and riparian- dependent resources in riparian management areas. Best management practices and other appropriate conservation measures should be included in plans of operation to mitigate potential mine operation effects.
FW-GDL-ARGRZ-03	To maintain quality and quantity of water flows to, within, or between groundwater dependent ecosystems, water to new or reconstructed spring developments should be protected from livestock trampling.

Appendix 1 – Potential Guidelines to Convert to Standards

Plan Component	Plan Component Text
FW-GDL-WL-04	New authorizations and permit reauthorizations for domestic goat packing should follow best management practices and include provisions to prevent disease transmission between domestic goats and bighorn sheep.
FW-GDL-WLMU-01	When closing routes to motorized use, to ensure benefits to wildlife habitat are realized, include measures to sufficiently exclude motorized use on closed routes.
GA-GDL-NHL-05	New temporary or permanent road and trail construction should not be permitted within the Landmark unless the integrity of the National Historic Landmark is maintained and the purpose of the action is to benefit the National Register integrity of the Landmark.

Appendix 2 (LMP)
Tribal Trust Responsibilities

The *Niimíipuu* (pronounced Ne-Mee-Poo) people aboriginally occupied a territory that encompassed about 13,204,000 acres of land, including nearly all land now managed by the Nez Perce-Clearwater. According to the Nez Perce Tribe Department of Fisheries Resource Management Plan 2013-2018 (Nez Perce Tribe Department of Fisheries Resources Management 2013):

> The land and its waters define the Nez Perce way. Over the course of thousands of years, nature has taught us how to live with her. This intimate and sacred relationship unifies us, stabilizes us, [and] humbles us. It is what makes us a distinct people and what gives us our identity. We cannot be separated from the land or our rights without losing what makes us Nez Perce. We defend our rights to preserve who we are and what we hold sacred (5).

The Nez Perce Tribe has ancestral and treaty-reserved rights to uses and resources on the Nez Perce Clearwater. Indian treaty rights are property rights held by the sovereign Indian tribes who signed the treaties. Under the Nez Perce Treaty of 1855 and subsequent treaties, the Nez Perce Tribe was reserved separate reservation lands, but also retained certain rights to hunt, fish, graze, and gather on the lands ceded to the United States. These rights retained on ceded lands are known as “off-reservation treaty rights” or “other reserved rights.”

Trust responsibility arises from the United States' unique legal and political relationship with Indian tribes. It derives from the Federal Government's consistent promise in the treaties that it signed to protect the safety and well-being of the Indian tribes and tribal members. The federal trust responsibility is a legally enforceable fiduciary obligation on the part of the United States to protect tribal treaty rights, lands, assets, and resources, as well as a duty to carry out the mandates of federal law with respect to all federally recognized American Indian and Alaska Native tribes and villages.
The Nez Perce People have manipulated the land to create conditions favorable for their existence. The Nez Perce are intimately integrated with the ecology of the land and have played a role in defining the ecology since time immemorial.

Goals

FW-GL-TT-01. Proposed practices and management activities honor treaty reserved rights of Native American tribes or tribal members.

FW-GL-TT-02. Proposed practices and management activities recognize the role the Nez Perce have had on the ecology of the area and integrate traditional ecological knowledge into future projects.

FW-GL-TT-03. Proposed practices and management activities are coordinated with other government agencies and Indian tribes to ensure requirements of all laws and regulations are met and terms of Indian Treaties are upheld.

FW-GL-TT-04. The Forest coordinates with the Nez Perce Tribe to restore, promote, and enhance traditional botanical species that are accessible to tribal members.

FW-GL-TT-05. The Forest supports the Nez Perce Tribe’s interest in food sovereignty for Nez Perce Tribe members.

FW-GL-TT-06. The Forest coordinates with the Nez Perce Tribe to maintain and enhance access for tribal members to exercise treaty reserved rights.

FW-GL-TT-07. Consultation with the Nez Perce Tribe, traditional cultural practitioners, consulting parties, adjacent landowners, and project designers aid the FS in protecting and enhancing traditional cultural properties, cultural landscapes, sacred sites, and other culturally significant areas that provide tangible links to historically rooted beliefs, customs, and practices.

Desired Conditions

FW-DC-TT-01. Vegetative conditions provide a sustainable diversity of habitats necessary to provide plant and animal species that are of tribal importance.

FW-DC-TT-02. Habitats support wildlife and other resources at huntable and harvestable population levels for the exercise of treaty reserved rights.

FW-DC-TT-03. At the forest scale, culturally important botanical species are present and vigorous in quantities that are harvestable and accessible to Nez Perce tribal members.

FW-DC-TT-04. Hot springs are natural and free flowing in function and appearance. The hydrological, biological, and aesthetic resources in and around them are preserved, and are accessible for traditional cultural uses. Water quality meets state water quality standards for beneficial uses. Human use impacts are minor and consistent with traditional cultural uses of the site.

Objectives

FW-OBJ-TT-01. Restore 1,000 acres of forested stands in habitat types that could produce huckleberry in a manner that promotes huckleberry abundance over the long-term every 5 years.

FW-OBJ-TT-02. Increase wet meadow associated culturally important botanical species, such as camas, production on 50 acres every 5 years.

Standards

FW-STD-TT-01. *PENDING*

FW-STD-TT-02 (NEW). Commercial collection of special forest products shall not be permitted in an area if the Nez Perce Tribe Executive Committee determines it would result in limiting tribal member access to those treaty reserved resources. Areas shall be re-requested by Nez Perce Tribe Executive Committee on an annual basis if tribal member access limitations to treaty reserved resources persist.

Guidelines

FW-GDL-TT-01. Collection of special forest products should not result in destruction of resources.

FW-GDL-TT-02 (NEW). To ensure tribal access to first foods and culturally important botanical species, personal use collection of special forest products should not be permitted in areas of known conflict with tribal uses when identified and requested by the Nez Perce Tribal Executive Committee.

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Honorable Shannon Wheeler
Chairman
Nez Perce Tribe Executive Committee (NPTEC)
P.O. Box 305
Lapwai, ID 83540

Dear Chairman Wheeler;

As the Nez Perce-Clearwater National Forests and the Nez Perce Tribe continue to cooperate and collaborate on the revised Land Management Plan, I want to sincerely thank you for the historic visit to Washington D.C. and meeting with Chief Moore. We were humbled to have Vice-Chairman Miles and Mr. Lopez speak to the revised plan and our relationship in their own words. Chief Moore and Regional Forester Marten have voiced their appreciation for and their recognition of the significance of your visit on several occasions since. The comprehensive nature of the plan itself with respect to Treaty Rights is a first in the Agency and our Office of Tribal Relations recognized the collaborative relationship between the Nez Perce Tribe and Forest.

We are committed to meeting our Treaty obligations and upholding our trust responsibilities. As we work through our remaining differences, I have listened and learned we sometimes speak different languages informed by different world views. I am proposing the attached resolution document as our attempt to bridge the gap and demonstrate our commitment to meet and exceed those obligations. This document is a comprehensive response to your November 2nd letter and incorporates discussions we have had since, including those held in person in Washington, DC. We intend to make these changes in the Land Management Plan prior to the public release of the documents.

Moving to the next stage of the public process will not limit or change the ability for us to continue government to government consultation. Through that process, we can make additional mutually agreed upon changes throughout the objection period and up until decision is made, just as we have done in site specific projects. We are prepared to clearly state this in the draft Record of Decision with the language as shown in the attached document. As we listen to NPTEC and your staff, we continue to augment the Tribal Trust Responsibility section of the draft plan as well. I have attached the latest version to this letter. This is only the Tribal Trust section and does not include the more than 300 plan components throughout the Plan specifically developed to restore, sustain and/or promote treaty reserved resources across the Forest. We will continue government to government consultation as the Regional Forester works through the objections received and I am committing to including the Tribe in any potential changes requested by other interested parties.

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We sincerely appreciate the time you and your staff have spent over many years to help us arrive at this point. I am confident that we will continue to work through our remaining differences and when a Record of Decision is signed, we will be standing together in celebration.

Sincerely,

Cheryl F. Probert
Forest Supervisor

cc: Mike Lopez, OLC; Aaron Miles, Sr., Director, DNRM; Dave Johnson, Director, DFRM

Enclosures: Proposed Resolutions
Tribal Trust Responsibilities Section as of 11092023
Draft ROD language Tribal Trust Government to Government Status as of 11102023

Proposed Resolutions

Standards and Guidelines

As viewed through the lens of the Nez Perce Tribe, standards are needed to provide certainty, accountability and safeguards that tribal treaty rights will not be eroded. Both parties agree that standards, defined under the 2012 planning rule are much the same as the definitions under the 1982 framework. They are constraints on activities that must be followed unless the Plan is amended, through a public and analytical process.

As viewed by the Forest Service through the definitions in the 2012 planning rule, standards are not the only mechanisms that provide safeguards. Guidelines for instance, are now mandatory constraints on activity. While there may be flexibility in how they are implemented, there is no flexibility in meeting the intent of the guidelines and there are the same regulatory constraints on actions as on standards. Any utilization of the flexibility of a guideline could only be done after consultation with the Tribe, with the regulatory agencies and through a public process.

Both parties agree that these distinctions in the 2012 planning rule have not been tested in Court and that the Tribe does not feel treaty rights are adequately protected without a standard stating such. Out of respect for these two different world views between sovereign nations, both parties agree that legal counsel will confer to assist the parties in developing a standard similar to the standard in the 1987 Clearwater Plan that meets the 2012 planning rule framework and provides certainty for the Tribe.

In addition, to further safeguard treaty reserved resources, the Forest Service agrees to convert 12 guidelines to standards using the verbiage below.

> **FW-STD-WTR-07**. Large woody debris shall not be removed from stream channels or floodplains unless it threatens public safety, such as fire ingress/egress; critical infrastructure, such as mid-channel bridge piers; or for the implementation of restoration projects when there will be a net increase in the amount of woody debris in the RMZ post project.
>
> **FW-STD-RMZ-08**. New road, trail, and landing construction, including temporary roads, shall not be constructed in riparian management zones except where:

- needed for the implementation of restoration projects, or
- necessary for stream crossings, or
- a road or trail relocation contributes to attainment of aquatic and riparian desired conditions, or
- a road or trail inside the RMZ would greatly reduce the total ecological, cultural or social impacts of an existing or proposed route outside the RMZ, or
- Forest Service authorities are limited by law or regulation (e.g., General Mining Act of 1872).

FW-STD-RMZ-09. Aerial application of chemical retardant, foam, or other fire chemicals and petroleum shall be avoided in mapped aerial retardant avoidance areas.

FW-STD-RMZ-10. New incident bases, camps, helibases, helispots, staging areas, and other centers for incident activities shall be located outside of riparian management zones. When no practical alternative exists, measures shall be taken to restore riparian features that were impacted by the activities.

FW-STD-RMZ-11. Construction of machine fireline in riparian management zones shall be avoided, except where needed to cross streams or reduce risk to responders or the public to an acceptable level.

FW-STD-ARINF-08. Culverts and bridges in fish-bearing and perennial streams shall allow for passage of fish and other aquatic and riparian dependent species through the establishment of banks inside or beneath the crossing structure and mimicking the natural channel features, unless precluded by site characteristics such as bedrock or high channel gradient.

FW-STD-AREM-04. Mineral exploration, processing, and extraction projects, except for suction dredging, shall not have direct water flow paths to streams, lakes, or wetlands. Projects shall install barriers between streams, lakes, wetlands, or groundwater dependent ecosystems and construction- related pollutant hazards such as sumps, processing pits, fuel storage, latrines, adits and shafts, underground workings, open pits, overburden, development rock and waste rock dumps, tailings impoundments, leach pads, mills, and process water ponds or natural pollutant hazards such as acidity, metals, sulfate, cyanide, or nitrate or a combination of the preceding.

FW-STD-AREM-05. Mineral operations shall minimize adverse effects to aquatic and riparian- dependent resources in riparian management areas. Best management practices and other appropriate conservation measures shall be included in plans of operation to mitigate potential mine operation effects.

FW-STD-ARGRZ-04. Water to new or reconstructed spring developments shall be protected from livestock trampling.

FW-STD-WL-03. New authorizations and permit reauthorizations for domestic goat packing shall follow best management practices and include provisions to prevent disease transmission between domestic goats and bighorn sheep.

FW-STD-WLMU-01. When closing routes to motorized use, measures shall be included to sufficiently exclude motorized use on closed routes.

GA-STD-NHL-02. New temporary or permanent road and trail construction shall not be permitted within the Landmark unless the integrity of the National Historic Landmark is maintained and the purpose of the action is to benefit the National Register integrity of the Landmark.

The Forest also agrees to develop a crosswalk of terminology intended to bridge the gap between our respective understanding of the labels on Plan Components. This will be included in the “Other Plan Content” section of the Revised Forest Plan.

Access to Treaty Reserved Resources

The Forest has a responsibility to ensure both sustainability of and access to treaty reserved resources. Those resources come in many forms—plants for medicine and other uses, animals for spiritual and physical sustenance, geographic areas for ceremonies, celebrations and connections. All of these can be impacted by activities permitted within the scope of the Forest Service mission and other laws pertaining to Forest activities. They can also conflict with one another. The parties agree that the Treaty of 1855 ensures access in order to exercise “the right of taking fish at all usual and accustomed places... together with the privilege of hunting, gathering roots and berries, and pasturing their horses and cattle on open and unclaimed land," and this ability can sometimes be impacted by non-tribal members or activities.

Thus, the Forest agrees to add the following plan components to the Tribal Trust Responsibility section to ensure that activities have co-stewardship at the very core and that tribal members’ ability access to forest products is not eroded:

> **FW-DC-TT-05 (NEW).** Through Co-stewardship, consultation and collaboration, the Forests provide for the past, present and future of the Nez Perce culture.
>
> **FW-STD-TT-02 (NEW).** Commercial collection of special forest products shall not be permitted if the Nez Perce Tribe Executive Committee determines it would result in limiting tribal member access to those treaty reserved resources. This determination shall be reviewed annually.
>
> **FW-GDL-TT-02 (NEW).** To ensure tribal access to first foods and culturally important botanical species, personal use collection of special forest products should not be permitted in areas of known conflict with tribal uses when identified and requested by the Nez Perce Tribal Executive Committee for the duration of one harvest season.

Species of Conservation Concern

The Tribe requested that Coho and Spring Chinook Salmon be added to the Regional Forester’s list of Species of the Conservation Concern. Because these are non-native stock, they do not meet the definition of SCC in the 2012 planning rule. In recognition of the importance of these species to the Tribe and to honor our relationship, the Forest agrees to add the following guideline:

> **FW-GL-WLMU-02 (NEW).** In support of the Nez Perce Tribe's healthy and harvestable fisheries objectives for Coho and spring Chinook, and the Lower Snake Compensation Plan's mitigation efforts for harvest fisheries in the Clearwater basin, the Nez Perce-Clearwater coordinates with the Tribe and the State of Idaho to conserve Clearwater River Spring Chinook and Coho fisheries on the Nez Perce-Clearwater.

Elk

Following the Tribe's 2020 comments on elk, a meeting with all cooperating agencies was reconvened to discuss what both the Tribe and Idaho Department of Fish and Game had daylighted in the draft version of the FEIS. Based on this productive conversation and an additional internal review of the Elk plan components in the revised plan, an e-mail was sent to the Nez Perce Tribe and all cooperating agencies in July 2022 requesting feedback on our alternate language. Prior to the November 2nd letter, we had received no response from the Tribe or any of our cooperating agencies. In order to address the Tribe's recent letter on elk, while continuing to base management on best available science, the Forest agrees to modify five plan components using the verbiage written below; this includes converting two guidelines to standards.

> **FW-STD-WLMU-01.** When closing routes to motorized use, measures shall be included to sufficiently exclude motorized use on closed routes.
>
> **MA2-STD-WL-01.** New NFS motorized trails open to the public should not be authorized in Idaho Roadless Areas unless there are adjacent areas of 5,000 acres without open motorized system routes. This standard does not apply to:
>
> - Community Protection Zones (CPZs) as defined by the Idaho Roadless Rule.
> - Areas with existing motorized access that are currently less than 5,000 acres.
> - Existing trails that are relocated or reconstructed to mitigate negative impacts to ecological resources.
>
> **FW-GL-WLMU-01**. The forest cooperates with the Nez Perce Tribe and the Idaho Department of Fish and Game to provide habitat conditions that contribute to wildlife populations at levels meeting tribal trust responsibilities and Idaho Department of Fish and Game species management plan objectives.
>
> **FW-DC-WLMU-06.** Habitat conditions maintain or improve elk habitat use and provide nutritional resources sufficient to support productive elk populations. The amount and distribution of early seral nutritional resources are consistent with the desired conditions in the Forestlands and Meadows, Grasslands, and Shrublands sections. Elk habitat quality is not significantly degraded by invasive species or motorized access.
>
> **MA3-GDL-WLMU-01.** To improve vital rates of female elk by increasing predicted percent body fat, treatments designed to improve elk habitat should focus on one or more of the habitat covariates likely to improve predicted cow elk body fat condition while also considering distance from open motorized routes.

Presidential Memorandum

Regarding the September 27th Presidential memorandum on recovery of Steelhead and Salmon, the memorandum speaks to dams in the Columbia River basin and directs each Agency to work within its mission framework. The Forest Service is responsible for managing the upper watersheds in a sustainable way to promote and support recovery of salmon and steelhead. In this context, the Forest Plan includes hundreds of plan components designed to restore ecological systems in the face of climate change. From a land management plan level, the Forest Service believes the desired conditions for forested, nonforested, meadow and aquatic systems moves us towards those resilient forests. The plan components in the ARCS mitigate and reduce the potential for negative impacts from activities that would reduce habitat quality below thresholds. Priority watershed, desired conditions moving vegetation towards natural range of variability, restrictions on new consumptive uses and motorized access, and much more contribute to meeting the Presidential memorandum.

Based on the analysis in the FEIS, further restriction on activity would exacerbate the problem as critical restoration work in the uplands that would reduce the likelihood of uncharacteristic wildfire or perpetuate the insects and disease that are affecting our forests like a cancer, would be negatively impacted. While impacts of carefully planned and implemented vegetative restoration projects are unlikely to contribute to extinction of a species, uncharacteristic wildfire does have the potential to cause local extinctions in the blink of an eye, especially in a warming and drying climate. We see mitigating this potential impact as a primary duty under NMFA as well as in response to the Presidential memorandum. We have a long-standing partnership with the Nez Perce Tribe that utilizes the economic value of the vegetative restoration projects to restore aquatic ecosystems in concert with the Tribe. In 2023 we have integrated aquatic restoration projects into addressing the wildfire crisis so that we can leverage those opportunities to reduce long-term fire risk while reclaiming and restoring aquatic resources. It is through these multitudes of avenues, all of which involve collaboration with the Tribe, that we believe we are meeting the new Presidential memorandum. We are very concerned about the long-term fate of ESA listed Salmon and Steelhead and believe the focus of this plan on restoring aquatic and forested systems through a multitude of tools will ensure resilient habitats await returning salmon and steelhead, even in the face of climate change. We look forward to co-stewarding these areas with the Tribe and expanding our collaborative work to include ridgetop to ridgetop restoration. As a demonstration of our commitment to meeting this new Presidential Memorandum, I will include a section discussing compliance with this in the Record of Decision.

CHANGES SINCE SEPT 2023 ARE IN RED.

Tribal Trust Responsibilities

The *Niimíipuu* (pronounced Ne-Mee-Poo) people aboriginally occupied a territory that encompassed about 13,204,000 acres of land, including nearly all land now managed by the Nez Perce-Clearwater. According to the Nez Perce Tribe Department of Fisheries Resource Management Plan 2013-2018 (Nez Perce Tribe Department of Fisheries Resources Management 2013):

> The land and its waters define the Nez Perce way. Over the course of thousands of years, nature has taught us how to live with her. This intimate and sacred relationship unifies us, stabilizes us, [and] humbles us. It is what makes us a distinct people and what gives us our identity. We cannot be separated from the land or our rights without losing what makes us Nez Perce. We defend our rights to preserve who we are and what we hold sacred (5).

The Nez Perce Tribe has ancestral and treaty-reserved rights to uses and resources on the Nez Perce-Clearwater. Indian treaty rights are property rights held by the sovereign Indian tribes who signed the treaties. Under the Nez Perce Treaty of 1855 and subsequent treaties, the Nez Perce Tribe was reserved separate reservation lands, but also retained certain rights to hunt, fish, graze, and gather on the lands ceded to the United States. These rights retained on ceded lands are known as “off-reservation treaty rights” or “other reserved rights.”

Trust responsibility arises from the United States' unique legal and political relationship with Indian tribes. It derives from the Federal Government's consistent promise in the treaties that it signed to protect the safety and well-being of the Indian tribes and tribal members. The federal trust responsibility is a legally enforceable fiduciary obligation on the part of the United States to protect tribal treaty rights, lands, assets, and resources, as well as a duty to carry out the mandates of federal law with respect to all federally recognized American Indian and Alaska Native tribes and villages.

Sustaining these lands that we now know as both the Nez Perce homelands and the Nez Perce-Clearwater National Forests, our obligation goes beyond the treaties and to the people and culture themselves. We have collaboratively developed over 300 plan components to sustain and restore the resources reserved in the treaties. It is our greatest responsibility to implement this plan to honor our moral and legal responsibilities to support the past, present and future of the Nez Perce culture and their connection to the land. The Nez Perce are intimately integrated with the ecology of the land and have played a role in defining the ecology since time immemorial, not differentiating between the land and themselves.

Nimiipuu are deeply and inseparably interconnected with the land and the resources. To the Nez Perce, there would not be one without the other. The Nimiipuu names for places describe this connection and understanding in a rich and wholistic way. This Tribal Trust Responsibilities section has specific plan components that honor and signify our obligation to honor the treaties while the entirety of this plan honors and supports sustaining Nez Perce culture.

> Treaties are the law of the land, but the essence of our existence is the uniqueness of who we are as Nimiipuu. Those aspects that define us are tribal, individual, familial. These aspects include but are not restricted to our language, cultural values, customs, ceremonies, rights of passage, history, heritage, hunting, fishing, and gathering. All these aspects are the duties that we as a Tribe must protect and maintain for future generations.

~Simone Wilson, in *Treaties: Nez Perce Perspectives, page 48*

As the Nez Perce do not differentiate themselves from the land, this Tribal Trust Responsibilities section is deliberately placed between the Biophysical Environment and Human Uses of the Forest sections as a bridge between the land and people, a position the Nez Perce have held since time immemorial.

Goals

FW-GL-TT-01. Proposed practices and management activities honor treaty reserved rights of Indian tribes or tribal members.

FW-GL-TT-02. Proposed practices and management activities recognize the role the Nez Perce have had on the ecology of the area and integrate traditional ecological knowledge into future projects.

FW-GL-TT-03. Proposed practices and management activities are coordinated with other government agencies and Indian tribes to ensure requirements of all laws and regulations are met and terms of Indian Treaties are upheld.

FW-GL-TT-04. The Nez Perce-Clearwater coordinates with the Nez Perce Tribe to restore, promote, and enhance traditional botanical species that are accessible to tribal members.

FW-GL-TT-05. The Nez Perce-Clearwater supports the Nez Perce Tribe's interest in food sovereignty for Nez Perce Tribe members.

FW-GL-TT-06. The Nez Perce-Clearwater coordinates with the Nez Perce Tribe to maintain and enhance access for tribal members to exercise treaty reserved rights.

FW-GL-TT-07. Consultation with the Nez Perce Tribe, traditional cultural practitioners, consulting parties, adjacent landowners, and project designers aid the FS in protecting and enhancing traditional cultural properties, cultural landscapes, sacred sites, and other culturally significant areas that provide tangible links to historically rooted beliefs, customs, and practices.

Desired Conditions

FW-DC-TT-01. Vegetative conditions provide a sustainable diversity of habitats necessary to provide plant and animal species that are of tribal importance.

FW-DC-TT-02. Habitats support wildlife and other resources at huntable and harvestable population levels for the exercise of treaty reserved rights.

FW-DC-TT-03. At the forest scale, culturally important botanical species are present and vigorous in quantities that are harvestable and accessible to Nez Perce tribal members.

FW-DC-TT-04. Hot springs are natural and free flowing in function and appearance. The hydrological, biological, and aesthetic resources in and around them are preserved, and are accessible for traditional cultural uses. Water quality meets state water quality standards for beneficial uses. Human use impacts are minor and consistent with traditional cultural uses of the site.

FW-DC-TT-05. Through Co-stewardship, consultation and collaboration, the Forests provide for the past, present and future of the Nez Perce culture.

Objectives

FW-OBJ-TT-01. Restore 1,000 acres of forested stands in habitat types that could produce huckleberry in a manner that promotes huckleberry abundance over the long-term every 5 years.

FW-OBJ-TT-02. Increase wet meadow associated culturally important botanical species, such as camas, production on 50 acres every 5 years.

FW-OBJ-TT-03. Develop a long-term strategy with the Nez Perce Tribe to improve Tribal member access to Wyakin sites on the Forests, consistent with the Treaty of 1855 within 5 years.

Standards

FW-STD-TT-01. RESERVED FOR NEW WORDING

FW-STD-TT-02. Commercial collection of special forest products shall not be permitted if the Nez Perce Tribe Executive Committee determines it would result in limiting tribal member access to those treaty reserved resources. This determination shall be reviewed annually.

Guidelines

FW-GDL-TT-01. To ensure tribal access to first foods and culturally important botanical species, collection of special forest products should not be authorized if it would result in destruction of resources and should minimize conflicts with Nez Perce tribal uses.

FW-GDL-TT-02. To ensure tribal access to first foods and culturally important botanical species, personal use collection of special forest products should not be permitted in areas of known conflict with tribal uses when identified and requested by the Nez Perce Tribal Executive Committee for the duration of one harvest season.

Excerpt of Commitment from Draft ROD to continue Government to Government Consultation

[Bolded for emphasis in dROD]

At the time of release of this draft Record of Decision, we are continuing to work with the Nez Perce Tribe, through government-to-government consultation with their sovereign nation's elected officials. This effort has been ongoing for over a decade. Through the years the Forest and Tribe have developed and worked through many plan components to ensure this Revised Plan protects Tribal treaty rights and trust resources as viewed by the Nez Perce Tribe. The Plan reflects this cooperative relationship throughout its chapters and within its direction. In the weeks leading up to this release we have continued our consultation and have come to consensus on a number of additional specific items, described below. While we are in agreement on concepts, we will continue to collaborate and coordinate on the specific wording especially, but not limited to, how the revised plan will ensure we meet our treaty obligations over the life of the plan from the perspective of the Tribe. In order to do that, I will include a standard specific to treaty rights in the Plan. The draft land management plan now includes a placeholder reflecting my commitment to develop language for this standard in cooperation with the Nez Perce Tribe's Office of Legal Counsel. We have included similar language already as a goal along with multiple desired conditions so that all projects recognize our responsibility to manage tribal trust resources from the very inception. Upholding our treaty obligations is a solemn duty I have as responsible official and am committed to ensuring this plan does that in working with the Nez Perce Tribe's government.

Some of these changes to plan components, arising from government-to-government consultation, were not incorporated into the analysis in the FEIS. These plan component changes, in general, result in more certainty of protection for specific ecological values and less flexibility managing in the future, as requested by the Tribe. Unless noted otherwise, it can be assumed that the analyzed impacts are less than or equal to the impacts described in the FEIS. These changes will be incorporated into the FEIS prior to the publication of the Notice of Availability following the objection period.

Our government-to-government obligations do not end, even with a decision on this Revised Plan, nor is our co-stewardship work with the Nez Perce Tribe limited to these words on paper. We continue to work together outside of the planning process to implement restoration projects, build a collective understanding of the vast ecological knowledge of the Tribe, restore traditional Place Names across the Forest, increase visitor awareness and appreciation for past, present, and future Nez Perce culture, recognize and support Nez Perce business enterprises, and much more. As we move forward to the next step in the public process of revision of our land management plan, I am committed to continuing collaboration and consultation with the Nez Perce Tribe. As the Objection Reviewing Official contemplates changes based on the administrative public process, we also will continue to consult on any items outstanding now as well as any requested or considered changes that may result from the pre-decisional objections process. We endeavor to be standing together with the Tribe at the signature of the ROD knowing that

we have fully met our obligations under the treaty of 1855 and perpetuated our desired to exceed our trust responsibilities into the future. Projects developed under this Plan will begin with tribal trust responsibilities at the forefront and be designed and constructed to meet those obligations socially, ecologically and economically.

In addition to the Tribal Trust Responsibility plan components, and the over three hundred other plan components that ensure protection of and access to treaty reserved resources, we have made the following specific changes and additions through government-to-government consultation since August of 2023:

- **A re-wording of the Tribal Trust Responsibilities Standard 01 to better convey the Forest's obligations related to the Treaty of 1855.—*in development***
- **The addition of a desired condition in the tribal trust responsibilities section to document our intent to co-steward the land and resources of the Nez Perce-Clearwater National Forests together with the Nez Perce Tribe.**
- **The addition of a guideline and a desired condition in the tribal trust responsibilities section to ensure access to treaty reserved resources are not diminished by permitted commercial and personal forest products uses.**
- **The conversion of twelve (12) guidelines to standards-- primarily related to aquatic conditions, wildlife habitat and cultural resources.**
- **An introduction to the land management plan written by the Nez Perce Tribe Cultural Director to set the context and importance of the Forests as the Nez Perce homeland.—*in development***

USDA **United States Department of Agriculture** **Forest Service** **Nez Perce -Clearwater National Forests Supervisor's Office**

903 3rd Street
Kamiah, ID 83536
208-935-2513
Fax: 208-935-4275

File Code: 1920; 1560
Date: November 27, 2023

Honorable Shannon Wheeler, Chairman
Nez Perce Tribe Executive Committee
P.O. Box 305
Lapwai, ID 83540

Dear Chairman Wheeler;

On November 28th, the Nez Perce-Clearwater National Forests is releasing our 2023 land management plan, final environmental impact statement (FEIS), and draft record of decision (ROD). The release of these documents is a milestone in the plan revision process that you and your staff helped develop. This milestone also initiates a 60-day objection filing period. We sincerely appreciate the time you and your staff have spent over the many years to help us arrive at this point.

As I have mentioned in the past, including while in Washington D.C and in our November 13, 2023 letter to you, moving to the objection process will not limit or change the ability for us to continue government to government consultation. We can make additional mutually agreed upon changes throughout the objection period and up until decision is made, just as we have done in site specific projects. You will see that I have incorporated the language in the attachments from the November 13, 2023 letter in the draft ROD and throughout the land management plan. I also have left a placeholder for the language of the Tribal Trust Standard 01 as we have committed to using the wording your OLC and our OGC develop together.

The 2023 land management plan represents the preferred alternative. The FEIS analyzes the preferred alternative, four additional action alternatives, and taking no action. The FEIS weighs the benefits and trade offs of each alternative over the life of the land management plan. The draft ROD documents my decision rationale to propose approving the Nez Perce-Clearwater National Forests Land Management Plan.

Key aspects of this land management plan include:

- Guidance for increased partnerships and co-stewardship with the Nez Perce tribe, with a focus on fostering relationships.
- Direction for co-stewardship with the Nez Perce Tribe, a "Tribal Trust" section, and geographic areas of Tribal importance to enhance collaboration and ensure Tribal perspectives and traditional ecological knowledge help shape project design.
- Protects old-growth and mature forests and implements a climate adaptation strategy that holistically positions the Forests to be resilient to climate change.
- Provides for treatment of up to 64,500 acres annually for multiple objectives, including

up to 10,000 acres of timber harvest to improve vegetative conditions that maintain or move the Forests toward desired conditions for forested ecosystems, and reduce fuels to address the wildfire crisis.

- Provides public benefits by supporting approximately 4,000 jobs, a projected doubling from the current plan, and supports $163 million in labor income across local and regional economies.
- Replaces PACFISH with an aquatic and riparian conservation strategy developed with the Nez Perce Tribe and other partners to improve aquatic conditions and recover anadromous fisheries.
- Addresses local communities' request for additional motorized opportunities in certain areas while identifying other key areas as not suitable in order to provide habitat to benefit at-risk species.
- Recommends three areas for inclusion in the National Wilderness Preservation System. Hoodoo (also referred to as The Great Burn), Mallard Larkins, and East Meadow Creek.
- Identifies 11 rivers as "suitable" for inclusion in the National Wild and Scenic Rivers System and includes interim protection measures for management. The Little North Fork Clearwater River, was determined to be "eligible." Seventy-seven rivers were determined to be "not suitable" and will be protected by other plan components, but not interim protection measures.
- The Regional Forester has identified 36 species of conservation concern in the plan with management direction for the ecological conditions necessary to maintain the long-term persistence of these species.

All documents, maps, and release material, including information on participating in the objection process for land management plans are available for download online at: http://bit.ly/NezClearFPR.

The Nez Perce-Clearwater National Forests is grateful for the opportunities and wide variety of review, dialogue and comment, and collaboration that has been displayed throughout the plan revision process. This level of review and engagement truly helps build a more robust, and stronger comprehensive plan. I hope that you will see your input reflected in how and where we have assembled the pieces of the puzzle to complete a socially, ecologically and economically sustainable picture.

How to Participate in the Forest Plan Objection Process

The objection filing period is open for 60 days from the publication of the legal notice in the *Lewiston Morning Tribune*.

Electronic objections are strongly preferred by submitting to the Objection Reviewing Officer via the Comment Analysis Response Applications objection webform at: https://cara.fs2c.usda.gov/Public//CommentInput?Project=44089.

Electronic submissions must be submitted in a format (e.g. Word, PDF, Rich Text) that is readable with optical character recognition software and be searchable. The following address should be used for objections submitted by mail, courier, or hand-delivery:

Objection Reviewing Officer
USDA Forest Service Northern Region
26 Fort Missoula Road
Missoula, MT 59804

Objections or objection content specific to the identification of species of conservation concern will be forwarded to the SCC Reviewing Officer. The business hours for those submitting a hand-delivered objection are: 8:00 a.m. to 4:30 p.m., Monday through Friday, excluding Federal holidays. Contact Sara Daugherty, 208-963-4206, sm.fs.fpr_npclw@usda.gov during business hours to obtain instructions for faxing an objection.

Information received is part of the public record including names and contact information. It is the responsibility of the person submitting objections to submit information by the close of the objection period.

If you would like to schedule a meeting, or have additional questions, please contact Public and Governmental Relations Staff Officer, Zach Peterson, at 208-935-4239 or by e-mail at zachary.peterson@usda.gov.

Thank you again for your time on the revision process. We will continue government to government consultation as the objections process proceeds and I am committing to including the Tribe in any potential changes requested by other interested parties.

Sincerely,

CHERYL F. PROBERT
Forest Supervisor

Cc: Mike Lopez, OLC; Aaron Miles, Sr., Director, DNRM; Dave Johnson, Director, DFRM

From: Leslie Bursch
To: Probert, Cheryl - FS, ID
Subject: Extension Request Letter
Date: Wednesday, January 10, 2024 8:45:58 AM
Attachments: image001.png
image002.png
image003.png
image004.png
Extension Request Letter.pdf

Cheryl,
Please see the attached letter sent on behalf Chairman Wheeler.

Leslie Bursch
Nez Perce Tribal Executive Committee (NPTEC) | NPTEC Support Staff

W: 208-621-3683
F: 208-843-7354
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Nez Perce
TRIBAL EXECUTIVE COMMITTEE
P.O. BOX 305 • LAPWAI, IDAHO 83540 • (208) 843-2253

January 9, 2024

Sent Via Email Only To: cheryl.probert@usda.gov

Ms. Cheryl Probert, Forest Supervisor
Nez Perce-Clearwater National Forests
1008 Highway 64
Kamiah, ID 83536

Re: Nez Perce Tribe's Request for Additional Time to File Objection to the Nez Perce-Clearwater National Forests' Revised Land Management Plan

Dear Supervisor Probert:

The Nez Perce Tribe ("Tribe") previously appealed to you and Chief Moore on November 2nd and 6th, 2023, respectively, to delay publication of the Objection period for the Draft Record of Decision for the Nez Perce-Clearwater National Forests' ("Forest") revised land management plan ("Forest Plan") and the Regional Forester's list of species of conservation concern ("SCC list") for the Forest. The purpose of that request was to allow additional time for Tribal staff to review the Forest Plan and SCC list and for the Tribe and Forest to discuss, and hopefully resolve, the Tribe's outstanding concerns. The Forest elected to publish the Forest Plan and SCC list for Objection on November 28, 2023. In a November 13, 2023, letter to the Tribe, you stated, however, the Forest's intention to continue government-to-government consultation with the Tribe and to make mutually agreed upon changes to the Forest Plan and SCC list throughout the Objection period and up until a decision is made.

Today I write to you on behalf of the Nez Perce Tribal Executive Committee ("NPTEC") with a slightly different request—that the Forest extend the Forest Plan Objection deadline or, alternatively, permit the Tribe to file a legally-valid Objection, pursuant to the Tribe's and Forest's government-to-government relationship, after the official Objection deadline of January 29, 2024. If the Forest is amenable to the second option, I request confirmation in writing that any Objection filed by the Tribe after the official deadline would be considered by the Forest to be part of the Forest Plan's official record.

The Forest Plan and SCC list are significant documents that will affect the Tribe's rights and resources and Tribal member experiences on the Forest for decades to come. Although Tribal staff have engaged to varying extents in the development of the Forest Plan and SCC list for several years, Tribal staff did not see final drafts until this fall. Tribal staff are now reviewing the Forest Plan and SCC list, but, due to other work obligations and the complexity of the review, all relevant departments will have difficulty completing their review and fully briefing the NPTEC by the NPTEC's meeting on January 23rd—when the NPTEC will need to decide whether to Object and on what grounds. I, therefore, write to ask for additional time for the Tribe to consider the Forest Plan and SCC list, take action on whether to Object, and, potentially, formulate an Objection. Ideally, the NPTEC would like to postpone a decision until its February 27th meeting but could possibly make a decision at its February 13th meeting.

I am certain that allowing the Tribe additional time to consider and formulate an Objection will ultimately lead to a more thoughtful Objection process and government-to-government discussions. I am also hopeful that additional time will lead to a mutually-satisfying resolution of the Tribe's concerns. Please give me a call to discuss at your earliest convenience.

Sincerely,

Shannon F. Wheeler
Chairman

BRAD LITTLE
Governor
STATE OF IDAHO

RAÚL R. LABRADOR
Attorney General
STATE OF IDAHO

May 10, 2023

Sent via electronic and certified mail

The Honorable Deb Haaland, Secretary
U.S. Department of the Interior
1849 C Street, N.W.
Washington, D.C. 20240
exsec@ios.doi.gov

The Honorable Martha Williams, Director
U.S. Fish and Wildlife Service
1849 C Street, N.W.
Washington, D.C. 20240
fws_director@fws.gov
Martha_Williams@fws.gov

Re: 60-day Notice of Intent to Sue for ESA Violations

Dear Secretary Haaland and Director Williams:

This letter serves as a 60-day notice of intent to sue you in your official capacities as the Secretary of the U.S. Department of Interior, Director of the U.S. Fish and Wildlife Service (USFWS), and your respective Department and Service. We provide this notice pursuant to the citizen suit provision of the Endangered Species Act (ESA), 16 U.S.C. § 1540(g) and implementing regulations.

Absent USFWS action to correct the violations of the ESA identified below, we intend to file suit to enforce the provisions of the ESA, as well as other applicable federal laws.

The listing of grizzly bear of the conterminous (lower 48) United States on the List of Endangered and Threatened Wildlife (50 CFR 17.11(h)) is an ongoing unlawful federal action because it exceeds USFWS' statutory authority under the ESA. This listing unlawfully applies the ESA's protections to an entity that is not a "species" as defined by the Act (16 U.S.C. § 1532(16)).

On March 9, 2022, Idaho sought administrative remedy of this wrong by formally petitioning USFWS for delisting to remove the unlawful listing. However,

P. O. Box 83720, Boise, Idaho 83720
Telephones: 208) 334-2100 // (208) 334-2400

on February 6, 2023, USFWS made an arbitrary, unsupported, and unlawful negative "90-day" determination on Idaho's request. 88 Fed. Reg. 7,658.

The continuing violation of the ESA by a listing that exceeds USFWS' statutory authority injures Idaho's sovereign interests, as does USFWS' unlawful 90-day determination. For example, these violations injure Idaho's sovereign interests in management of our resident wildlife, particularly where robust, expanding grizzly populations are involved increasingly in human-bear conflict. Idaho's rural communities face increasing public safety risks and property damage with limited recourse under federal law. Furthermore, the ESA carries criminal and civil liability for the take of grizzly bears in defense of agricultural and other domestic animals and other private property. Idaho officials are currently defendants in an ESA citizen suit seeking to hold Idaho officials vicariously liable for potential take of grizzly bears by private individuals engaged in activities allowed under Idaho law. *See Center for Biological Diversity v. Little*, Case No. 1:21-cv-00479-CWD (D. Idaho). Idaho Fish and Game officials have also received a 60-day notice of intent to bring an ESA citizen suit related to Idaho's authorization for its lethal removal of a grizzly bear sow with cubs that had been hazed out of Yellowstone Park, later relocated by Montana officials, and then entered Idaho where it became a public safety risk in a rural Idaho subdivision.

The unlawful "lower-48" listing also interferes with the state's sovereign interests in the proper function of the ESA and in the allocation and prioritization of limited state conservation resources. Idaho, our rural communities, effective conservation of robust grizzly bear populations, and conservation of legitimate species actually warranting ESA protections, deserve the righting of this unlawful listing.

Idaho's March 9, 2022 petition sought delisting on the basis that the "lower 48" listed entity is not a "species" as defined by the ESA. Idaho's petition relies primarily on USFWS' own documents, including the USFWS' 2021/2022 status assessment and 5-year status review for grizzly bear in the "lower-48" listed entity. It is unfathomable how USFWS could determine its prior documents do not constitute "substantial information" that would lead a reasonable person to conclude that the delisting sought by Idaho's petition may be warranted. 50 C.F.R. § 424.14(h)(i).

USFWS has directly acknowledged error of the "lower-48" listing for well over a decade, and has made various findings supportive of a determination that the lower-48 listing does not meet the ESA definition of "species" (16 U.S.C. § 1532(16)).

The lower-48 grizzly bear listing is indisputably <u>not</u> a biological (taxonomic) species or a biological (subspecies). Grizzly bear (*Ursus arctos horriblis*) is a subspecies of brown bear (*Ursus arctos*), and most of the world's roughly 50,000-60,000 grizzly bears (inhabiting western Canada and Alaska), and the world's roughly 200,000 brown bears, are not ESA-protected because of their relative security (Figure 1 is from USFWS' status assessment depicting current and historic range of the grizzly bear subspecies taxon).

SSA for Grizzly Bear in the Lower-48 States January 2022

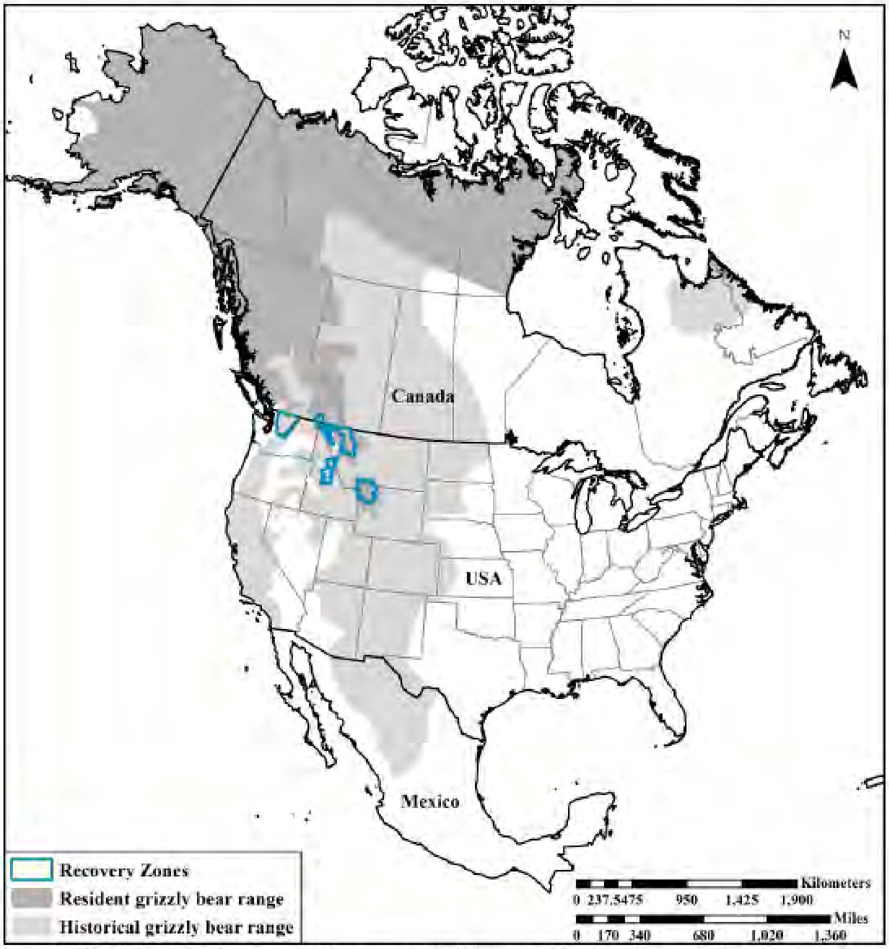


Figure 1. Map of historical and current grizzly bear range in North America and the six recovery zones for grizzly bear in the lower-48 States. Currently, grizzly bears primarily exist in four ecosystems: the Northern Continental Divide (NCDE), Greater Yellowstone (GYE), Cabinet-Yaak (CYE), and Selkirk (SE) ecosystems. There are currently no known populations in the North Cascades and Bitterroot (BE) ecosystems and no known populations outside these defined ecosystems, although we have documented bears, primarily solitary, outside these ecosystems. Ecosystems are generally considered to be the larger area surrounding the recovery zones in which grizzly bears may be anticipated to occur as part of the same population.

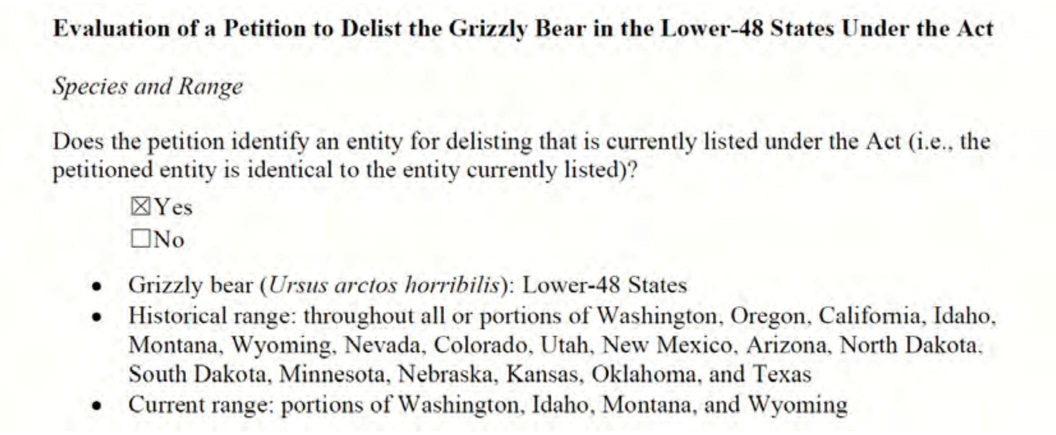
There is therefore only one category other than taxonomic species and taxonomic subspecies to which ESA protections may apply, namely a "distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." In 1996, NOAA and USFWS issued a Policy Regarding the Recognition of Distinct Vertebrate Population Segments under the Endangered Species Act (61 Fed. Reg. 4,722) (1996 DPS Policy). The 1996 DPS Policy notes that "Congress has instructed the Secretary to exercise this authority with regard to DPS's "* * * sparingly and only when the biological evidence indicates that such action is warranted." (61 Fed. Reg. at 4,722, citing Senate Report 151, 96th Congress, 1st Session).

In addition to the requirement that a DPS "interbreed when mature," the 1996 DPS Policy applies requirements for population "discreteness" and "significance" relative to the taxonomic species/subspecies for identifying DPSs. Applying the statutory and regulatory definitions, the 1996 DPS Policy, USFWS' own documents, and other documents readily available to USFWS, should result in the conclusion that the lower-48 listing does not identify a DPS, and is therefore not a "species" to which ESA listing status may lawfully apply.

USFWS' dismissive findings to the contrary in its denial of Idaho's petition exemplify arbitrary and capricious agency action, and violate the legal standards for the ESA and APA.

ESA implementing regulations require the Secretary to make any listing/delisting determination based solely on the basis of the best available scientific and commercial information regarding a species' status. 50 CFR 424.11(b). The regulations also impose a duty on the Secretary/USFWS to delist a species if the Secretary finds that, after conducting a status review based on the best scientific and commercial data available that the listed entity does not meet the statutory definition of a species. 50 CFR 424.11(e)(3).

USFWS' "90-day Finding Petition Review Form" itself admits that the current range of the "lower 48" listing only includes "portions of Washington, Idaho, Montana, and Wyoming." The form also admits that historical range only included all or portions of 18 states." Below is an excerpt from the Form:



Evaluation of a Petition to Delist the Grizzly Bear in the Lower-48 States Under the Act

Species and Range

Does the petition identify an entity for delisting that is currently listed under the Act (i.e., the petitioned entity is identical to the entity currently listed)?

☒Yes
☐No

- Grizzly bear (*Ursus arctos horribilis*): Lower-48 States
- Historical range: throughout all or portions of Washington, Oregon, California, Idaho, Montana, Wyoming, Nevada, Colorado, Utah, New Mexico, Arizona, North Dakota, South Dakota, Minnesota, Nebraska, Kansas, Oklahoma, and Texas
- Current range: portions of Washington, Idaho, Montana, and Wyoming

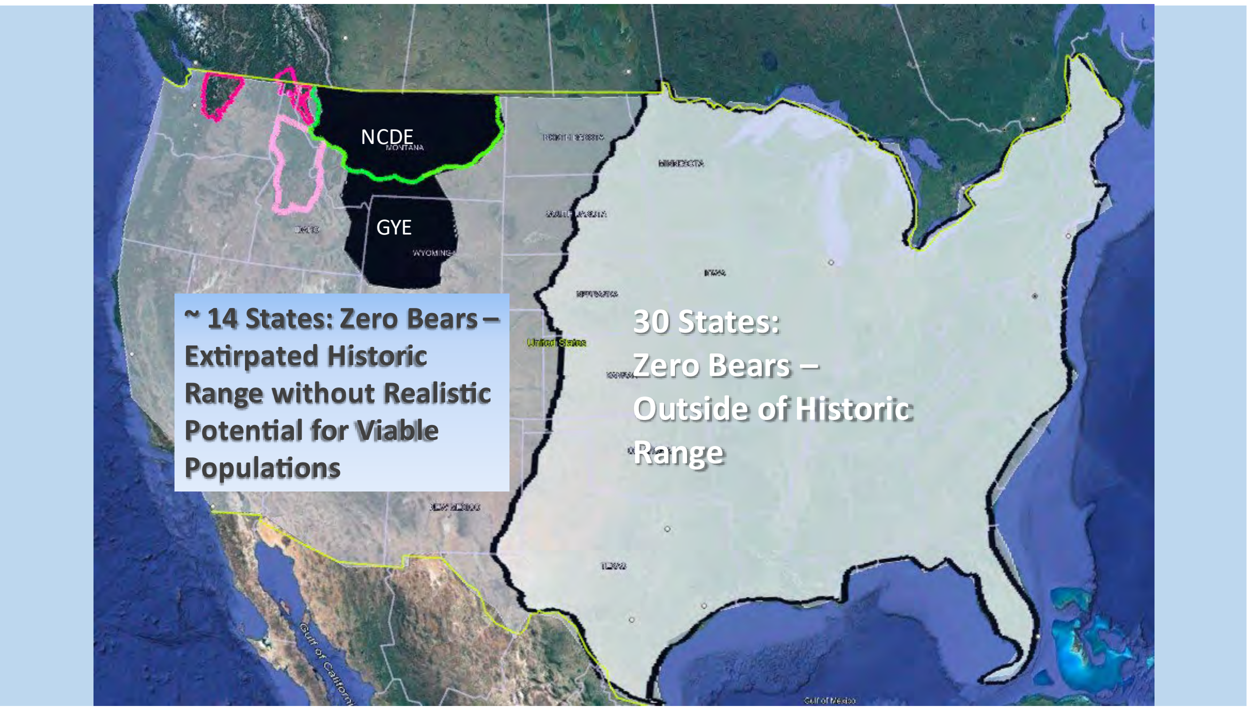
The Form also references USFWS' 2021 status assessment, which reflects that grizzly bear natural recolonization is "almost impossible" in any areas of the 14 states with historic range that that are now outside of current range (i.e., states containing only extirpated historic range). This Assessment also found that even if a population were reintroduced in remaining suitable grizzly habitat in these 14 states, "there is a very low likelihood of natural linkage to existing populations needed to maintain long-term fitness and become self-sustaining" (2021 Assessment, pages 54-55).

In making findings on Idaho's petition, USFWS stated that "[t]he Act does not require the Service to make an explicit finding of interbreeding among various groups of organisms that make up a DPS." USFWS' interpretation in this regard is arbitrary and capricious and in violation of the ESA. The ESA and its implementing regulation include the words "interbreeds when mature" specific to "distinct population segment." USFWS' interpretation unreasonably renders the express use of "interbreeding" specific to DPSs in the statute superfluous, resulting in "interbreeding" being the same for taxonomic species, subspecies, and DPSs. In addition, USFWS' interpretation is erroneous and inconsistent with DPS policy, which indicates DPSs and "populations" are below the "subspecific level" and logically must "be circumscribed in some way that distinguish [them] from other representatives of the species." 61 Fed. Reg. 4,724.

USFWS' own documents do not describe grizzly bear in the "lower-48" states as a discrete population. Instead, they reflect that they listed "lower-48" entity defines an area that largely never supported a grizzly bear population or is now incapable of supporting a viable, self-sustaining grizzly bear population:

- 30 states of the 48 states are outside of grizzly bear current and historic range entirely.

- 14 states consist of a combination of unoccupied/extirpated historic range and areas outside of historic range.
- 4 states with current range that also include areas of unoccupied/extirpated historic range and areas outside of historic range (such as the high desert areas of Idaho and Washington).



~ 14 States: Zero Bears – Extirpated Historic Range without Realistic Potential for Viable Populations

30 States: Zero Bears – Outside of Historic Range

USFWS's own documents, including the contemporaneous 90-day findings on other grizzly bear delisting petitions, describe portions of the 4 states south of Canada with grizzly bears (Idaho, Montana, Washington, Wyoming) as encompassing 6 "Ecosystems" or "Recovery Areas." These areas do not form a single interbreeding distinct population segment. Instead, USFWS' own findings have described two of these Ecosystems as extirpated populations that are discrete or "wholly separate" from the other four Ecosystems with current grizzly bear populations. USFWS has also made various findings that the other four Ecosystems (or at least three of them) are discrete from each other. USFWS findings also call into question the "significance" to the subspecies taxon of Ecosystems identified with limited carrying capacity of 50 to 350 bears.

As referenced in Idaho's petition, USFWS has made various findings that all 6 (or at least 5) of these recovery areas "may" warrant or have warranted differing ESA status (see, e.g., 82 Fed. Reg. 57,699):

- USFWS has previously determined that the Greater Yellowstone Ecosystem identifies a discrete population, reproductively isolated from other populations, supporting its identification as a DPS independent from the lower-48 listed entity. USFWS has twice issued delisting rules identifying this ecosystem as a DPS for purposes of delisting. E.g., 82 Fed. Reg. 30,502-633 (2017); *see also* 83 Fed. Reg. 18,741

  After analysis in response to the court remand of the 2007 and 2017 rules, on February 6, 2023, USFWS made a favorable "90-day" petition finding that identifying and delisting a Greater Yellowstone Ecosystem DPS "may be warranted." 88 Fed. Reg. 7,660. This area is shown in black on the preceding map (tri-state area in Wyoming, Montana, and Idaho).

- On February 6, 2023 USFWS made a favorable "90-day" petition finding that identifying and delisting the grizzly bear population in the NCDE as a DPS "may be warranted." Delimitation of the petitioned DPS was based on its discreteness from other grizzly bear populations south of Canada and bounded by the international US-Canada border on the north (with Montana bears not actually physically discrete from those in Canada). This area is shown in black on the preceding map in Montana. 88 Fed. Reg. 7,7659-60.

- USFWS has previously identified the North Cascades Ecosystem as a discrete extirpated population, that even if reintroduced would be discrete and reproductively isolated from all other US populations. In 2022 USFWS revived a previous proposal to reintroduce a small number of bears to this Ecosystem as a nonessential, experimental population because of the absence of a grizzly bear population and the "geographically separate" nature of this Ecosystem from other nonexperimental populations. 87 Fed. Reg. 68,190.

- USFWS has previously identified the Bitterroot Ecosystem as a discrete extirpated population. In 2000, USFWS identified an Experimental Population Area as suitable for reintroduction of nonessential, experimental population because of the absence of population and its "geographically separate" nature from other nonexperimental populations. 65 Fed. Reg. 69,624; *see also* 83 Fed.

Reg. 18,739-40 ("the [Bitterroot Ecosystem] is unoccupied and isolated from other populations…). A district court decision has recently ordered USFWS to supplement the 2000 EIS prepared for 2000 10j rulemaking. *See Alliance for the Wild Rockies v. Cooley,* Case No. 21-136-M-DWM.

- USFWS has previously identified the Selkirk Ecosystem and Cabinet-Yaak Ecosystems at times as a single discrete population delineated at the U.S. – Canada border (with U.S. bears not actually physically discrete from those in Canada). E.g., 64 Fed. Reg. 26,275 (1999). At other times USFWS has identified the Selkirk and Cabinet-Yaak as two populations discrete from each other. E.g., 82 Fed. Reg. 57,699. USFWS has made various findings that uplisting of these Ecosystems as single DPS or a combined DPS was warranted (but precluded), in part based on of the Ecosystems' physical discreteness from other U.S. populations. E.g., 64 Fed. Reg. 26,725. USFWS' Grizzly Bear Recovery Office has at times recognized that the small carrying capacity of these Ecosystems (as well as the North Cascades and Bitterroot) might preclude them from qualifying as significant relative to the subspecies taxon. E.g., USFWS Administrative Record for the 2017 GYE Delisting Rule, *Crow Indian Tribe v. United States*, Consolidated Case No. 9:17-cv-00089-DLC, FWS_Del Doc_52870-2871; FWS_Del Em_00000150105-6 (describing DPS policy compliance issues).

USFWS' response to Idaho's petition fails to provide reasonable explanations for the parade of previous and contemporaneous USFWS findings, which are inconsistent with its 90-day determination on Idaho's petition regarding the lower-48 listed entity. USFWS' determination also fails to provide a reasonable explanation as to how it is consistent with the requirements for an ESA designation as a distinct population segment which interbreeds when mature.

The bar for favorable 90-day determinations that a petitioned listing/delisting action "may be warranted" is supposed to be low. However, on February 6, 2023, USFWS made an arbitrary, unsupported, and unlawful negative "90-day" determination. USFWS ignored ample information supportive of the petitioned action presented in Idaho's petition, USFWS' own documents, and other documents readily available to USFWS. USFWS failed to provide a reasonable explanation for this decision, including its inconsistency with the 1996 DPS Policy, past determinations, and contemporaneous findings on petitions to identify major portions of the "lower 48" listing as independent DPSs.

USFWS' inconsistent determinations and findings support a determination that USFWS has violated its statutory and regulatory duties to make delisting decisions based on best available scientific and commercial information, and to delist entities that do not met the statutory definition of species.

In the absence of administrative action to retract USFWS' negative determination on Idaho's petition and action to remove the unlawful "lower-48" listing, and the associated ESA listing of an experimental nonessential "10j" population, Idaho is prepared to bring suit.

Idaho does not send this notice lightly. We prefer to invest the resources of federal and state conservation agencies on actual conservation, rather than on lawsuits. However, the current listed entity does not meet the ESA definition of "species," and we have robust grizzly bear populations that continue to cause conflict in our rural communities and injure Idaho's sovereign interests in managing our resident wildlife and conservation resources.

Idaho has analyzed the ESA, implementing regulations, USFWS' ESA policies, and a tangled web of court decisions interpreting "lower-48" listings and DPS designations. Idaho determined the reasonable course of action is to address the primary cause of judicial concern with the "lower-48" listing at its source: remove the erroneous 1975 listed entity that was not based on taxonomy, actual populations, or biology from the beginning, and that is not an entity on which current ESA jurisdiction may be based.

Addressing this violation is not merely a matter of legal compliance, it is a matter of restoring the statutory priorities and purpose of the ESA. Although well-intentioned, the 1975 listed entity of grizzly bears of the conterminous lower-48 states is not a "species" under the ESA, and continuing to consider it to be one means that ESA resources are being focused on something that is <u>not</u> a "species" at all. Protecting a non-species comes at the expense of protecting imperiled entities that <u>are</u> species. As the 1996 DPS Policy recognized, the ESA "is not intended to establish a comprehensive biodiversity conservation program, and it would be improper for the Services to recognize a potential DPS as significant and afford it the Act's substantive protections solely or primarily on these grounds." 61 Fed. Reg. 4,724.

If there were a DPS of grizzly bears that interbreeds when mature, that is discrete and significant relative to the taxon, and that does warrant listing as an endangered or threatened species consistent with Congress' directive to use DPSs “sparingly,” then the ESA makes it incumbent on the USFWS to follow the administrative process specified for listing.

Please contact Mike Edmondson, Administrator Idaho Governor's Office of Species Conservation at (208) 332-1552 or Jim Fredericks, Director Idaho Department of Fish and Game, if you wish to discuss the scientific basis regarding this matter further. Idaho’s Office of the Attorney General is also available to discuss the legal aspects of this matter with your Solicitor’s Office or with your Department’s representatives at the U.S. Department of Justice.

Sincerely,

Raúl R. Labrador

BRAD LITTLE
Governor
State of Idaho

RAÚL R. LABRADOR
Attorney General
State of Idaho

Integrating Knowledge for Simulating Vegetation Change at Landscape Scales

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ABSTRACT: *Managers of public lands are increasingly faced with making planning decisions for dynamic landscapes with conflicting objectives. A modeling system has been designed to serve as a decision support system to help managers and resource specialists integrate the available knowledge of vegetation change and disturbance processes, and quantify concepts that are often difficult to interpret for specific landscapes. The system is named SIMPPLLE, an acronym taken from "***SIM***ulating vegetation* ***P****atterns and* ***P****rocesses at* **L***andscape sca***LE***s." SIMPPLLE can be used to help define and evaluate future conditions at landscape scales, to identify areas that are more prone to disturbances over a given time frame, to identify the options for influencing these disturbance processes, and to help design and evaluate different strategies for achieving desired future conditions. The emphasis in this article is to give an overview of the design of the system, the types of knowledge integrated, and the type of output produced. The initial validation work discussed indicates that the approach used for capturing and integrating process knowledge in SIMPPLLE does predict realistic results at landscape scales. SIMPPLLE provides managers a tool to integrate and interpret concepts of desired future conditions, range of variability, and the interaction between vegetation patterns and disturbance processes. SIMPPLLE provides a way to help evaluate proposed management scenarios within a future that includes stochastic processes. West. J. Appl. For. 19(2):102–108.*

Key Words: Disturbance processes, simulation models, landscape models, insect outbreaks, wildfire.

Land management for the USDA Forest Service is a continuing evolution of designing and applying management practices in response to changing demands by society and an increased awareness of ecological concepts. This evolution has grown from an emphasis on the effects on individual plant communities to a concern with the cumulative effects on many individual communities within landscapes at a range of spatial scales. Management of landscapes attempts to incorporate concepts expressed as "desired future conditions," "historic range of variability," "dynamic disturbance processes," and "interactions between processes and vegetation patterns." A modeling environment that captures and integrates the available knowledge of vegetation change and the processes that drive the change can assist incorporation of these concepts.

This article presents a modeling system designed for simulating vegetation patterns and processes at a range of spatial scales. The system is named SIMPPLLE, an acronym taken from "**SIM**ulating vegetation **P**atterns and **P**rocesses at **L**andscape sca**LE**s." Our primary objective is to provide an overview of the design of the SIMPPLLE system, the types of data and expert knowledge incorporated into the model logic, and the format of output available to users for incorporating simulation results into landscape management planning. Examples of the work used to verify the system's performance are presented.

Model Design Criteria

SIMPPLLE is designed to serve as a decision support system to help managers and resource specialists quantify and incorporate concepts that are often difficult to interpret for specific landscapes. Managers can use the SIMPPLLE system to help define and evaluate desired future conditions at landscape scales, to identify what parts of a landscape are more prone to disturbance processes over a given time frame, and to help design and evaluate different strategies for achieving desired future conditions. As with the work by Baker (1992) on modeling landscape structure, this model is not intended to predict precisely when and where processes will occur. Rather, the objective is to provide a prediction of behavioral trends. The emphasis is on behavioral validity, not on numerical precision. The relationships between trends in vegetation conditions and insect activity such as the maturing of lodgepole pine (*Pinus contorta*) and an

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NOTE: Jimmie Chew can be reached at (406) 542-4171; jchew@fs.fed.us. Copyright © 2004 by the Society of American Foresters.

increase in mountain pine beetle (*Dendroctonus ponderosae*) activity are more important than the actual acres of mountain pine beetle activity simulated. The simulated relationship between the mountain pine beetle activity and fire processes is more important than the simulated acres of either process. Spatially explicit output from single simulations can be provided as possible outcomes and the output from multiple stochastic simulations can be used to estimate the probability of disturbance processes and vegetation attributes.

The system is designed to be consistent with the field inventories and satellite imagery that exist for the range of landscape scales within the Forest Service. The vegetation attributes are limited to a dominant species or cover type, size class and structure, and canopy closure. Nonspatial attributes can come from queries on vegetation databases maintained by the Forest Service. The use of a geographic information system (GIS) provides the means to identify the set of neighbors for each plant community so that the unique pattern of each landscape can influence disturbance processes. A variety of commercially available GIS software packages have been used. However, because of the goal of designing SIMPPLLE as a management tool for the Forest Service, customized ArcInfo utility functions and ArcView project files have been developed.

The initial emphasis in system development was to provide the means to represent and integrate the available knowledge on disturbance processes and vegetation conditions and patterns. Much of the initial knowledge on relationships between disturbance processes and between processes and vegetation pattern has come from expert opinion. Rigorous methodologies are available for the steps of quantifying expert opinion (Reynolds and Holsten 1994). However, for this first version of SIMPPLLE, this information was gathered through a series of workshops with silviculturists, ecologists, entomologists, and pathologists from the Forest Service. With the system's design, the initial knowledge from both expert opinion and research results can be easily replaced as new information and research results become available.

General Model Characteristics

SIMPPLLE was designed to be spatially explicit because of the significance of the interaction between processes and vegetation patterns (Forman and Godron 1986, Turner 1989). Each existing vegetation unit is represented individually. A probability for each disturbance process is calculated for each vegetation unit. Each unit's unique set of neighbors has an influence on the probability. Simulations can be made individually or in multiples. Multiple simulations are used to provide an average level of conditions and a range. Simulations can be made with or without fire suppression and vegetation treatments. Change is simulated based on either decade or yearly length time steps.

Model Components

Existing Vegetation

The attributes used to describe a vegetation unit must address three important criteria. First, the attributes must be possible to obtain from available inventory data; second, the attributes must be of sufficient detail to enable prediction of process probability; and third, the attributes must contain enough information to make interpretations for specific resources such as wildlife habitat. The inventories available are often a combination of data from on-the-ground surveys and interpretation from aerial photographs or classified satellite imagery. An existing vegetation unit is described by a combination of habitat type (Pfister et al. 1977), dominant species, size-class and structure, and density. These attributes are consistent with the hierarchical inventory system used by Northern Region of the Forest Service and are sufficient to use other knowledge that has been developed such as the hazard rating systems used for mountain pine beetle (Amman et al. 1977), or western spruce budworm (*Choristoneura occidentalis*) (Carlson and Wulf 1989).

Potential Vegetation States

Although vegetation development is a process of continuously changing species, size class, structure, and density characteristics, it is often convenient for modelers to view the community as making transitions from one state to another (Kessell and Potter 1980). The continuum is divided into a suitable number of states based on the knowledge available and the resolution needed to address the management issues. It is assumed that the likelihood and intensity of disturbance processes can be associated with these discrete vegetation states based on the interaction of vegetation with fuel loadings, life history characteristics, dispersal interactions, and resource availability (Pickett and McDonneil 1989). This approach has been used in representing both succession (Arno et al. 1985) and fire ecology relationships (Fischer and Bradley 1987). Each combination of dominant species, size-class/structure, and density by habitat type group that can represent an existing vegetation unit is identified as a potential vegetation state within SIMPPLLE. Each potential state stores the knowledge of what disturbance processes can occur and what the next vegetation state would be. The collections represent a sequence of vegetation states with processes being the agents for change from one state to another within a decade interval.

Processes

The processes represented in this initial version are succession, fire, mountain pine beetle in lodgepole pine and ponderosa pine, western spruce budworm, and root fungi. Tree regeneration is also treated as a process. There are two types of knowledge for each process: the knowledge associated with the probability of the process occurring, and the knowledge associated with the processing spreading. The fire processes, western spruce budworm, and mountain pine beetle all may spread from one unit to another. Most rating systems for insect and disease processes use very specific stand level data (Amman et al. 1977, Carlson and Wulf

1989, Stevens et al. 1980). As a result, several assumptions and generalizations were incorporated into the model logic to work with the level of input data associated with the vegetation attributes at landscape scales. Many of these assumptions are based on expert opinion from silviculturists, fire managers, and ecologists. A significant assumption associated with this representation of knowledge is that only the most dominant outcome of a process is given. Multiple outcomes for the same process are not represented. If more than one outcome is important to represent, then a variation of the process is created. For example, mountain pine beetle in lodgepole pine is represented as two processes: light-mountain pine beetle and severe-mountain pine beetle.

Treatments

Different scenarios of treatment applications can be evaluated and compared without having to make changes within the collection of potential states. Vegetation treatments can have a combination of impacts: they can change a vegetation state; change the probabilities and types of other processes; or they may change all of these components. For example, a thinning can change the structure class from multistory to single story, which also changes the type of fire process that may occur from stand-replacing to light-severity. Treatments can be used to change the vegetation pattern that can influence probability and spread for some processes. Treatments in this current version of SIMPPLLE include thinning to control density of the plant community, final harvest practices used for regenerating a new plant community, and burning treatments used to change species composition and structure of the community. The user interface is used to build a schedule of treatments to assign to specific vegetation units or it can be used to identify vegetation attributes and an acreage goal to let SIMPPLLE select units to treat.

Table 1. Display of output from a single simulation for an individual vegetation unit showing the vegetation state and the disturbance process for each time step.

Time step	Condition at end of time step	Process that occurred
1	DF/MU/2	Light western spruce budworm
2	DF/LMU/1	Root disease
3	DF/MM/1	Root disease
4	DF/PMU/1	Root disease
5	DF/SS/1	Stand replacing fire

SIMPPLLE System Output

The system provides output for both individual vegetation units and the entire landscape. For individual units, the system provides the disturbance processes modeled, their occurrence probabilities, the changes in vegetation state, and whether a process originated within a unit or spread to a unit. The unique sequence of processes from a single simulation can be examined for each vegetation unit (Table 1). The acres of each vegetation attribute and acres of each process are displayed by time step for the landscape. Table 2 displays the acres of disturbance processes for the entire landscape by time step for a single simulation. These results can be produced in a report or the attributes for individual units can be mapped in a customized ArcView project. Reports can be made that lists the number of fire events, identifies the events origin, the units it spreads to, smoke emissions produced by wildfires and prescribed fires, and fire suppression costs. For multiple simulations, the display for individual units includes the frequency for each unique value of species, size-class/size-structure, and density, and disturbance process (Table 3). The time step summaries for the entire landscape display an average and the high and low values from the multiple simulations (Table 4). The individual attributes for each time step can be mapped in ArcView. The attribute and process frequencies for individual units can also be displayed as "probability" maps in ArcView.

Interpretations for various resource values are currently being added as reports. Examples are reports for acres of potential habitat for wildlife species such as Flammulatted owls (*Otus Flammeolus*), black-backed woodpeckers (*Picoides arcticus*), and potential old-growth conditions.

Model Verification

Verification of the model is an ongoing process. We are currently evaluating the ability of the system to simulate fire behavior that is comparable to the large fire complexes from year 2000 in the Bitterroot Valley in Montana. We are using FARSITE (Finney 1998) on sample fire events to verify the "type-of-fire" and "fire-spread" logic within SIMPPLLE. The Forest Vegetation Simulator (Stage 1973, Wykoff et al.

Table 2. Output for the entire landscape from a single simulation showing the acres of disturbance processes by decade time steps.

Process	Time step 1	Time step 2	Time step 3
		(ac)	
Succession	350,350	38,627	387,665
Light western spruce budworm	3,969	1,911	1,936
Severe western spruce budworm	5,340	719	709
Light lodgepole pine mountain pine beetle	975	307	648
Severe lodgepole pine mountain pine beetle	699	175	444
Ponderosa pine mountain pine beetle	946	3,322	2,193
Stand replacing fire	59,119	30,071	32,000
Mixed severity fire	21,330	17,436	11,066
Light severity fire	2,844	2,484	1,756
Root disease	9,178	12,055	16,333

Table 3. Output from multiple simulations for an individual vegetation unit showing the frequency at which each attribute occurred.

Species value	Frequency (%)	Size-class value	Frequency (%)	Density value	Frequency (%)	Process value	Frequency (%)
PP-DF	90	Large	23	2	10	Mixed severity fire	12
PP	10	Pole	33	1	90	Light western spruce budworm	4
		Medium	24			Succession	72
		TS	20			Light severity fire	12

Table 4. Output from multiple simulations for the entire landscape showing mean level and the high and low values of acres of disturbance processes by decade time steps.

Process	Time step 1 mean ac	Time step 1 min-max ac	Time step 2 mean ac	Time step 2 min-max ac
Succession	26,499	20,697–48,643	49,913	41,389–53,245
Light western spruce budworm	196	0–981	257	31–1,043
Severe western spruce budworm	336	0–1,681	134	0–636
Light lodgepole pine mountain pine beetle	10	0–50	13	0–51
Severe lodgepole pine mountain pine beetle	0	0–0	0	0–0
Ponderosa pine mountain pine beetle	22	0–77	369	111–850
Stand replacing fire	14,560	1,006–18,376	3,484	1,017–8,248
Mixed severity fire	11,984	1,790–15,141	851	384–2,022
Light severity fire	2,786	1,159–3,888	771	374–1,278
Root disease	285	0–1,340	886	375–1,906

1982) will be used on sample plant communities to verify the information in SIMPPLLE's collection of potential vegetation states, the time spent in a size class, and the resulting next state. The verification work that has been completed consists of the comparison of past change in an actual landscape with stochastic simulations of the same landscape, the comparison of cycles of disturbance processes from long-term simulations with how we think the processes interact, and the comparison of the simulation of a relatively small year 2000 fire with the actual event.

The Coram Experimental Forest in northwestern Montana was used as the initial data set to test the SIMPPLLE system. Coram contains 6,800 ac of mountainous terrain on the Flathead National Forest. The comparison of the Coram landscape was made using timber types delineated in the early 1930s. For model verification, 10 6-decade stochastic simulations were made with SIMPPLLE starting with the 1930 vegetation. These simulations take into account the vegetation treatments that have been implemented in connection with research work in the Experimental Forest over the last 6 decades. The average from these simulations from the 1930 vegetation resulted in a simulated current landscape that has less seedlings/saplings and more pole and medium size classes than found in the actual current landscape. The simulations also resulted in more acres for mixed western larch (*Larix occidentalis*) and Douglas-fir (*Pseudotsuga menziesii*) stands than exists in the current inventory. The difference in the species is attributable to the difference in the way the inventories were assigned a cover type. The 1930s vegetation maps delineated mixed-species communities. Mixed communities of western larch and Douglas-fir were common, while communities dominated by single species were rare. The current delineation is based on the summarization of plot data that determines a plurality of basal area by species. The difference in the smaller size classes, seedling/saplings, pole, and medium was determined to be the result of SIMPPLLE moving the vegetation units through these size classes too fast. The initial time in these size classes comes from a summarization of Forest Vegetation Simulator runs on sample stands that represent these forest types by habitat type groups for the entire Northern Region. The observed growth rates from unpublished data collected in spacing studies for Coram provided a better basis for the time to move through the smaller size classes for this part of the region.

Fire is the only disturbance process for which records have been kept at Coram. Table 5 compares the average fire attributes from the original ten simulations with the fire attributes that actually occurred over the last six decades. Three attributes are compared, the number of fire events, the percentage of fire events suppressed at less than 0.25 ac, and the total number of acres burned. Using the past 10-year fire occurrence for the Flathead Forest as the basis for the probability of a fire event resulted in significantly greater

Table 5. Comparison of three fire attributes from the actual occurrence at Coram Experimental Forest, averages from the original ten simulations, and averages from revised ten simulations.

	Number of fire events at <0.25 ac	Percent of events suppressed	Acres burned
Actual fires	24	96	35
Original simulation	109	52	229
Revised simulation	30	90	59

number of simulated fire events. The percentage of these events that were suppressed at less than 0.25 ac was much lower than actually achieved. The simulated burned acres were greater than those actually burned. Changes were made to provide the user flexibility to base the probability of fire events on a more localized area, to be able to adjust fire suppression logic for differences in landownership and road status, and to provide access to adjust the type-of-fire and fire-spread logic. The results of using these changes are shown in the revised-simulations row in Table 5. There is an improvement in the number of fire events and the percent suppressed at less than 0.25 ac. However, the acres burned are still above the actual. Additional adjustments to the fire logic could get the simulation values closer to the actual.

The application of the system to numerous other areas within the Northern Region have provided the opportunity to continue model verification and fine tuning of its performance. Long-term simulations without fire suppression for 400 years on a 1.5 million-ac area provide the basis for examining how simulated cycles for processes compare to our expected relationships between disturbance processes. Figure 1 displays the resulting cycles of stand-replacing fire, mixed-severity fire, and mountain pine beetle in lodgepole pine from one long-term simulation. Significant levels of mountain pine beetle activity tend to occur only after periods of minimal fire activity that allow time for lodgepole pine to mature and become susceptible. When a significant level of mountain pine beetle activity occurs creating fuels, it is followed by an increase in the level of fire. Cycles of mixed-severity fire are more frequent than the cycles of stand-replacing fire and through their reduction of density in lodgepole pine stands keep mountain pine beetle activity at a minimum.

The fires of 2000 in the Bitterroot Valley of Montana provide another opportunity to verify SIMPPLLE's performance. A comparison of one of the smaller fires of 11,475 ac was made with a simulation starting a fire event in the same plant community in which the fire occurred. Figure 2 displays the actual fire and the simulated fire. Differences between the two were the result of inaccurate mapping of what was typed as nonforest, rock, and assumptions concerning fire suppression. Areas that were identified for SIMPPLLE as rock were actually low-density forested areas that did support a fire. Areas along the wilderness boundary that SIMPPLLE's suppression logic indicated would be suppressed were not, but continued to spread. Both of these areas need additional emphasis. The need for improved typing of the vegetation used for SIMPPLLE and an expansion of the fire suppression logic will be addressed in the additional work being done on the large fire complexes from the year 2000. However, the current performance of modeling the fire process is considered adequate. Using multiple simulations over decades to create probability maps for processes and vegetation attributes can involve

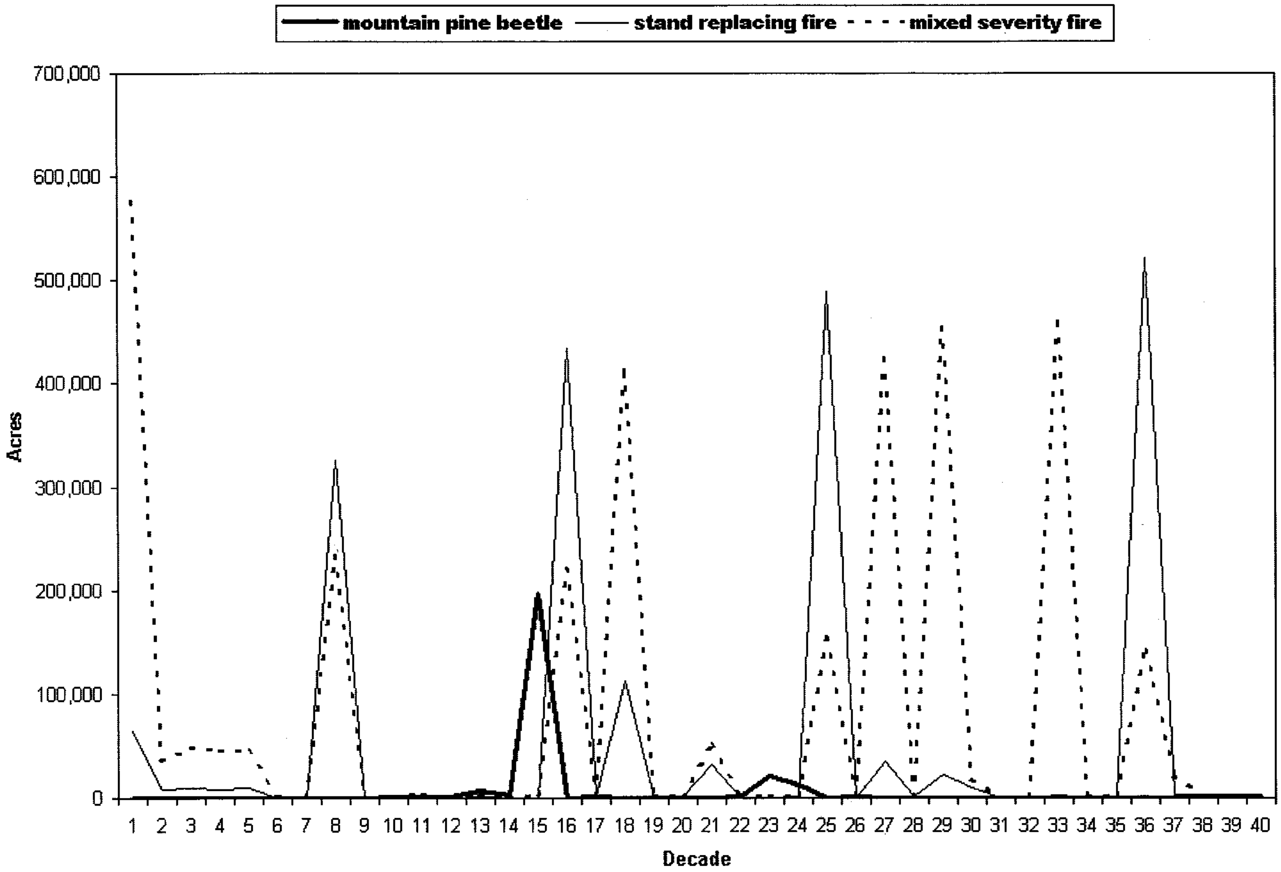

Figure 1. Cycles of mixed severity fire, stand-replacing fire, and mountain pine beetle from multiple simulations of a historic representation of a 1,086,000-ac landscape on the Beaverhead-Deerlodge National Forests.

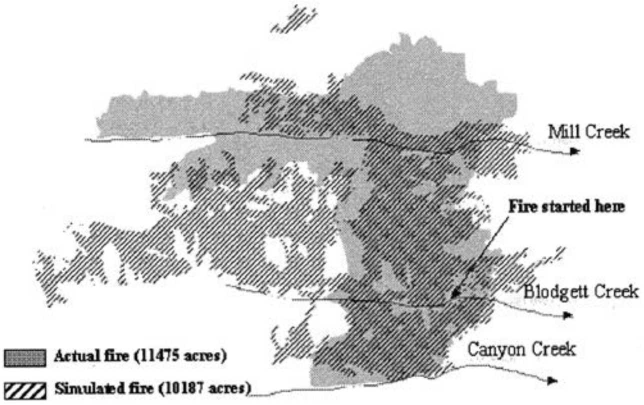

Figure 2. Comparison of the actual Blodgett Trail Head fire with the simulated fire.

hundreds of fire events. The degree of accuracy considered appropriate for landscape planning is not the same required for planning fire suppression activities on an ongoing fire.

Model Application

The first version of SIMPPLLE was delivered to the Northern Region in January 1997. To account for variability within the habitat type groups in the region, SIMPPLLE has been structured to provide a Westside and Eastside option. The system has been applied to a number of landscapes within Montana and Idaho for the Northern Region and the Bureau of Land Management at scales from 26,800 to 1.8 million ac. Its use has ranged from project planning to landscape assessment, and analysis of the management situation prior to forest plan revision. Each level of analysis involves different uses of the system. The comparison of mountain pine beetle activity in lodgepole pine for a number of alternatives in a landscape on the Helena National Forest (Figure 3) is typical of its use at the project planning level. The potential for providing desired vegetation conditions can be evaluated spatially over time. The change in vegetation attributes as a result of both treatments and disturbance processes were mapped by decades for a number of management alternatives for a landscape on the Kootenai National Forest. The vegetation attributes selected were those used to identify potential old-growth conditions.

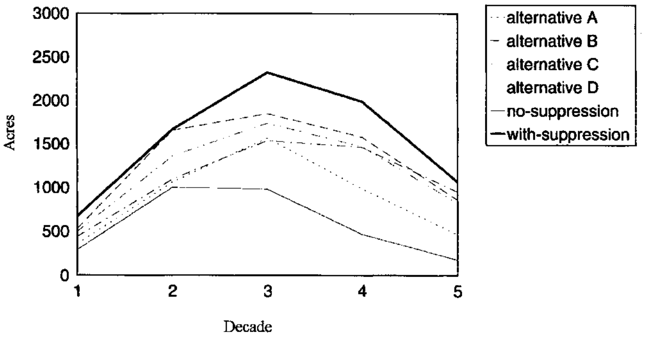

Figure 3. Acres of mountain pine beetle activity in lodgepole pine for alternatives on the Poorman Landscape, Helena National Forest. All levels are the average of five simulations. Alternatives include both treatments and fire suppression. The "no-suppression" level does not include fire suppression or treatments. The "with-suppression" level includes fire suppression but no treatments.

Additional versions of SIMPPLLE are currently being developed for use in a study that compares various models for evaluating fuel treatments at landscape scales (Weise et al. 2000). Within this application, SIMPPLLE is used with the MAGIS optimization and scheduling model(Zurring et al. 1995) to quantify risks from disturbance and schedule fuel treatments at landscape scales (Jones and Chew 1999). Versions of SIMPPLLE are being developed for Yosemite National Park and Angeles National Forest in California, the Kenai Peninsula in Alaska, Gila National Forest in New Mexico, Conecuh National Forest in Alabama, Huron-Manistee National Forest in Michigan, and the Blackwater State Forest/Eglin Air Force Base in Florida. The mixture of ownerships in these areas displays the ability to use SIMPPLLE for lands other than National Forests.

Discussion

SIMPPLLE provides a modeling tool for managers to integrate and interpret concepts such as desired future conditions, range of variability, and the interaction between vegetation patterns and disturbance processes. SIMPPLLE offers an environment in which the knowledge developed by scientists and managers can be integrated into the quantification of potential vegetative conditions, disturbance process probabilities, and the logic for the interaction between processes and vegetation patterns. SIMPPLLE provides a way to help evaluate proposed management scenarios within a future that includes stochastic processes. Proposed schedules of management activities may not be possible when the likely occurrences of numerous disturbance processes are considered. Without the consideration of likely disturbance processes, effects of no action alternatives are often underestimated.

Stochastic simulations with SIMPPLLE can help in designing management strategies by quantifying what processes may have a higher occurrence on the landscape, or what parts of the landscape are more prone to disturbance processes. Does one use a management strategy that focuses action in those areas that have the highest likelihood of severe disturbance events with the intent of reducing the disturbance events? Does one use a strategy of treatments to create a vegetation pattern that reduces process spread? Or does one use a strategy of putting investments in management actions on those parts of the landscape that have a lower likelihood of significant change to minimize the chance of losing investments?

In the initial versions of SIMPPLLE, the emphasis is on the ability of the system design to capture our knowledge of vegetation change and the interaction between vegetation patterns and disturbance processes at different spatial scales. Future work will place an emphasis on improving the knowledge within the system. The initial validation work with Coram Experimental Forest in NW Montana indicates that the approach used for capturing and integrating process knowledge in SIMPPLLE does predict realistic results at landscape scales.

Complete documentation of the system is under development as a general technical report, and additional documentation and examples of use can be found on the website www.fs.fed.us/rm/missoula/4151/SIMPPLLE.

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EFFECTS OF SUMMER-AUTUMN NUTRITION AND PARTURITION DATE ON REPRODUCTION AND SURVIVAL OF ELK

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Abstract: Recent declines in numbers and juvenile recruitment in many elk (*Cervus elaphus*) herds in the western U.S. has sparked interest in factors that may cause these declines. Inadequate nutrition or delayed parturition, the latter of which may be caused by inadequate numbers of mature bulls (i.e., highly skewed sex ratios), may have separate or synergistic effects on population dynamics and productivity. We evaluated the implications of late parturition and summer-autumn nutrition on reproduction and survival of Rocky Mountain elk (*C. e. nelsoni*) using a captive herd of 57 cow elk.

We induced early (Sep) and late breeding (Oct) and 3 levels of summer-autumn nutrition on the cows. Food was offered ad libitum at 3 levels of digestible energy (DE): high = 2.9–3.0 kcal of DE/g of diets, medium = 2.6–3.0 kcal/g, and low = 2.3–3.0 kcal/g. Within these ranges, DE content was gradually reduced from late June through early November to mimic seasonal changes in the wild. During summer and autumn, we measured calf growth; body mass, nutritional condition, and breeding dynamics of cows; and growth and pregnancy of yearlings. We also measured carry-over (i.e., time-lag) responses including over-winter calf and cow survival and parturition date and birth mass, as functions of previous summer-autumn nutrition and previous parturition date. Between autumn 1995 and spring 1998, we conducted 2 years of parturition-date, summer-autumn nutrition experiments, 2 winters of calf survival experiments, and 1 winter of cow survival experiments.

Early birth provided calves with more time to grow before onset of winter. This "head-start" advantage was maintained through late autumn, but its magnitude was diluted in some instances due to faster growth of some late-born calves. Body mass, body fat, and timing and probability of conception by cows in autumn were little influenced by parturition date the previous spring.

Summer-autumn nutrition significantly affected calves and their mothers. Growth of calves in the low and medium nutrition groups ceased by mid-September and late October. By December, calves in the high nutrition group were 40% and 70% heavier than calves in the medium and low groups, respectively. Cows in the high nutrition group accumulated about 75% and 300% more fat than cows in the medium and low groups by mid-October. Eighty percent of cows in the low nutrition group failed to conceive, and those in the medium group bred 10–14

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days later than cows in the high group. Summer-autumn nutrition of calves influenced their probability of becoming pregnant as yearlings. Probability of pregnancy approached 100% for those yearlings that had high summer-autumn nutrition as calves and yearlings, despite near starvation their first winter of life.

Winter survival of calves was related to their size at the onset of winter. Smaller calves lost more body mass daily than did large calves, and thus they survived fewer days through winter. Summer-autumn nutrition largely determined calf body size at the start of winter and, consequently, determined the proportion of winter survived. Survival of cows over winter was as related to body fat at the onset of winter as it was to nutrition during winter.

Carry-over effects of summer-autumn nutrition and parturition date on birth characteristics the following spring were minor. We detected no significant carry-over effect of summer-autumn nutrition or autumn condition on birth mass, although reduced condition in autumn delayed subsequent parturition date. Extent of body fat depletion in cows during the winter-survival experiments in 1998 accounted for 45% of the variation in parturition date. Ninety percent depletion delayed parturition an average of 34 days.

Delayed parturition, of a magnitude expected due to highly skewed sex ratios (≤3 weeks under extreme conditions), probably has only a weak influence on vital rates of free-ranging elk. In contrast, fat accretion and probability of pregnancy of cows, and growth and overwinter survival of calves, were sensitive to small (10–20%) differences in DE content of food. Digestible energy levels of our 2 lower nutrition levels reflect DE ranges reported for large ungulate herds during summer and autumn in western North America. Thus, our data suggest that limiting effects of summer-autumn nutrition on populations may be greater than often assumed, perhaps greater than those during winter in some ecosystems, and consequently indicate a need for greater understanding of nutrition's influence on population dynamics and how this influence varies across space and time. To enhance future research, we present animal- and vegetation-based guidelines for evaluating nutritional influences on elk populations.

WILDLIFE MONOGRAPHS 155:1–61

Key words: *Cervus elaphus*, digestible energy, dry-matter intake, elk, gestation, growth, habitat, lactation, nutrition, nutritional condition, Oregon, population dynamics, pregnancy, reproduction, survival.

CONTENTS

INTRODUCTION 3
  Acknowledgments 4
STUDY AREA 5
METHODS AND DATA ANALYSIS 6
  Experimental Animals 6
  Overview 6
  Weather 7
  Autumn Through Spring Feeding Regimes 7
  Direct Effects of Summer-Autumn Nutrition and Parturition Date 8
    Cow-calf performance 8
    Lactating versus nonlactating cow performance 13
    Cow-calf food intake dynamics 13
    Yearling growth, intake, and breeding 14
  Carry-over Effects of Summer-Autumn Nutrition and Parturition Date 14
    Winter survival of cows and fetuses 14
    Calf winter survival 15
    Calf birth characteristics and gestation length 16
RESULTS 17
  Weather 17
  Autumn-Spring Body Mass Dynamics 18
  Direct Effects of Summer-Autumn Nutrition and Parturition Date 19
    Body mass dynamics of cows 19
    Nutritional condition of cows 20
    Breeding dynamics 21
    Aummer-autumn performance of lactating versus nonlactating cows 22
    Calf responses 25
    Food intake by cows and calves 31
    Yearling growth, intake, and breeding 35
  Carry-over Effects of Summer-Autumn Nutrition and Parturition Date 36
    Winter survival of cows and fetuses 36
    Calf Winter Survival 39
    Calf birth characteristics and gestation length 42
DISCUSSION 44
  Direct Effects 44
    Calf responses 44
    Cow responses 46
    Yearling responses 48
    Food intake patterns 49
    Digestible energy requirements 50
  Carry-over Effects 51
    Winter calf survival 51
    Winter cow survival 52
    Birth characteristics and gestation length 53
MANAGEMENT IMPLICATIONS 54
LITERATURE CITED 57

INTRODUCTION

Management and conservation have increased elk numbers from an estimated 100,000 to nearly 1 million over the last century in the United States (Christensen et al. 1999). Nevertheless, what may be perceived as a "golden" era may be coming to a close in some areas of the country. Like mule deer (*Odocoileus hemionus*) herds across much of the West (Carpenter 1998), productivity and population size of many elk herds in Idaho, Washington, and Oregon are declining, in some cases precipitously (Irwin et al. 1994, Gratson and Zager 1999, Ferry et al. 2001). The economic and social values of elk are enormous, and their declines threaten operating revenues of several state wildlife management agencies.

Declining ungulate populations in the western United States present important new challenges to wildlife biologists. These challenges are particularly intractable because causes of the declines are not well understood. Increasing predation, highly skewed sex ratios (i.e., a preponderance of yearling bulls and few mature bulls), inadequate habitat, and interactions among these and other factors are often cited as causes (Cook et al. 1995, Noyes et al. 1996, Carpenter 1998). This ambiguity probably is caused by scientist's failure to identify influences of limiting factors that regulate populations (Morrison 2001). Whatever the case, if the changing demographics are to be understood and managed, greater understanding is required of population regulation, particularly regarding top-down versus bottom-up influences.

Bottom-up influences on productivity of herds result from habitat's capability to provide food and thermal protection from harsh weather. For elk in many ecosystems, contributions of thermal cover probably are minor (Cook et al. 1998), suggesting in turn that habitat's contribution to elk productivity is largely a function of its nutritional adequacy and production of forage. Nutrition influences herbivores through density-dependent mechanisms (Fowler 1987), can limit productivity via density-independent effects (nutritional inadequacy may occur regardless of herbivore density), or perhaps indirectly by complex interactions with such top-down factors as predation. Considerable livestock research has established nutrition's influence on a variety of life processes, and substantial work with selected wild ungulates such as white-tailed deer (*O. virginianus*) and red deer (*C. elaphus elaphus*) also have advanced our knowledge. Nevertheless, the nature and extent to which nutrition regulates free-ranging populations of even these oft-studied species remain poorly understood.

Research of nutritional influences on elk is particularly rare. Canadian efforts have provided useful insights in recent years (e.g., Haigh and Hudson 1993). However, research focused on effects of nutrition during summer and autumn on reproductive performance of lactating elk and their calves is virtually absent (exceptions include Hudson and Adamczewski 1990, Cook et al. 1996). This apparent lack of interest undoubtedly stems from perceptions that forage on summer ranges is adequately abundant and nutritious so as to preclude important limiting affects on reproduction, survival, and population dynamics (Wallmo et al. 1977, Marcum 1975, Lyon 1980, Nelson and Leege 1982, Leege 1984, Christensen et al. 1993, Unsworth et al. 1998).

Forage quality and quantity certainly are greatest during the growing season. Nevertheless, nutritional requirements for lactation and juvenile growth place considerable demands on large herbivores (Verme and Ullrey 1984, Oftedal 1985, Cook et al. 1996) that limit reproduction if unsatisfied. Nutritional deficiencies in summer and autumn have been reported (Julander et al. 1961, Pederson and Harper 1978, Verme and Ullrey 1984, Merrill and Boyce 1991, Parker et al. 1996, Parker et al. 1999, Alldredge et al. 2002), and these may reduce pregnancy rates, delay sexual maturity and breeding, and reduce overwinter survival of adults and juveniles. Moreover, forest management is the primary land management activity on most summer-autumn ranges of elk in the western U.S., and forestry can have appreciable effects on forage quantity and quality available on these ranges (Hett et al. 1978, Cook 2002). The potential effect of this activity on productivity of elk herds may depend on the extent to which summer-autumn forage conditions affect reproduction and survival.

Selective hunting of bulls has appreciably reduced abundance of mature bulls in many elk populations (Schommer 1991, Leckenby et al. 1991). Low mature bull:cow ratios can delay breeding (Noyes et al. 1996), suggesting that inadequate numbers of mature bulls might reduce herd productivity by delaying parturition and, in turn, by reducing calf survival. This hypothesis depends on at least 4 assumptions: (1) breeding delays result in similar delays in parturition; (2) late-born calves are unable to "catch-up" with their early-born counterparts; (3) breeding delays are of sufficient magnitude to be relevant to calf survival; and (4) differences in body size of juveniles at the onset of winter influence probability of winter survival.

Validity of these assumptions may depend to some extent on limitations imposed by nutrition. During summer and autumn, nutrition may influence potential for late-born calves to catch-up or may influence the probability that late-born calves fall further behind. During winter, differences in juvenile body size may affect survival if winter weather and nutritional conditions are harsh, but have little or no influence if winter conditions are mild (Hobbs 1989). Hence, influences of adult sex ratios on herd productivity may be mediated by nutrition.

This study was designed to simultaneously compare effects of summer-autumn nutrition and breeding and birth dates on a host of reproduction and survival variables of elk. We conducted a series of experiments from summer 1995 through spring 1998 using a captive herd of 57 cow elk to achieve 3 primary goals:

1. estimate the main and interactive influences of summer-autumn nutrition and parturition date on reproduction and survival;
2. quantify nutritional requirements of lactating cows and their calves in summer and autumn; and
3. quantify the relation between magnitude of nutritional restriction and magnitude of reduction in reproduction and survival.

We tested specific hypotheses regarding influences of summer-autumn nutrition and parturition date. The first 4 hypotheses pertain to direct effects of summer-autumn nutrition and parturition date on reproduction; the final 3 pertain to carry-over effects of nutrition and birth date on subsequent reproduction and survival:

1. Nutritional condition (i.e., as defined by Harder and Kirkpatrick [1994]), timing and probability of becoming pregnant (breeding dynamics), summer-autumn calf growth and body size in late autumn, and yearling growth and pregnancy probability are sensitive to summer-autumn nutrition.
2. These variables (nutritional condition and so forth) are sensitive to variation in parturition date (and by extension, timing of breeding) that can be attributed to marked differences in bull age (e.g., ≤21-day delay in average conception date in herds in which most breeding is by yearling bulls [Noyes et al. 1996]).
3. These variables are influenced by interactions between parturition date and summer-autumn nutrition (i.e., the combination of late parturition and low nutrition or early parturition and high nutrition has greater influence on reproduction than would be expected based on the separate effects of these 2 factors).
4. Nutritional condition of lactating and nonlactating cows in summer and autumn is differentially influenced by different levels of nutrition.
5. Winter survival of pregnant cows and their fetuses is influenced by nutrition of the cow during the previous summer and autumn, across varying levels of winter nutrition.
6. Calf mass at birth and timing of parturition is influenced by the mother's nutrition during the previous summer and autumn, and her timing of parturition the previous spring (i.e., there is a carry-over effect of summer-autumn nutrition and parturition date from one year to the next).
7. Probability of winter survival of calves maintained on low winter nutrition is sensitive to levels of nutrition the previous summer and autumn and their birth date.

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STUDY AREA

The study site was located on private timberlands 30 km west of La Grande in the Blue Mountains of northeast Oregon. It was on traditional summer range of elk in the grand fir (*Abies grandis*) zone on a northeast-facing aspect at 1,300–1,350 m. Average annual precipitation was 87 cm, most falling in winter and spring. Average minimum and maximum temperature was –5.8 and 0.1°C in January and 11.0 and 24.7°C in July (National Oceanic and Atmospheric Administration 1966–75). The study site received about 10 cm of precipitation each month during the winter, most falling as snow. During this study, snow began to accumulate in mid-November, attained a depth of about 1 m by mid-winter, and melted from most of the study area by early April (see Cook et al. 1998 for more details).

Facilities consisted of 2 pen complexes (Fig. 1). The primary complex was rectangular and built to enclose a 3-ha clearcut,

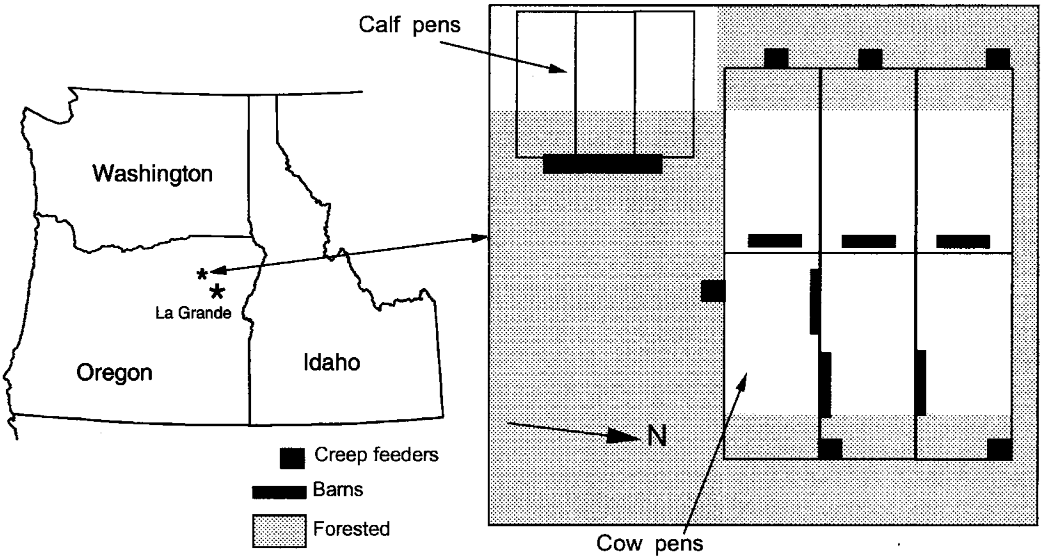

Figure 1. Layout of calf and cow elk pen complexes used for nutrition-reproduction studies in northeastern Oregon, 1995–1998. Each of the 6 pens for cows was 0.75 ha, and each of the calf pens was 0.3 ha. Both were constructed in clearcuts and contained mature forest. The barns were used for individually feeding food, weighing, and collecting physiological samples. Creep feeders attached to the cow pens were used to feed solid food to calves and were inaccessible to their mothers. All pens were interconnected to facilitate frequent rotation of elk among pens, to reduce potential microsite influences on elk performance. All forage was eliminated from all pens.

plus a small amount of adjacent forests. An access road running north-south split the complex in half, and each half was subdivided into 3 pens, providing a total of 6 pens 0.75 ha in size. Each pen contained similar amounts of forest (20%) and clearcut (80%) habitats. Small, 9-stall barns were built in each pen and used for individualized feeding, weighing, and handling as described by Cook et al. (1998). We held adult cows in this complex year-round, including during the breeding season when bulls were introduced to them.

A smaller complex about 1 ha in size held calves after weaning each year (Fig. 1). This complex consisted of 3 rectangular pens of equal size, each of which extended 20–30 m into forested habitat. A barn consisting of 55 stalls adjacent to the pens provided for individualized feeding and handling during winter survival experiments with the calves.

We also used five smaller pens built for previous studies (Cook et al. 1998) during the study. These were 0.1 ha in size, occurred with a feeding-handling barn, and were located in forested habitat. Feed storage facilities, an automated weather station, and technician housing also were present on the site (see Cook et al. 1998).

Elk were used during the summer of 1995 to eliminate vegetation within the pens by grazing and trampling. Pens remained unvegetated throughout the study.

METHODS AND DATA ANALYSIS

Experimental Animals

We used 2 cohorts of bottle-raised female elk, the first born in 1991 and the second in 1993 (Cook et al. 1996). The calves were captured when 1–4 days of age from the Starkey Experimental Forest and Range and adjacent areas in northeast Oregon. We used 22 4-year-old and 35 2-year-old cows at the beginning of the study. All bulls used for breeding during all 3 years were at least 3 years old; they were captured from wild stock held in the Starkey Experimental Forest and Range. They were transferred to the site each year at the start of the rut.

Overview

Preparation for the study started in early summer 1995, when all cows were fed a high quality diet so that they were in good to excellent nutritional condition at the start of the study (Fig. 2). In autumn 1995, cows were bred for the first time during 2 breeding

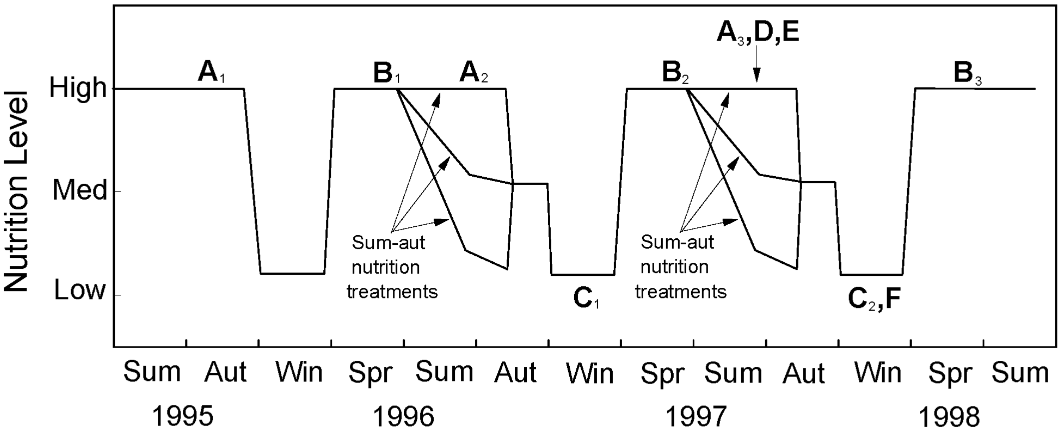

Figure 2. Chronological sequence of key events and experiments, and associated nutrition levels of calf and cow elk, northeastern Oregon, summer 1995 through summer 1998. The nutrition levels refer to relative differences in digestible energy intake: high corresponds to levels that supported a positive energy balance, medium roughly corresponds to maintenance levels, and low corresponds to levels that induced a negative energy balance. Large bolded letters identify timing of events and experiments: A = breeding times, B = birthing times, C = the experiments of calf winter survival, D = the experiment of lactating versus nonlactating cow performance, E = the experiment of yearling nutrition, breeding, F = the experiment of adult cow winter survival. At A_1, early and late breeding dates were induced in 2 groups of cows; at A_2 and A_3, timing of breeding was uncontrolled. Calves used in the C_1 and C_2 calf survival experiments were born at B_1 and B_2, respectively. Yearlings used in the experiment of summer nutrition-breeding (E) were born at B_1. The nutrition levels relate only to cows and calves in the experiments of summer-autumn nutrition (nutrition levels for experiments of calf winter survival, yearling nutrition-breeding, and cow winter nutrition are not presented in this figure).

periods to induce different parturition dates. We conducted experiments of direct effects of summer-autumn nutrition and parturition date on reproduction in 1996 and 1997. We compared nutritional effects on fat accretion of lactating and nonlactating cows in summer 1997. We also evaluated effects of summer-autumn nutrition on breeding dynamics of yearling cows this second summer using the cohort of calves born in spring 1996 (Fig. 2). We conducted experiments of carry-over effects of summer-autumn nutrition and parturition date on (1) adult cow and fetal survival in winter 1998, (2) survival of calves in winter 1997 and 1998, and (3) timing of birth and birth mass of calves in spring of 1997 and 1998 (Fig. 2).

Nutritional treatments were implemented only during summer and autumn; cows were offered identical diets the rest of the year (except for a subgroup during the winter survival experiment of 1998).

All pen complexes were constructed so that we could routinely rotate calves and cows among pens. This was intended to eliminate potential effects of microsite characteristics in each pen on elk responses to treatments. We rotated elk among pens twice per month, except during the parturition period to avoid disrupting mother-calf bonds. We emphasized varying digestible energy (DE) rather than protein or minerals. This was based on the assumption that energy, rather than protein or minerals, is most limiting to anabolic processes (Holter and Hayes 1977, Lyford and Huber 1988, Parker et al. 1999). We had insufficient elk for simultaneous examination of 2 or more nutritional constituents.

We conducted all statistical analyses with Statistical Analysis Systems (SAS Institute 1988), usually with the general linear models procedure (PROC GLM), except where noted.

Weather

We used an automated weather station, centrally located in a clearcut, to monitor weather conditions during the study. The station included probes to measure wind speed (Met-one 014A wind-speed sensor) and temperature (HMP 356 temperature-relative humidity probe). A CR10 control module accumulated and stored data on a SM192/716 storage module in a PC compatible format (Cook et al. 1998). All equipment was obtained from Campbell Scientific, Inc., Logan, Utah, USA. We calculated average, maximum, and minimum daily temperature and wind speed by month for the entire study.

Autumn Through Spring Feeding Regimes

Winter-spring feeding of cows used in the summer-autumn nutrition experiments was intended to be identical each winter of the study. We fed these cows submaintenance diets in winter to induce about 10% mass loss over winter. They received ad libitum, high quality diets during spring, to simulate natural seasonal cycles in forage conditions (see Cook 2002) and to eliminate nutritional restriction on fetal growth during the third trimester. During the breeding season until mid-December 1995, we fed all cows identical diets consisting of a mix of high quality pellets and alfalfa hay (Table 1) fed ad libitum. During the second (1996) and third (1997) years, we set feeding levels from the end of the rut (5 Nov) until the beginning of the winter mass loss period (mid-Dec) to hold body condition of the cows constant until early winter (Fig. 2). The purpose for this was to determine carry-over effects of parturition date and summer-fall nutrition on cow responses during winter and the following spring-summer period (i.e., prevent compensation by poor-condition cows in autumn).

Starting in mid-December of 1995, we fed cows a lower quality pellet and lower quantity of food to induce mass loss of 10% during winter. We occasionally adjusted feeding levels to ensure meeting our mass-loss goal. We monitored mass loss of non-pregnant cows to determine the need for adjusting feeding levels of pregnant cows, because fetal growth masked mass changes in pregnant cows. We terminated restricted feeding by the second week of March, re-acclimated the cows to the high quality rations and ad libitum feeding over a 2-week period, and then maintained this feeding regime through parturition, when the summer-autumn nutrition treatments were initiated. The feeding regimes of the subsequent winters and spring were

Table 1. Crude protein (CP), gross energy (GE), in vitro digestible dry matter (DDM), digestible energy (DE), and primary ingredients of rations fed to elk cows and calves, northeastern Oregon, 1995-1998.

Season	Year	Ration[a]	CP	GE	DDM	DE	Primary ingredients[b]
Sep-Nov	95	Pel-h	14.0	4.314	74.0	3.19	Oats, wheat, alf
		Hay-h	18.0	4.458	57.0	2.54	Alf
Dec-Feb	96	Pel-m	15.9	4.282	65.4	2.80	Feeder alf, ryegr, wheat middens
		Hay-h	17.9	4.363	64.4	2.81	Alf
Mar-Jun	96	Pel-h	15.7	4.315	79.4	3.43	Oats, wheat, alf
		Hay-h	16.7	4.340	63.2	2.74	Alf
Jul-Nov	96	Pel-h	15.7	4.315	79.4	3.43	Oats, wheat, alf
		Pel-l	13.8	4.062	56.5	2.30	Ryegr, straw, feeder alf, bent
		Hay-h	15.5	4.316	61.9	2.67	Alf
		Hay-m	13.6	4.337	56.7	2.46	Alf, orchard grass
		Hay-l	8.0	4.333	54.2	2.35	Fescue, mixed meadow grasses
Dec-Feb	97	Pel-m	14.3	4.291	67.1	2.88	Feeder alf, ryegr, wheat middens
		Hay-h	15.5	4.316	61.9	2.67	Alf
Mar-Jun	97	Pel-h	15.8	4.345	79.7	3.46	Oats, wheat, alf
		Hay-h	15.5	4.316	61.9	2.67	Alf
Jul-Nov	97	Pel-h	15.9	4.380	83.6	3.66	Corn, wheat middens, 19% alf
		Pel-l	14.2	3.997	56.3	2.25	Ryegr, straw, feeder alf, bent
		Hay-h	15.3	4.350	59.1	2.57	Alf
		Hay-m	8.3	4.361	57.7	2.52	Alf, orchard grass
		Hay-l	7.8	4.427	51.6	2.28	Fescue, mixed meadow grasses
Dec-Feb	98	Pel-m[c]	14.8	4.093	53.5	2.19	Feeder alf, ryegr, wheat middens
		Hay-h	15.3	4.350	59.1	2.57	Alf
Mar-Jun	98	Pel-h	15.9	4.371	79.9	3.49	Oats, wheat, alf
		Hay-h	15.3	4.350	59.1	2.57	Alf

[a] Ration codes are Pel = pellet and h, m, and l indicate relative level of DE content (i.e., high, medium, low). Units of nutritional constituents are percent CP, kcal of GE/g of food, percent DDM, and kcal of DE/g of food.

[b] Abbreviations are: alf = alfalfa hay; bent = bentonite (added to lower gross energy content); and ryegr = ryegrass screenings.

[c] Both the gross energy and DDM content of this pellet suggests the manufacturer inadvertently substituted the low-energy pellet for the medium-energy pellet formulation. The lower DE content of this pellet would account for the greater mass loss of cows in winter 1998 compared to the previous 2 winters.

intended to be identical (but see footnote "c" in Table 1).

For the first 2 winters of the study, we graphically illustrate body mass (BM) patterns, differences in mass loss between pregnant and open cows, and increases in mass during spring through the end of parturition.

Direct Effects of Summer-Autumn Nutrition and Parturition Date

Cow-calf performance.—In August 1995, the 57 cows were randomly assigned to 6 treatment groups in a 2 × 3 factorial design with 2 levels of breeding date and 3 levels of nutrition. We restricted randomization such that 2.5- and 4.5-year-old cows were equally distributed among each of the 6 groups. All cows assigned to the early breeding group were moved to the eastern 3 pens (Fig. 1), gates were opened so that cows could travel among these pens, and a bull was introduced on 5 September. We introduced the bull to the other cows on 5 October in the western 3 pens, and removed him from the study area on 5 November. This provided breeding dates expected of mature bulls (Sep breeding) and yearling bulls (Oct breeding) as described by Noyes et al. (1996).

Our objectives included evaluating effects of the treatments on probability and timing of breeding during the second and third (1996 and 1997) breeding seasons, so we provided cows with equal access to bulls during the entire rut of 1996 and 1997 and made no effort to induce different breeding dates. For this, we combined the 6 pens into 3 pens by opening gates to allow comingling of cows, within nutrition groups. We held wild-caught bulls in the pens, 1 in each pen, from about 5 September through 5 November both years. Thus, the early- and late-breeding treatments during the second breeding season (1996) resulted from post-hoc segregation of cows based on observed parturition dates the following spring, rather than from random assignment to breeding-date categories as in the first year.

We formulated the summer-autumn nutritional treatments to meet 3 criteria. First, we selected DE levels with biological relevance to free-ranging elk on summer ranges of the Blue Mountains Ecoregion of eastern Oregon and southeastern Washington. Our "high" nutrition treatment was formulated to avoid restriction of reproductive performance, without being substantially greater in DE content than wild elk might obtain on native range. We based the DE level (Fig. 3A) on beef cattle requirements (National Research Council 1984) and earlier experiments with these elk (e.g., Cook et al. 1996). The "low" nutrition treatment was selected to represent DE levels that elk might encounter in xeric coniferous forest zones (e.g., ponderosa pine [*Pinus ponderosa*], Douglas fir [*Pseudotsuga menziesii*], and grand fir [*Abies grandis*]) of the Blue Mountains during relatively dry years (Holechek et al. 1981, J.G. Cook, unpublished data). We used time-specific averages from these data as the target DE level for cows in the low nutrition group. Target DE levels for the "medium" nutrition group were the average of those fed to the low and high groups (Fig. 3A).

Second, we based the summer-autumn nutrition treatments solely on food quality (quantity offered was unrestricted), because we wanted to evaluate effects of quality on amount of food consumed. Further, we had no criteria on which to select biologically relevant feeding levels (i.e., quantity). The DE targets also were used for calves when they began consuming solid food.

Third, we emphasized using hay rather than pelleted rations to implement the nutrition treatments, particularly in the second year of the study. Pelleted rations simplify such studies (e.g., enhance individualized feeding), but pellet formulation renders fibrous tissue into small particles that can increase passage rates and food intake (Minson and Wilson 1994, Grey and Servello 1995). During the first summer of the study, we fed pellets and hay in a 45:55 ratio. We reduced this ratio the second summer: the high nutrition group received a 30:70 ratio, the medium group received a 20:80 ratio, and the low group received a 10:90 ratio. The low group received just enough pellets to entice elk into their barn stalls. The higher levels were required for the other groups to achieve target DE levels (i.e., hay DE levels needed augmentation).

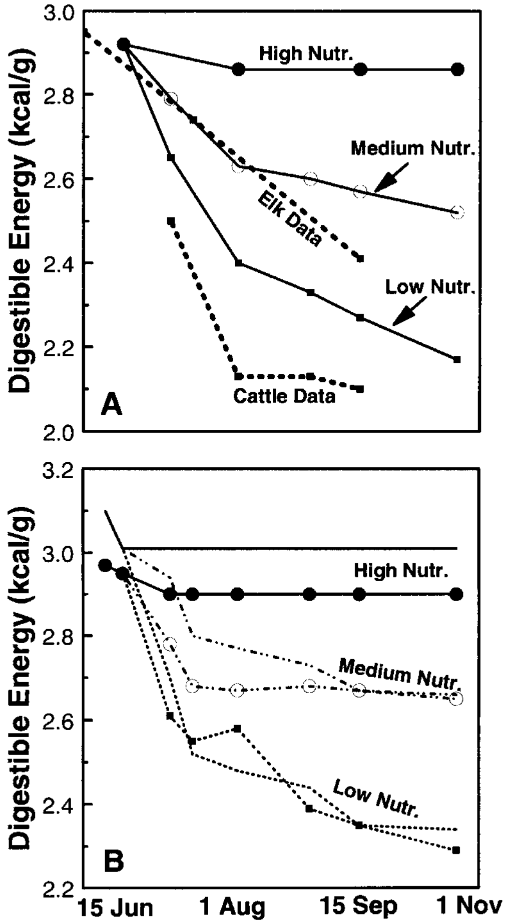

Figure 3. In graph A, target digestible energy (DE) content of food offered to cow elk and calves from late June through early November, 1996 and 1997, northeastern Oregon. Dashed lines labeled "elk" and "cattle" are dietary DE levels of elk (J.G. Cook, unpublished data) and cattle (Holechek et al. 1981) determined during drought years at moderate to low elevations in forest zones in the Blue Mountains Ecoregion of northeast Oregon. The average of these 2 DE levels set the target for the low nutrition treatment group. In graph B, actual DE content of food consumed by cows and calves from late June through early November, 1996 (lines without circles and squares) and 1997 (lines with circles and squares).

Attaining target DE levels across treatments involved combining foods of different quality. We used 2 pellet formulations and 3 different hays with varying levels of DE (Table 1). We formulated pelleted rations to provide required mineral concentrations based on beef cattle (National Research Council 1984). Mineral blocks were provided in pens. Type of hay offered at any given time over summer and autumn was that which most closely matched the target DE levels for the treatment group for that period, and the 2 pellet types were mixed in ratios so that the overall DE actually consumed by the elk matched the target for their nutrition group. This approach required monitoring of intake, because required pellet ratios reflected amount of hay eaten. We adjusted rations weekly to comply with desired DE levels and desired pellet:hay ratios. We increased DE in the high energy pellet formulation in 1997, compared to 1996, to compensate for the lower pellet:hay ratio of that year (Table 1).

We fed cows twice daily (typically at 0800 and 1300 hr). They were fed pelleted food individually in the barns in the mornings. Amount of pellets fed to each elk was based on metabolic body mass ($BM^{0.75}$). They generally consumed their pellets within 1–2 hours and were then released back to their calves. We fed hay communally within treatment groups in the hay mangers outside of the barns at the second feeding. All orts were collected and measured individually for pellets and communally for hay. We fed hay ad libitum, and the amount was adjusted each day such that cows in aggregate generally left no more than a few kg uneaten. This minimized selective feeding and waste. Thus, cows had access to food 24 hours each day, thereby ensuring our estimates reflected true voluntary intake (Minson 1990). However, we could estimate total daily intake of food only for treatment groups, not for cows individually within groups, thereby precluding variance estimates of daily intake by individuals.

We fed hay and pellets to calves in creep feeders (i.e., small pens that allowed calves to have continuous access to food while excluding cows [Fig. 1]). Hay was fed ad libitum to all calves. We offered calves about 1 kg more hay each day than was consumed the previous day, to provide ad libitum amounts while minimizing selection. We adjusted the ratio of high energy to low energy pellets such that the overall target dietary quality was achieved. Orts were removed from the feeders and weighed each day. Just after the rut, calves were weaned from their mothers and moved to the calf-pen complex (5 Nov in 1996, 15 Nov in 1997), where they remained segregated by nutrition level through late November. For experiments of winter calf survival, described below, we trained calves to enter the barns for feeding. Weaning, and this training, initiated a period of disrupted feeding that lasted 1–2 weeks.

Estimates of DE levels of each of the pellet and hay types were known sufficiently to formulate mixes of hay and pellet rations. More exact estimates of DE and crude protein were determined from samples of each collected over the feeding period. The Habitat Analysis Laboratory at Washington State University, Pullman, Washington, USA, conducted quality assays—crude protein by macro-Kjeldahl analysis, gross energy by bomb calorimetry, and dry-matter digestibility by 2-stage in vitro trials (Association of Official Agricultural Chemists 1980). We estimated DE content as the product of gross energy and in vitro digestibility (Hobbs et al. 1982).

Treatment responses included BM dynamics of cows and calves, nutritional condition of cows, and timing of breeding and pregnancy rates of cows. We weighed cows twice weekly on electronic scales in weighing chutes as they entered and exited the feeding barns (Cook et al. 1998). We weighed neonates with hand-held spring scales and older calves in the weighing chutes.

We estimated nutritional condition using 2 techniques developed in a companion study (Cook et al. 2001*a,b*). We developed a body condition score (BCS) in autumn 1996 and used it for the duration of the study. Our BCS, derived from the caribou (*Rangifer tarandus*) BCS by Gerhardt et al. (1996), relied on palpation of the withers, ribs, and rump (Cook et al. 2001*a,b*). Beginning in autumn 1997, we combined subcutaneous rump fat thickness, measured using ultrasound (Stephenson et al. 1998), and BCS into an index, referred to as LIVINDEX, that is superior to either measure used separately (Cook et al. 2001*a,b*). We used BCS solely from autumn through summer 1996–97 and

LIVINDEX thereafter. We also used ultrasound to measure thickness of the longissimus dorsi (loin) muscle between the twelfth and thirteenth rib. This provided an index to catabolism of lean mass that was particularly useful for cows in poor condition (Cook 2000). We sedated cows to measure condition using xylazine hydrochloride (0.5 mg/kg BM) administered intramuscularly by hand-injection with syringes. We reversed sedation by intravenous injection of yohimbine hydrochloride (0.1 mg/kg).

We converted BCS estimates to estimates of body fat (%) and gross energy (GE: Mcal/kg) of the ingesta-free body using the following equations (Cook et al. 2001*a,b*):

$$\text{FAT} = -5.53 + 4.78(\text{BCS}),$$

and

$$\text{GE} = 0.842 + 0.381(\text{BCS}).$$

We calculated LIVINDEX from estimates of BCS and rump fat thickness and, in turn, converted LIVINDEX estimates to ingesta-free body fat and GE. Fat and GE were calculated from LIVINDEX using the following equations (Cook et al. 2001*a,b*):

$$\begin{aligned}\text{FAT} = {} & -9.9 + 9.187(\text{LIVINDEX}) \\ & - 1.383175(\text{LIVINDEX}^2) \\ & + 0.0839512(\text{LIVINDEX}^3),\end{aligned}$$

and

$$\begin{aligned}\text{GE} = {} & -0.37 + 0.823(\text{LIVINDEX}) \\ & - 0.128536(\text{LIVINDEX}^2) \\ & + 0.0077629(\text{LIVINDEX}^3).\end{aligned}$$

We determined pregnancy status in all years of the study using pregnancy-specific protein B (PSPB) (Noyes et al. 1997) in serum collected in late autumn. Timing of conception in 1996 was determined also with PSPB, by sampling in selected windows such that conception during the first (5–24 Sep), second (25 Sep–15 Oct), and third (16 Oct–5 Nov) 3-week periods of the 9-week rut could be determined. Based on the assumption that PSPB could reliably identify pregnancy at about 30 days post-conception (it is now recognized that accuracy may increase up to about 40 days post-conception [G. Sasser, personal communication.]), we collected serum from all cows on 21 October, again on 12 November for cows found nonpregnant in October, and all cows again in mid-December. From this we assigned conception dates to each of the 3 periods. In 1997, timing of breeding was determined by direct observation. We collected feces daily and assayed them for progesterone metabolites, providing indications of estrus that confirmed field observations (Cook et al. 2001*c*).

These experiments evaluated effects of nutrition and parturition date on cow and calf performance from the end of parturition, when nutrition treatments were initiated, until early November, when calves were weaned. We used percent fat and GE of the ingesta-free body and BM changes to examine nutritional condition responses of cows. We averaged the 2 estimates of mass collected each week and converted them to change-in-mass (%) for statistical analysis. Change-in-mass was calculated as the difference between starting mass and mass each subsequent week, divided by starting mass, and converted to percent.

Effects of parturition date and summer-fall nutrition on BM dynamics were analyzed with fixed-effects, repeated measures 2-way ANOVA, using the multivariate mode of PROC GLM. The key effects for these analyses were the following interactions: week × nutrition, week × parturition date, and week × nutrition × parturition date effects. In an experiment of this type, only the interactions are of interest because effects appear after the experiment commences, if indeed the treatments influence the dependent variable (e.g., BM). We identified differences among treatments each week using least squares means. The assumption of sphericity (SAS Institute 1988: 605) was routinely violated, and we used the Huynh-Feldt adjustment to account for it (SAS Institute 1988: 605).

Before analyzing parturition date and nutrition effects, we identified potential confounding from calf gender, cow age, and, in the second year, the influence of previous-year nutrition (carry-over effect). For the first year, we conducted the repeated measures ANOVA with all variables included (e.g., parturition date, nutrition, gender, and cow age), plus interactions, to identify calf gender and cow age effects. For the second year, insufficient df precluded repeated measures ANOVA with all independent variables (plus previous-year nutrition level). Hence, we conducted a sequential approach: (1) all main effects and highest order interactions (4- and 5-way interactions), (2) main effects and 3-way interactions, and (3) main effects and 2-way interactions. Although this was not an optimal analysis, it helped identify the nature and extent of influences of the potentially confounding variables.

We removed influences of significant confounding variables from the data set via the following. Within each of the 6 treatment groups, percent change-in-mass of cows of the first level of the potentially "confounding" factor (e.g., mean change-in-mass of mothers of female calves) was subtracted from that of the second level (e.g., mean change-in-mass of mothers of male calves) for each week of the data stream. The resulting difference should reflect the effect of the potentially confounding factor (e.g., calf gender effect). Next, we regressed these differences with time using linear and nonlinear (PROC NLIN) techniques. The models then were used to remove their confounding influences from the data set, providing a less confounded data set to illustrate parturition date and nutrition effects on cow performance.

We measured body fat and GE content of cows during the rut in late-October in 1996 and 1997, providing a single end-point estimate of summer-fall nutrition and parturition-date influences. Effects of nutrition and parturition date on body fat and GE content were identified using 2-factor, fixed-effects ANOVA, one for each attribute.

Influences of parturition date and nutrition on pregnancy rates were identified using logistic regression (PROC CATMOD) with pregnancy status as the dependent variable and parturition date and nutrition as the independent variables. We used a chi-square test as a supplemental analysis to compare influences of parturition date and nutrition (PROC FREQ). Then, we used logistic regression (PROC CATMOD) to provide equations of pregnancy probability as a function of nutritional condition during autumn.

We identified influences of parturition and nutrition on timing of conception (early, middle, and late) during the rut of 1996 using a chi-square test (PROC FREQ). Because actual breeding dates of cows were known in 1997, and thus the dependent variable was continuous, we conducted a fixed effects, 2-factor ANOVA for the second year of data, to identify influences of parturition date and nutrition.

Influences of birth date and summer-autumn nutrition on calf growth were evaluated in 3 stages. First, calf growth from birth until initiation of nutrition treatments in late June was evaluated as a function of birth date, birth mass, calf gender, cow age, in the first year, and previous-year nutrition of the mother, in the second year. We used fixed-effects analysis of covariance (ANCOVA), using all variables, and multiple regression (PROC GLM), using continuous variables, to compare effects of these factors on BM at the end of this period. To more thoroughly illustrate the contribution of birth mass to growth of neonates, we reran the ANCOVAs with birth mass excluded, generated residuals from the model, thereby removing the effects of all other variables, and regressed these residuals with birth mass. All potential interactions were included.

Second, we subtracted calf weights obtained when nutrition treatments were implemented from all subsequent calf weights. This removed the effects of birth date and other potential influences occurring soon after parturition on calf mass dynamics after the nutrition treatments were implemented. This permitted evaluation of a second potential effect of birth date: a lingering effect of birth date on growth rates later in summer and autumn (e.g., evidence of reduced or accelerated growth of late-born calves). We used fixed-effects, repeated measures ANOVA to identify influences of birth date, summer-autumn nutrition, and the potential for confounding due to calf gender and cow age. Because adjusted mass of all calves was zero at the start of the period, only the interaction terms with time were of interest. An initial run was conducted with all interactions included to provide initial indications of calf gender and cow age effects. We removed these effects if they were important as described above for cows.

Then, we re-ran the ANOVA to test for birth date and nutritional influences on calf growth over summer and autumn.

Third, we conducted a final 5-factor ANCOVA to determine effects of gender, nutrition, birth mass, cow age for the first year's experiment, previous-year nutrition of the mother for the second year's experiment, and actual birth date (rather than the early-late levels of the repeated measures ANOVA) on unadjusted BM of these calves at the time of their weaning by mid-November. To thoroughly examine the individual effects of these variables on BM at weaning, we reran the ANCOVA with 1 independent variable removed, calculated the residuals, then evaluated the relation between the removed independent variable with weaning mass, using simple linear regression, once for each independent variable. This provided a better illustration of each variable's effect on calf weaning mass with effects of all other independent variables removed.

Lactating versus nonlactating cow performance.—During the second summer, we compared differences in the effects of nutrition treatments between lactating and nonlactating cows over the summer-fall period. We used 12 nonlactating cows for this experiment. Six received a diet identical to that offered to the lactating cows in the high nutrition group, and 6 received the diet fed to the lactating cows in the low nutrition group. We monitored food intake and nutritional condition of these cows as described for their lactating counterparts.

We compared nutritional condition (LIVINDEX) estimated in mid-October using 2-factor ANOVA, with 2 levels of summer-autumn nutrition (low and high) and 2 levels of lactation status. Body condition scores collected the previous March and June were used to identify differences in condition, prior to the summer nutrition treatments, that might have accounted for differences in condition observed at the end of the summer-autumn nutrition period. We tested for differences in condition at each sampling time using 1-way ANOVA with 4 levels of the single factor: (1) summer lactating, high summer nutrition; (2) summer lactating, low summer nutrition; (3) summer nonlactating, high summer nutrition; and (4) summer nonlactating, low summer nutrition. Condition of 1/4 of the cows in this analysis was not determined in June, precluding a single, repeated-measures ANOVA in place of 3, 1-way ANOVAs.

Cow-calf food intake dynamics.—Our system of feeding provided direct, separate measures of pellets that cows and calves consumed each day. But it imperfectly segregated hay consumption by calves from that by cows, because calves were able to consume hay that was intended for the cows. We attempted to segregate hay consumption by cows and calves by constructing hay mangers for the cows that calves could not access. These were elevated above the reach of the calves, and a woven wire frame was built into the mangers to cover the hay and prevent cows from dropping flakes of hay out of the mangers. Casual observations indicated this approach worked when calves were small but was less effective as calves grew, particularly by late September.

Therefore, we conducted a 4-day trial at the end of the second summer-autumn season (10–14 Nov 1997), just after nutrition treatments for the cows were ended, to estimate how much hay intended for cows was consumed by their calves. During this trial, all food for cows was offered in the barn, such that all food consumed by calves was from their creep feeders and therefore could be estimated accurately.

In 1996 and 1997, cow-calf pairs within nutrition treatments were separated according to breeding group (i.e., early and late) through summer until the rut. Thus, we were able to measure food intake for each of the 6 treatment combinations during summer. However, when the rut began, we combined cows across breeding groups such that all cows within a nutrition treatment had access to the same bull (this was necessary because we had insufficient bulls for all 6 treatment combinations). Independent estimates of food intake for each parturition-date group therefore were obtained only through early September of both years.

Because elk within treatment groups were fed hay communally, we could not calculate variances of dry-matter intake, so we illustrated treatment effects on intake graphically. We first estimated intake for cow-calf pairs, simply because we were unable to completely segregate hay consumption by cows and their calves. Such a presentation of intake data is atypical and precludes comparisons to published estimates of requirements. Hence, we also estimated intake by cows and their calves using the following approach. For cows, we calculated an initial estimate of total dry-matter intake based on pellet consumption in barn stalls and hay consumption from mangers. We next plotted with time, on an age and $BM^{0.75}$ basis, (1) estimates of dry-matter intake from 5 published studies of elk calves, red deer calves, and white-tailed deer fawns (reviewed by Cook et al. 1996) and (2) dry-matter intake of our calves, estimated from food consumed in the creep feeders, in the high nutrition group. We assumed that the time of divergence between the published estimates of intake versus that measured from the creep feeders in our study would indicate when in summer our calves began taking appreciable amounts of hay from the cow mangers. At the end of the experiment in early November, differences in hay intake by calves immediately prior to versus during the 4-day trial (where all hay fed to cows was provided in the barns and thus inaccessible to calves) indicated the amount of hay intended for cows that was actually consumed by calves. From these beginning and ending points, we calculated an adjustment to account for the hay calves stole from their mothers. We expressed all intake data on a daily basis averaged across weekly time intervals.

Yearling growth, intake, and breeding.—We evaluated carryover effects of summer-autumn nutrition/birth date of the first cohort of female calves on their pregnancy status as yearlings (n = 19). In early April 1997, we placed the 19 female calves from the winter calf survival experiment of 1996–97 on an ad libitum, high-quality feeding regime. The ration consisted of the high quality pellet (Table 1), fed in a ratio of 60:40 with alfalfa hay. This ration provided an overall DE level in the diet of 3.2 kcal/gram of dry-matter. Also in April, the 19 elk were ranked by BM and randomly assigned to 1 of 2 nutrition groups, such that the distribution of BM was similar in each. We fed elk in the high nutrition group the high quality ration through early September. We fed those in the medium nutrition group this ration until 1 August, then reduced their pellet:hay ratio to implement a DE feeding level of 2.9 kcal/g of food. Hay fed to both groups remained identical and was offered ad libitum. We maintained this feeding regime through 8 September.

These 19 females, now yearlings, along with 21 adult, nonlactating cows, were placed with a bull from 9 September through 7 November 1997. We fed all cows alfalfa hay (2.6 kcal of DE/g; Table 1) ad libitum during this time (intake was not measured). After the rut, we fed the yearlings only alfalfa hay through winter until parturition. They were closely monitored during parturition, and birth date, birth mass, and calf gender were determined for calves born to these cows.

We determined differences in total growth over summer between the high and medium nutrition levels using a t-test on BM at the end of summer. We also compared differences in BM between pregnant and nonpregnant yearlings for this cohort at 4 time periods: when these cows were 6-month-old calves (late Nov 1996), 10-month-old calves (Mar 1997), yearlings just prior to rut (Sep 1997), and yearlings just after the rut (Nov 1997). We used logistic regression (PROC CATMOD) to model probability of pregnancy as yearlings as a function of BM for each of these 4 time periods. These analyses provided insights particularly regarding influences of summer and autumn nutrition of calves on their probability of pregnancy as yearlings. We included the summer nutrition factor in these regressions to evaluate the combined influences of summer nutrition and BM.

Carry-over Effects of Summer-Autumn Nutrition and Parturition Date

Winter survival of cows and fetuses.—During the final winter of the study (1997–98), we evaluated influences of summer-autumn nutrition, autumn condition, and winter nutrition of cows on probability of winter survival of cows and their fetus. Our original intent with this experiment was to bolster understanding of carry-over effects of summer-autumn nutrition on fetal survival, but it provided data more useful for identifying carry-over effects on cow survival.

Lactating cows used in the summer-autumn experiment of 1997 that re-bred during the rut (1997), and all cows that were nonlactating but became pregnant over the same period, were used for this experiment. We placed cows that were lactating the previous summer-autumn on the same winter diet fed the previous 2 winters, which we hereafter refer to as the "winter-high" nutrition level. Pregnant cows that were not lactating the previous summer-autumn ($n = 21$) were randomly assigned to 2 winter nutrition groups, a low nutrition level designed to induce rapid weight loss and a medium nutrition level that was intermediate between the low and high levels (Table 2). This provided 4 treatment groups: (1) lactating and fed high nutrition in summer-autumn and fed high nutrition in winter (SHWH); (2) lactating and fed medium nutrition in summer-autumn and fed high nutrition in winter (SMWH); (3) nonlactating in summer-autumn and fed medium nutrition in winter (SNWM); and (4) nonlactating in summer-autumn and fed low nutrition in winter (SNWL) (the latter 2 groups of cows were fed alfalfa hay ad libitum through summer and autumn). We chose not to randomly assign summer-lactating cows to the winter nutrition groups, so that feeding of the cows lactating in the previous autumn was identical each winter of the study.

We analyzed in 2 stages effects of winter and summer nutrition on winter survival of cows during the final winter of the study. First, 1-way, repeated measures ANOVA was used to identify differences in rates of declining condition, loin thickness, and BM from early, mid-, to late winter (thus the interaction between each of these factors and time was of interest) among the 4 treatment groups identified above. Least squares means were used to identify when these groups differed. Second, because 1 cow died and 5 more were removed from the study to prevent death, we were able to model probability of winter survival based on winter nutrition level and beginning nutritional condition. We used logistic regression to predict (1) probability of surviving from mid-December through early March as a function of late-autumn nutritional condition and winter nutrition and (2) probability of surviving from mid-February through early March as a function of mid-February condition and winter nutrition.

Table 2. Dry matter (g of DM/kg BM$^{0.75}$) and digestible energy (kcal of DE/kg BM$^{0.75}$) feeding levels and strategies for 3 nutrition treatment groups (high, medium, and low) of cow elk, northeastern Oregon, winter 1997–98.

Date	Feeding strategy	High DM	High DE	Medium DM	Medium DE	Low DM	Low DE
13 Nov	Maintenance	82	195	82	195	82	195
27 Dec	Begin treatment	51	121	44	105	36	84
28 Jan	Adjust treatment	47	112	40	95	33	79
19 Feb	Adjust treatment	37	87	31	74	26	61
27 Feb	Adjust treatment	47	112	40	95	33	79
06 Mar	End treatment	67	159	67	159	67	159
18 Mar	Ad libitum	90	212	90	212	90	212
05 Apr	Ad libitum	100	308	100	308	100	308
13 Apr	Ad libitum	105	325	105	325	105	325

Calf winter survival.—Our intention for this work was to evaluate the influences of birth date and summer-autumn nutrition on the ability of calves to survive during winter (i.e., test the hypothesis that larger calves have a greater probability of surviving winter). We conducted 2 of these experiments, 1 each winter of the study.

We simulated harsh winter conditions by feeding calves diets markedly below levels required for maintenance from mid-December until mid-March. In early December, all calves were individually fed identical diets of moderate quality that initiated a period of transition from the summer-autumn nutrition treatments to the overwinter submaintenance diets. At the end of the transition, we reduced feeding level to induce BM loss at a level that would guarantee virtually 100% "mortality" of the calves at winter's end. We based this level on experience gained during submaintenance feeding experiments in other studies (Cook et al. 1998). We used 2 variations of this approach (Table 3). In the first winter (1996–97), feeding level was stepped down gradually, mimicking winters in which harshest conditions occur relatively late in winter (i.e., late Feb and early Mar). In the second winter (1997–98), feeding level was dropped more abruptly early, thereby mimicking winters in which harsh conditions occur early and persist throughout winter. We fed calves all food individually in the barns, so that the

Table 3. Daily levels of pellet and hay dry matter, digestible energy (DE), and crude protein (CP) fed to elk calves in winter survival experiments of 1996–97 and 1997–98, northeastern Oregon. All values are expressed on a dry-matter basis per kg of $BM^{0.75}$.

	Dry matter (g)				
Year/Date	Total	Pellets	Hay	DE (kcal)	CP (g)
1996–97					
4 Dec	61.0	33.6	27.4	170	9.2
10 Dec	50.0	30.0	20.0	140	7.5
27 Dec	45.0	26.5	18.5	126	6.8
17 Jan	40.0	23.7	16.3	112	6.0
10 Feb	35.0	20.7	14.3	98	5.3
18 Feb	30.0	17.7	12.3	84	4.5
9 Mar	25.0	14.8	10.3	43	3.8
1997–98					
7 Dec	61.0	24.4	36.6	148	9.2
11 Dec	45.0	26.9	18.1	106	6.8
19 Dec	40.0	20.0	20.0	95	6.0
30 Dec	35.0	17.5	17.5	83	5.3
15 Jan	30.0	15.0	15.0	72	4.5

complete diet of each calf was strictly controlled. We fed each calf identical dry-matter and DE/kg $BM^{0.75}$. Calves typically required 4 hours in the barn to consume all food offered (once-per-day feeding).

The primary response variable used to judge the influence of prior birth date and nutrition on winter survival was the number of days of winter "survived." We retained calves in the experiment to the point where death was imminent, proclaimed "dead" for the purposes of the study, and then moved to different pens to allow recovery.

Identifying this point was somewhat subjective, but we found in earlier studies (Cook et al. 1998) that elk calves become lethargic, hypoglycemic, and hypothermic near death, and that these signs generally occur at about 20% BM loss. To prevent unwarranted mortality, we developed the following criteria to identify the point at which death was imminent:

1. Any calf was removed if mass loss was ≥25% (we found that calves rarely reached this level and so continuing with them was pointless).
2. For mass loss ≥22%, calves were removed if (a) rectal temperature was ≤38.3°C (~38.8–38.9° is normal), or (b) any evidence of weakness was evident (reluctance to stand when approached, unsteady or wobbly gait, or "glazed" appearance in eyes).
3. For mass loss of 19–21%, calves were removed if (a) temperature was ≤38.1°C, or (b) weakness was clearly evident.
4. For mass loss of 15–18%, they were removed if there was clear evidence of weakness, particularly if temperature was ≤38.6°C and rectal temperature could be obtained with little or no resistance from the calf. (Nearly all of these dam-reared calves stridently resisted handling when in good physical condition; thus we considered lack of resistance a good indication that the calf was seriously debilitated).

We weighed calves once each week and once each day as status became more critical. We measured rectal temperature in the morning; temperature later in the day was less indicative of susceptibility to nocturnal hypothermia.

We began the winter submaintenance diets on 11 December and terminated them 100 days later on 20 March, even if all calves had not been removed from the study. Rate of mass loss, calculated from the time the experiments began until calves were removed from the study, also provided useful insights regarding calf tolerance to winter conditions. We first calculated average total percent mass loss, rate of mass loss (percent per day), and number of days of winter survived by gender, to look for potential confounding by calf gender. We evaluated rate of mass loss as a function of beginning BM and calf gender using ANCOVA, and eliminated gender as a variable in the analysis if no significant influences were found. We used polynomial regression to model nonlinear relations. Finally, we identified effects of summer-autumn nutrition and birth date of the calves using 2-factor ANOVA. Data for each winter were analyzed separately, because the nutritional regimes were markedly different (Table 3).

Calf birth characteristics and gestation length.—We evaluated birth date, birth mass, and gestation length as a function of summer-autumn nutrition and parturition date of the cow the previous year, winter nutrition (final winter only), and nutritional condition of autumn and winter the previous year.

We determined birth date by close observation. Neonates were first captured and weighed the second day after birth, when 1 day old, to facilitate bonding between mother and calf. For the first 2 cohorts of calves, exact gestation length was unknown because exact conception dates were unknown. Direct observations of breeding, which we assumed to be analogous to date of conception, during the final breeding season of the study provided a basis to calculate gestation length for the third cohort.

We conducted analyses to identify variables that influenced birth mass, parturition date, and gestation length. We evaluated birth mass of spring 1997 and 1998 as a function of (1) previous-year summer-autumn nutrition and previous-year parturition date, and (2) nutritional condition the previous autumn. The former, plus calf gender, was evaluated with 3-factor ANOVA and the latter, again with gender, was evaluated using ANCOVA. We also used ANCOVA to evaluate relations between birth mass and change-in-condition during the cow-fetal winter survival experiment. We conducted this analysis using data from the 21 cows in the cow-fetal winter survival experiment that were fed the medium and low winter nutrition treatments during winter 1998. Because these cows were not lactating the previous autumn, we could not examine carry-over effects of previous-year summer-autumn nutrition and previous-year parturition date. Calf gender, and the interaction between gender and condition-change, also were included in this ANCOVA.

Influences on parturition date and gestation length were identified in 3 steps. First, we used 3-factor ANOVA to evaluate relations between parturition date and previous-year summer-autumn nutrition and previous-year parturition date. We included "year" as the third factor, because we combined data from the parturition period of 1997 and 1998 in this analysis. Second, for those cows in which gestation length could be directly calculated (1998 data only), we identified effects of previous-year summer-autumn nutrition and previous-year parturition date using 2-factor ANOVA. All possible interactions were included in both ANOVAs. Third, for those cows not lactating in autumn of 1997, included in the cow-fetal winter survival experiment of 1998, and for which conception dates were not determined, we used parturition date (of spring 1998) as a surrogate of gestation length based on the assumption that conception dates were approximately equal (all these cows were in good condition and nonlactating during the rut). We regressed parturition date with the overwinter decline in body condition.

RESULTS

Weather

We collected weather data from October 1995 through January 1998 (Table 4). We intended to collect data through spring 1998, but technical difficulty with the recording equipment, not evident at the time, prevented data collection after January.

Table 4. Monthly means ± SE of daily average, maximum, and minimum temperature (°C) for elk study area, northeastern Oregon, October 1995 to January 1998.

	1995			1996			1997			1998		
Month	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Jan				–3.3±1.1	0.0±1.0	–6.3±1.3	–2.9±0.8	0.7±0.7	–6.2±1.0	–4.1±1.0	–1.2±1.2	–6.4±1.0
Feb				–2.0±1.3	3.7±1.3	–6.4±1.4	–1.7±0.7	3.3±0.6	–5.7±0.8			
Mar				1.6±0.6	6.9±0.8	–2.5±0.7	1.4±0.7	6.2±0.9	–2.6±0.6			
Apr				5.0±0.7	10.8±0.9	0.2±0.6	3.0±0.7	8.5±0.9	–1.7±0.7			
May				6.4±0.6	11.4±0.6	1.9±0.7	9.4±0.8	14.8±1.0	4.0±0.7			
Jun				12.2±0.3	18.1±0.8	5.7±0.6	11.6±0.5	17.3±0.6	6.1±0.5			
Jul				18.6±0.8	25.2±0.8	11.4±0.8	15.9±0.6	22.4±0.7	9.1±0.5			
Aug				17.7±0.8	24.8±1.0	10.6±0.7	18.0±0.5	24.6±0.6	11.0±0.4			
Sep				11.1±0.8	17.8±1.0	5.1±0.7	13.5±0.8	19.6±0.9	8.4±0.8			
Oct	4.7±0.7	9.8±0.9	0.5±0.6	8.0±1.5	14.5±2.0	3.1±1.2	5.3±0.6	10.7±0.8	1.1±0.5			
Nov	3.2±0.7	7.1±0.7	0.2±0.8	–0.6±0.6	1.3±0.5	–2.3±0.9	2.2±0.5	6.7±0.7	–0.8±0.5			
Dec	–1.9±0.6	1.4±0.6	–4.8±0.7	–1.8±0.6	1.3±0.7	–4.6±0.7	–2.4±0.5	0.5±0.6	–5.1±0.6			

Temperature during June through October averaged 13.5°C in 1996 versus 12.9°C in 1997, indicating similar regimes during both summer-autumn experiments. Temperature during December through February of 1995–96, 1996–97, and 1997–98 averaged –2.4, –2.1, and –3.3°C. Average daily and minimum temperatures were similar during both calf survival experiments of the latter 2 winters (Table 4). Moreover, temperatures during summer and winter throughout the entire study were within ranges typical for this area (see Cook et al. 1998).

Harsh winds were infrequent during all seasons. During both summer-autumn periods, average wind speed was 1.3 m/s and average maximum wind speed was 2.8 m/s.

Autumn-Spring Body Mass Dynamics

During the first fall and winter of the study (1995–96), BM of cows varied among early- and late-bred and pregnant and non-pregnant cows, despite identical rations offered to all (Fig. 4A). Before feeding was restricted in late December, non-pregnant cows tended to lose mass, whereas pregnant cows tended to gain mass, particularly in late autumn. Early-bred cows tended to gain more mass than did late-bred cows. Both patterns probably reflected accretion dynamics of uterine and fetal tissues.

Initiation of restricted feeding in December (1995) induced mass loss among all groups by early January, and mass loss continued to differ among groups (Fig. 4A). Pregnant cows lost 5–7% whereas open cows lost 9–11% of their mass between December and March, and early-bred cows tended to be heavier than late-bred cows during winter, despite being fed the same amount of identical rations. Accretion patterns of uterine and fetal tissues probably accounted for these differences. During the second winter of the study, there was little evidence of an effect of early and late breeding on mass dynamics, but a difference between pregnant and non-pregnant cows was evident (Fig. 4B). Non-pregnant cows lost 3–4% of their mass by mid-December and lost 10–11% by early March, approximately twice that of pregnant cows.

The third trimester in springs of 1996 and 1997 was marked by pronounced increases in BM as fetal mass increased (Fig. 5).

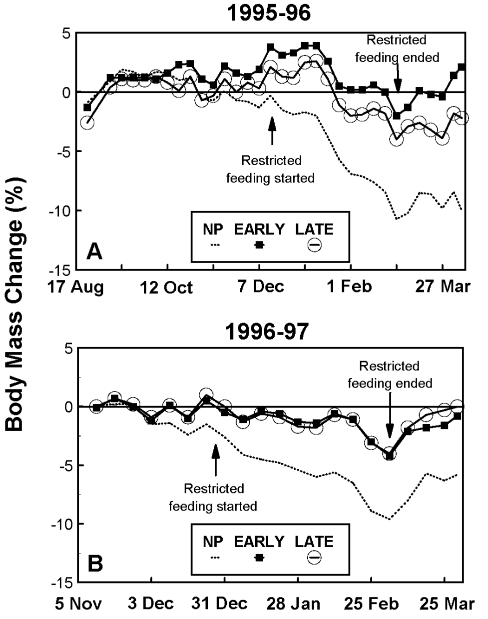

Figure 4. Body mass dynamics of elk cows during autumn through winter of 1995–96 (A) and during late autumn through winter 1996–1997 (B), northeastern Oregon. Category codes are: NP = nonpregnant; EARLY = early-bred treatment group; LATE = late-bred treatment group. Restricted feeding was set to reduce body mass 10% during winter; dry matter and digestible energy levels were as described for the "high" winter nutrition treatment presented in Table 2.

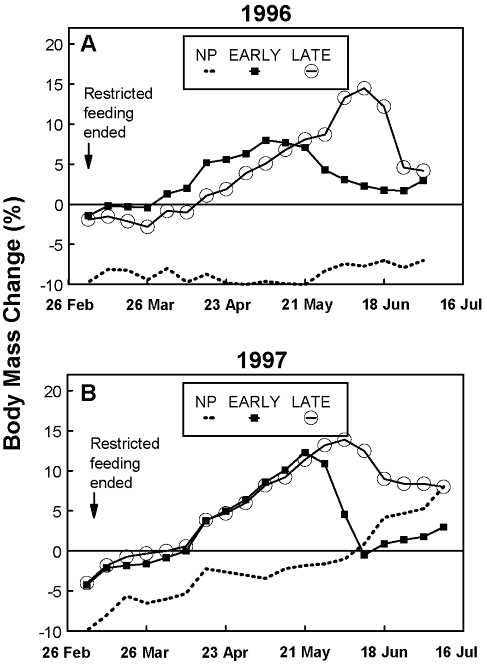

Figure 5. Body mass dynamics of elk cows during spring 1996 (A) and 1997 (B), northeastern Oregon. Category codes are: NP = nonpregnant; EARLY = early-bred treatment group; LATE = late-bred treatment group.

Differences were apparent between early- and late-bred cows in 1996, but not in 1997. Both groups increased mass 10–15% between early March and the birthing period, indicating rapid increases in fetal and uterine mass. In 1997, late-bred cows ended the parturition period several percentage points of mass higher than early-bred cows (Fig. 5B), perhaps suggesting some compensation for late parturition. Non-pregnant cows increased BM during spring in 1997, but failed to do so in spring 1996, reflecting a different feeding strategy (maintenance in 1996, ad libitum feeding in 1997) between the 2 years.

Direct Effects of Summer-Autumn Nutrition and Parturition Date

Breeding in fall 1995 produced 44 pregnant cows of the 57 placed with the bull; 31 2.5-year-old and 13 4.5-year-old cows bred. The 13 failures perhaps were due to lingering effects of porcine zona pellucida in previous experiments (Garrott et al. 1998), obesity in few cases, and permanent infertility in 2 cases. The subsequent spring, 2 small calves (<10 kg) were too weak to stand and nurse and were abandoned by their mothers 4–6 hours after birth, probably a function of low birth mass (Thorne et al. 1976). Another calf developed an umbilicus infection and was removed for veterinary care. Thus, 41 cows and calves were available for the experiment (Table 5). The induced breeding dates produced 2 parturition periods, ranging from 12 May through 10 June ($\bar{x}$ = 26 May ± 1.8 days [SE]) for the early-bred group, and 11 June through 29 June ($\bar{x}$ = 19 Jun ± 1.2 days) for the late-bred group.

Breeding during fall of 1996 produced 36 pregnant cows. Most of the cows in the low nutrition group of the previous autumn failed to breed, leaving a smaller sample size to evaluate summer-autumn nutrition influences in 1997 compared to that in 1996. Of the calves born in spring, 1997, 3 were abandoned and 3 died due to disease. Cows were split 50:50 into the early and late parturition-date categories at the end of parturition and randomly assigned to high, medium, and low nutrition levels. Of the cow-calf pairs used for the 1997 summer-nutrition experiment, parturition date of the early-bred group ranged from 20 May-9 June ($\bar{x}$ = 1 Jun ± 2.5 days) and 10 June through 8 July ($\bar{x}$ = 20 Jun ± 3.5 days) for the late-bred group (Table 5).

In both years, food was of higher quality than we anticipated, and fed diets averaged slightly higher in DE content than our targets (Fig. 3B). In 1996, all elk began the experiments consuming diets of 3.0 kcal of DE/g of food. The high nutrition level was held constant at 3.0 kcal/g until the end of the experiment (early Nov), the medium level was reduced to 2.7, and the low level to 2.3 (Fig. 3B). In 1997, elk began experiments consuming diets of 3.0 and then were reduced to 2.9 kcal of DE/g. The high nutrition group was fed this level until the end of the experiment, the medium group was reduced from 2.9 to 2.7 kcal of DE/g, and the low group from 2.9 to 2.3 kcal of DE/g.

Body mass dynamics of cows.—Nutrition treatments were initiated on 21 June; we analyzed BM dynamics of cows starting 25 June. Change-in-mass estimates indicated considerable influences of nutrition on BM dynamics of cows over summer (Fig. 6A). The initial repeated measures ANOVA indicated influences of calf gender ($P = 0.062$ [time × gender interaction effect]) and cow age ($P = 0.063$); no higher order interactions approached significance ($P \geq 0.54$). Mass gain of younger cows and cows with female calves was greater, or declined more slowly, than cows with male calves. Calf gender was an important confounding influence on parturition date and nutrition effects, because gender ratios varied markedly among the 6 treatment groups (Table 5). We therefore adjusted the data to remove effects of calf gender using the equation of Fig. 7A. This equation provided a time-specific adjustment (reflecting the time × gender interaction) that was equal across all treatment groups (reflecting no significant higher order interaction with gender) such that gender effects were removed (i.e., BM of cows with male calves was adjusted “up” as though they had given birth to female calves). We did not further complicate the data set by removing the cow age effect (Fig. 7B), because distribution of cow ages among the treatment groups was approximately equal (our initial randomization was designed to do this).

Table 5. Characteristics of elk cows and calves within treatment groups at the start of the 1996 and 1997 summer-autumn nutrition and parturition-date experiments, northeastern Oregon. Means of calf birth mass and birth date are presented for each treatment group.

		Number[b] of cows by birth year		Cow body[c] mass (kg)		Calf characteristics				
						Gender		Birth mass (kg)		
Year	Treatment[a]	1991	1993	Mean	SE	Male	Female	Mean	SE	Birth date
1996	EPHN	2	6	206.0	7.0	5	3	15.3	0.8	30 May
	EPMN	2	5	207.6	8.3	2	5	14.9	0.7	23 May
	EPLN	1	6	207.4	3.3	0	7	14.7	0.6	25 May
	LPHN	2	4	212.8	5.3	4	2	16.0	0.3	21 Jun
	LPMN	1	5	217.9	9.6	4	2	16.0	1.0	21 Jun
	LPLN	2	5	219.1	4.7	5	2	16.1	0.7	16 Jun
1997	EPHN	2	4	221.8	5.6	1	5	15.4	0.4	01 Jun
	EPMN	3	3	216.9	8.6	4	2	17.1	0.7	02 Jun
	EPLN	1	5	231.2	10.6	2	4	15.8	0.9	31 May
	LPHN	1	3	240.3	7.8	1	3	16.9	0.6	18 Jun
	LPMN	2	2	213.4	8.5	2	2	16.1	1.2	18 Jun
	LPLN	2	2	230.5	13.4	2	2	15.3	1.6	25 Jun

[a] Treatment groups are: EPHN = early parturition, high nutrition; EPMN = early parturition, medium nutrition; EPLN = early parturition, low nutrition; LPHN = late parturition, high nutrition; LPMN = late parturition, medium nutrition; and LPLN = late parturition, low nutrition.

[b] Birth year of cows.

[c] Body mass within 4 days after parturition.

With adjustments for calf gender, both nutrition and parturition date significantly influenced cow BM dynamics over summer and fall ($P < 0.001$ and $P = 0.010$, time × factor interactions). The 3-way interaction was not significant ($P = 0.304$), indicating that the relative influences of parturition date and nutrition were constant across time. Higher nutritional quality and earlier parturition date enhanced mass gain by cows; the magnitude of the nutrition effect was considerably greater than that of the parturition date effect (Fig. 6B). Body mass of cows on different nutritional treatments diverged within several weeks of implementing the nutrition treatments, when relatively small differences occurred in dietary quality. Divergence continued through August among treatment groups. After September, differences among treatment groups remained approximately constant through October.

In 1997, similar patterns emerged despite the smaller sample size (Fig. 8A). The initial analysis indicated no evidence of confounding by cow age and calf gender ($P \geq 0.25$ for interaction terms that included these 2 variables). However, potential confounding was evident for previous-year nutrition ($P = 0.025$, time × previous-year nutrition). Its effect was independent of nutrition and parturition date because there were no significant higher-order interactions. Cows in the previous-year medium and low nutrition groups gained more mass or lost less mass than cows fed the high nutrition level the previous year, suggesting accelerated anabolism to compensate for greater mass loss the previous year. Because cows with differing nutrition levels in 1996 were unequally distributed among the parturition date-summer nutrition treatment groups of 1997, we adjusted the 1997 data to remove the effects of previous-year summer nutrition using the equation of Fig. 9.

With adjustments for previous-year nutrition level, cow BM dynamics in 1997 were significantly related to summer-autumn nutrition ($P = 0.001$) and parturition date ($P = 0.001$) (Fig. 8B). Magnitude of the nutrition effect was greater than that of the parturition date effect, except that cows in the late parturition, high nutrition group gained no more mass than either medium nutrition group much of the summer (but see the nutritional condition data presented below).

Nutritional condition of cows.—Condition, based solely on BCS in autumn of 1996,

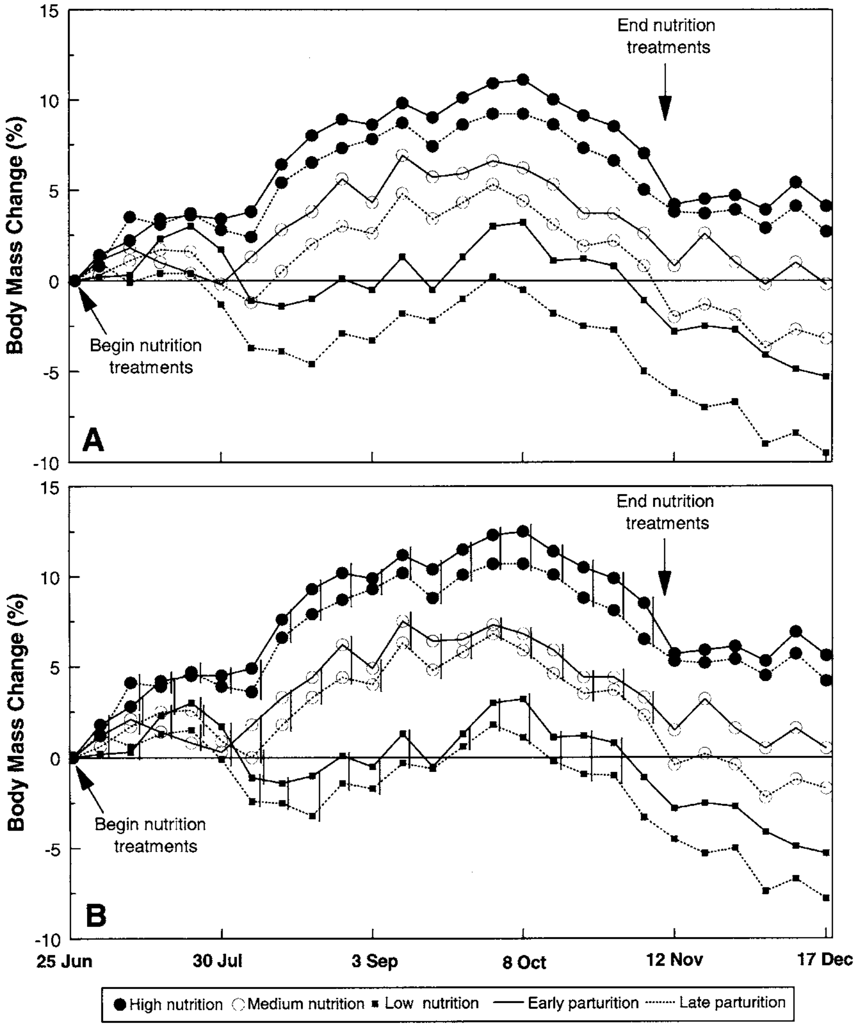

Figure 6. Body-mass dynamics of lactating elk during summer and autumn 1996, northeastern Oregon, across 3 levels of summer-autumn nutrition and 2 levels of parturition date. Graph A presents original data with no correction to remove effect of calf gender; data in graph B were adjusted to remove this effect. In graph B, percent changes in body mass not connected by vertical lines differ significantly ($P \leq 0.05$) within weekly periods.

varied markedly among nutrition groups ($P < 0.001$) and tended to vary among parturition date groups ($P = 0.058$) (Fig. 10). Cows in the high nutrition group averaged 14–15% body fat, compared to 10% in the medium group and 6–8% in the low group. Cows giving birth early had 1–3% more body fat than those giving birth late.

Condition in autumn 1997, based on ultrasound and BCS (Fig. 11) also was significantly influenced by summer-autumn nutrition ($P < 0.001$), but was unaffected by parturition date ($P = 0.46$). The magnitude of nutrition's influence evidently was greater the second year than the first (Fig. 11).

Breeding dynamics.—Our ability to simultaneously test influences of parturition date and summer-autumn nutrition on pregnancy was hindered by small sample sizes, yet analyses indicated important trends. In 1996, nearly all cows in the high and medium nutrition groups but only 25% of those in the low nutrition group became pregnant (Fig. 12). Logistic regression indicated that nutrition affected pregnancy probability ($P < 0.001$), but parturition date did not ($P = 0.92$). However, conducting this analysis required combining the high and medium

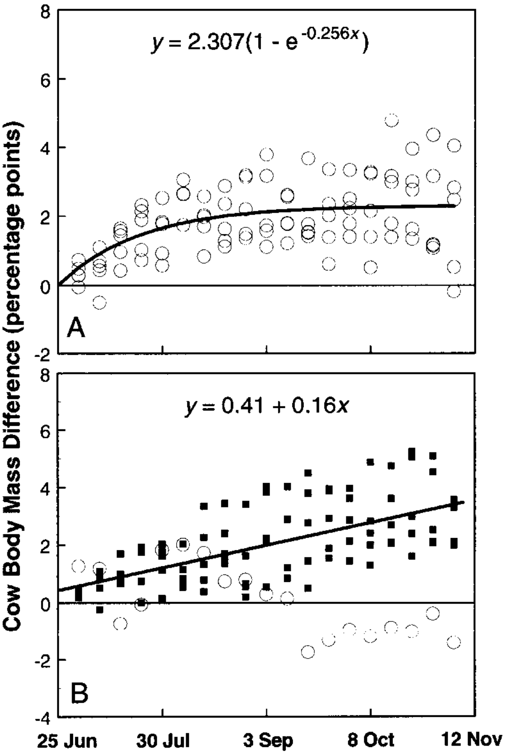

Figure 7. In graph A, observed differences in percent body mass of cow elk with female calves and those with male calves during summer and autumn 1996, northeastern Oregon. Data points were calculated as percent change in body mass of cows with females minus percent change in body mass of cows with males, within the nutrition-parturition date groups each week of the experiment. Thus, positive values indicate cows with female calves gained more, or lost less mass, than cows with male calves. The nonlinear equation describes this gender effect; the independent variable is number of weeks past 25 June. In graph B, observed differences in percent body mass change of 3-year-old and 5-year-old cows. Positive values indicate younger cows gained more, or lost less mass, than older cows, within nutrition-parturition date groups each week of the experiment. The linear equation describes the effect of cow age on their body mass changes; x is the number of weeks past 25 June. This equation was developed using data indicated by solid squares; data indicated by the open circles are from a treatment group (high nutrition, late parturition) that appeared anomalous and thus were treated as outliers for developing the equation.

nutrition groups, because the number of response functions was greater than the number of responses (1) in the high nutrition group (e.g., all cows bred). The chi-square test for each effect provided similar results (nutrition: $\chi^2 = 19.0$, df = 2, $P < 0.001$; parturition date: $\chi^2 = 0.09$, df = 1, $P = 0.76$) (conducted independently rather than simultaneously because of inadequate sample sizes). Because of the smaller sample size in 1997 ($n = 30$) than in 1996 ($n = 41$), we conducted only chi-square tests of each factor (Fig. 13). Summer-autumn nutrition affected pregnancy probability ($\chi^2 = 21.03$, df = 1, $P < 0.001$) whereas parturition date did not ($\chi^2 = 0.944$, df = 1, $P = 0.33$).

Probability of pregnancy increased as nutritional condition increased during both years ($P < 0.008$) (Fig. 14). Elk showed a threshold of condition (8–10% body fat, 1.9–2.1 Mcal/kg of GE), below which probability of pregnancy declined rapidly. Cows with <5% body fat or <1.6 Mcal/kg of GE had little probability of pregnancy (Fig. 14).

Timing of conception was similarly affected. In autumn 1996, all cows in the high nutrition group were pregnant by mid-October, compared to about 70% in the medium nutrition group.

The few cows that successfully bred in the low nutrition group did so even later than cows in the medium group (Figs. 12 and 13). Summer-autumn nutrition significantly influenced date of conception ($\chi^2 = 14.95$, df = 4, $P = 0.005$), but parturition date did not ($\chi^2 = 1.57$, df = 2, $P = 0.46$), although there was a trend of earlier conception of cows in the high and medium nutrition groups that gave birth early.

Observed breeding of individual cows in autumn 1997 allowed simultaneous comparison of nutrition versus parturition date on breeding date using ANOVA. As in 1996, summer-autumn nutrition significantly influenced breeding date ($P < 0.001$) whereas parturition date did not ($P = 0.22$), nor was the interaction between parturition date and nutrition significant ($P = 0.67$). Breeding date was nonlinearly related to both our measures of body condition. Above about 13% body fat, breeding date was insensitive to fat (Fig. 15).

Summer-autumn performance of lactating versus nonlactating cows.—Before the summer-autumn nutrition treatments began, nutritional condition of nonlactating and lactating treatment groups were similar (Fig. 16A). Nevertheless, considerable divergence occurred by mid-autumn ($P < 0.001$), but the differences occurred only among nutrition treatment groups of lactating cows. Both the low and high nutrition groups of nonlactating cows achieved a high level of condition equivalent to that of the high

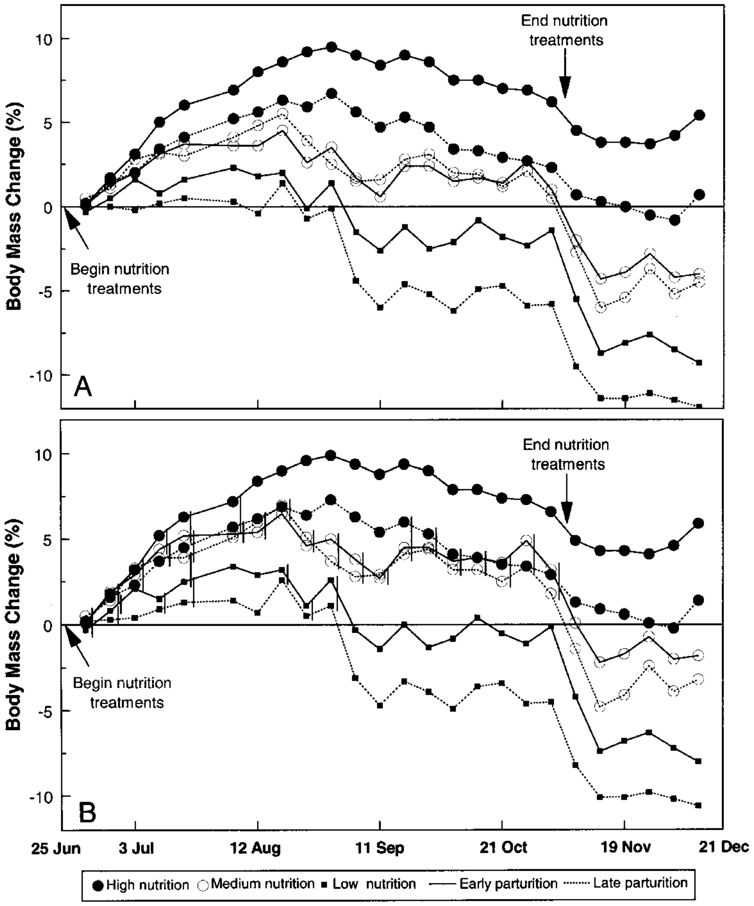

Figure 8. Body-mass dynamics of lactating elk during summer and autumn 1997, northeastern Oregon, across 3 levels of summer-autumn nutrition and 2 levels of parturition date. Graph A presents original data with no correction to remove effect of previous-year's nutrition treatment; data in graph B were adjusted to remove this effect. In graph B, percent changes in body mass not connected by vertical lines differ significantly ($P \leq 0.05$) within weekly periods.

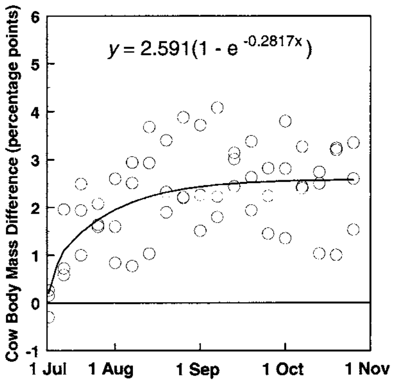

Figure 9. Observed differences in percent body mass change of cow elk during summer and autumn 1997 caused by previous year's (1996) summer-autumn nutrition treatment, northeastern Oregon. Data points were calculated as percent body mass change of elk in 1997 that were in the medium nutrition group of 1996 minus percent body mass change of elk in 1997 that were in the high group in 1996, within the nutrition-parturition date groups of 1997 for each week of the experiment. Thus, positive values indicate those cows in the medium nutrition group during summer-autumn in 1996 gained more mass, or lost less mass in 1997, than did those cows in the high nutrition group during summer-autumn in 1996. Values of the independent variable in the equation are number of weeks past 1 July.

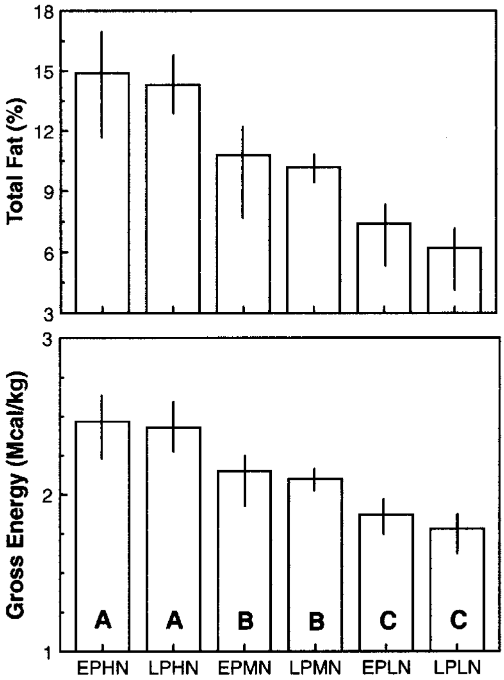

Figure 10. Nutritional condition of lactating elk near the end of the breeding season of 1996 across 3 levels of summer-autumn nutrition and 2 levels of parturition date, northeastern Oregon. Vertical lines indicate ranges of the data. Vertical bars with different letters differ ($P \leq 0.05$) and apply to both graphs. Total fat and gross energy content of the ingesta-free body were calculated from body condition scores using equations of Cook et al. (2001*a*). Parturition date-nutrition treatment codes are: EPHN = early parturition, high nutrition; EPMN = early parturition, medium nutrition; EPLN = early parturition, low nutrition; LPHN = late parturition, high nutrition; LPMN = late parturition, medium nutrition; LPLN = late parturition, low nutrition.

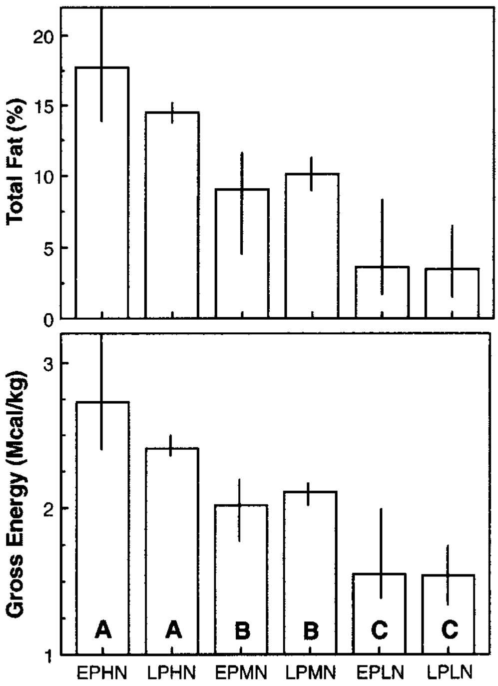

Figure 11. Nutritional condition of lactating elk near the end of the breeding season of 1997 across 3 levels of summer-autumn nutrition and 2 levels of parturition date, northeastern Oregon. Vertical lines indicate ranges of the data. Vertical bars with different letters differ ($P \leq 0.05$) and apply to both graphs. Total fat and gross energy content of the ingesta-free body were calculated from LIVINDEX scores (Cook et al. 2001*a*). Parturition date-nutrition treatment codes are: EPHN = early parturition, high nutrition; EPMN = early parturition, medium nutrition; EPLN = early parturition, low nutrition; LPHN = late parturition, high nutrition; LPMN = late parturition, medium nutrition; LPLN = late parturition, low nutrition.

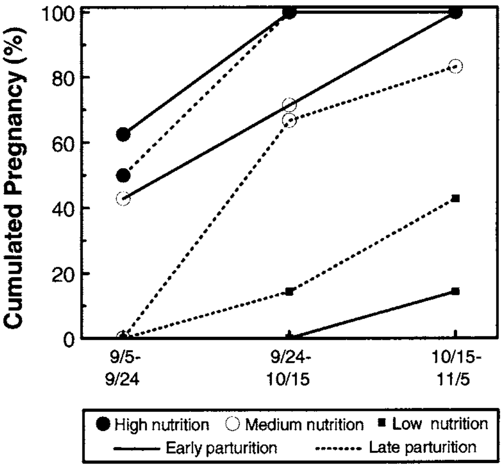

Figure 12. Cumulated pregnancy of lactating elk during the breeding season of 1996 across 3 levels of summer-autumn nutrition and 2 levels of parturition date, northeastern Oregon. Pregnancy status was determined with pregnancy-specific protein B (Noyes et al. 1997).

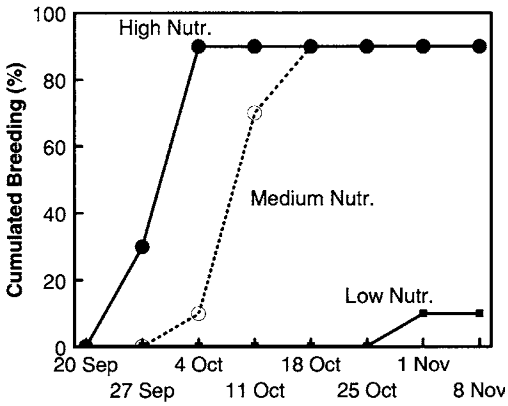

Figure 13. Cumulated breeding status of lactating elk during 1997 across 3 levels of summer-autumn nutrition, northeastern Oregon. Breeding dates were determined by direct observation.

nutrition group of lactating cows (>15% fat), based on both the BCS and LIVINDEX scoring systems (Fig. 16A,B,C).

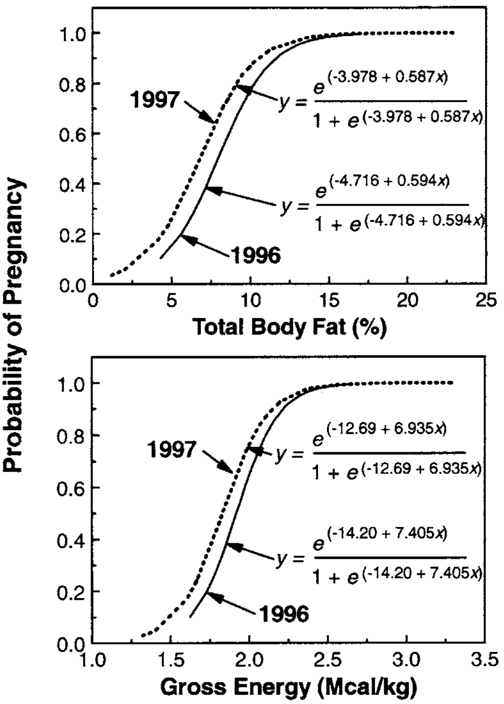

Figure 14. Logistic relations between nutritional condition during the breeding season and probability of pregnancy of lactating elk, 1996 and 1997, northeastern Oregon. Intercept ($P < 0.021$) and slope coefficients ($P < 0.008$) are significant for all logistic regression equations. Total fat and gross energy content of the ingesta-free body were calculated from body condition scores in 1996 and LIVINDEX in 1997 using equations of Cook et al. (2001*a*). For prediction, we recommend the equations for 1997 because they are based on LIVINDEX, a superior index of fat and GE compared to body condition scores.

Calf responses.—In 1996, birth mass of the entire calf crop ($n = 44$) averaged 15.0 ± 0.54 kg; birth date averaged 4 June and ranged from 12 May–29 June. Later-born calves were significantly larger at birth ($y = 3.19 + 0.075x$, where x = calendar day, $r^2 = 0.17$, $P = 0.006$). Twenty-three (52%) of the calves were females; they tended to be smaller than males at birth (14.4 ± 0.48 kg versus 15.6 ± 0.62 kg). However, when calf gender was included with birth date in the ANCOVA, BM at birth was similar between sexes ($P = 0.51$).

Forty-one calves were used for the summer-autumn experiments of 1996. Their mean birth mass was 15.5 kg, and mean mass at birth varied among treatments ≤1.4 kg (Table 5). Calf ages varied ≤7 days among nutrition groups. Calf gender, in contrast, differed markedly among the summer-autumn nutrition treatments (Table 5).

At the time the nutritional treatments were implemented in 1996, calf mass was a

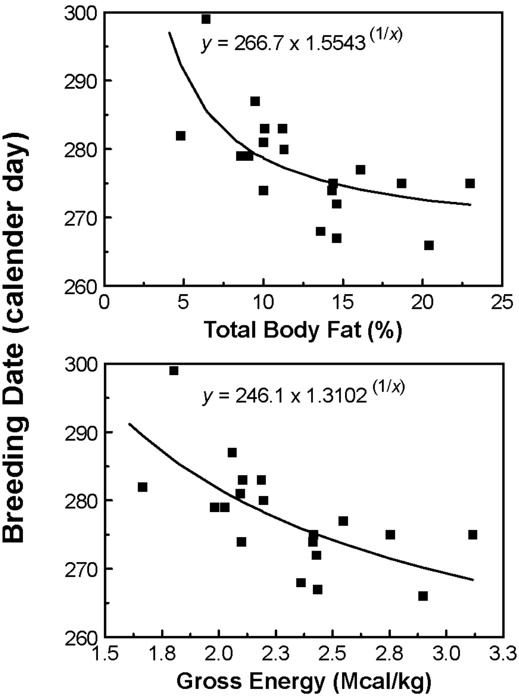

Figure 15. Relations between nutritional condition and timing of breeding by lactating elk, 1997, northeastern Oregon. Total fat and gross energy of the ingesta-free body were calculated from LIVINDEX using equations of Cook et al. (2001*a*). The nonlinear regression routine we used to calculate the curvilinear functions did not provide a coefficient of determination. A linear approximation indicates that $r^2 \geq 0.45$.

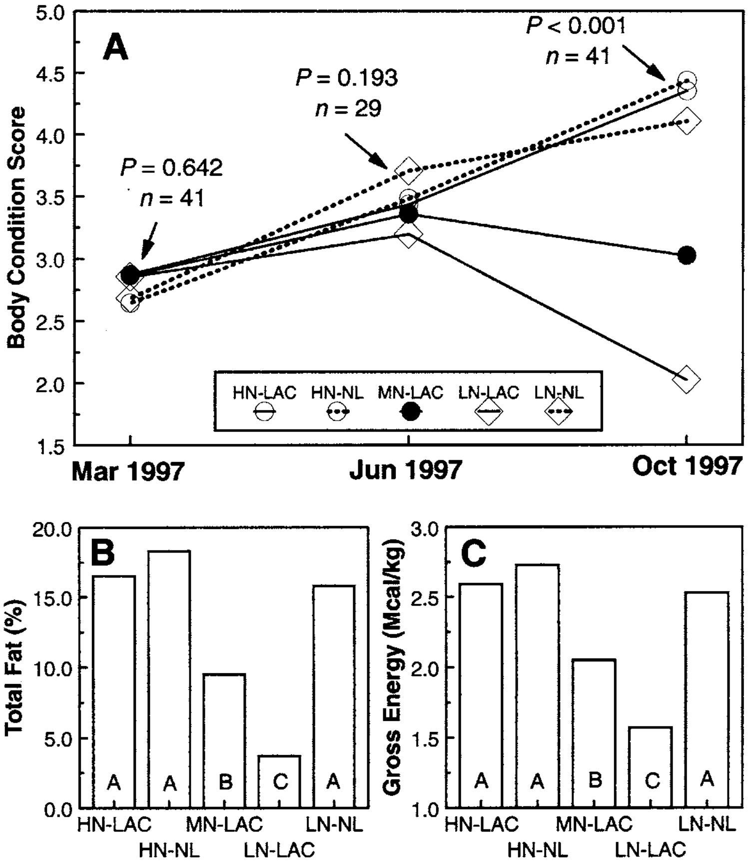

Figure 16. Body condition scores for lactating and nonlactating elk, spring through autumn 1997 (A), northeastern Oregon. The *P* and *n* values relate to 1-way ANOVAs conducted at each time period to identify differences in nutritional condition among cows in different treatment groups. Estimates of total fat (B) and gross energy content (C) of the ingesta-free body for cow elk in October 1997 were calculated from LIVINDEX (Cook et al. 2001*a*). Vertical bars with different letters differ ($P \leq 0.05$). The treatment codes are: HN-LAC = high nutrition and lactating; HN-NL = high nutrition and not lactating; MN-LAC = medium nutrition and lactating; LN-LAC = low nutrition and lactating; LN-NL = low nutrition and not lactating.

predictable function ($r^2 = 0.94$) of birth date ($P < 0.001$) (Fig. 17A) and birth mass ($P < 0.001$): $y = 117.05 - 0.68x_1 + 1.62x_2$, where y = calf mass on 3 July, x_1 = calendar day of birth, and x_2 = birth mass (kg). Adding birth mass into the equation increased the r^2 from 0.85 to 0.94, and residual analysis also indicated an appreciable affect of this variable (Fig. 17B). Body mass on 3 July was unaffected by calf gender or cow age ($P \geq 0.55$).

Response by calves to nutrition and birth date was simultaneously evaluated starting in early July 1996. An initial repeated measures ANOVA indicated an insignificant 5-way interaction between time, nutrition, birth date, cow age, and calf gender ($P = 0.93$). Of all other interaction terms that included either calf gender or cow age, only the 4-way interaction containing calf gender (e.g., time × nutrition × birth date × calf gender) was significant ($P = 0.047$). However, differences in growth between sexes were inconsistent and followed no biologically relevant pattern that we could discern (Fig. 18A). We concluded that gender probably had little potential to confound our analysis of nutrition and birth date effects on calf growth and excluded it from further analysis.

Subsequent analysis indicated a significant ($P = 0.001$) interaction among time, nutrition, and birth date on calf growth between early July and early December 1996 (Fig. 19A,B). Nutrition had a considerable influence on growth. Its effect increased

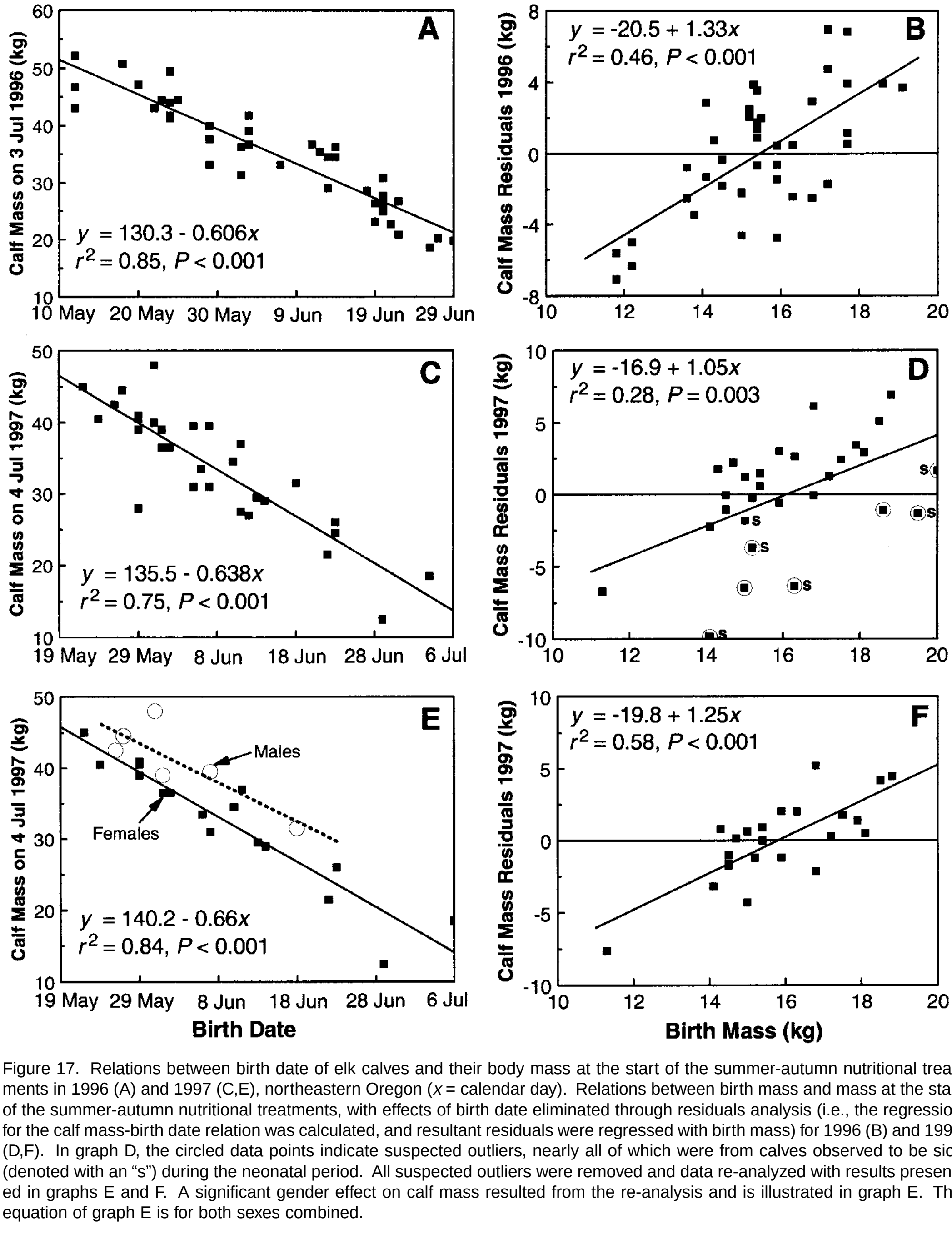

Figure 17. Relations between birth date of elk calves and their body mass at the start of the summer-autumn nutritional treatments in 1996 (A) and 1997 (C,E), northeastern Oregon (x = calendar day). Relations between birth mass and mass at the start of the summer-autumn nutritional treatments, with effects of birth date eliminated through residuals analysis (i.e., the regression for the calf mass-birth date relation was calculated, and resultant residuals were regressed with birth mass) for 1996 (B) and 1997 (D,F). In graph D, the circled data points indicate suspected outliers, nearly all of which were from calves observed to be sick (denoted with an "s") during the neonatal period. All suspected outliers were removed and data re-analyzed with results presented in graphs E and F. A significant gender effect on calf mass resulted from the re-analysis and is illustrated in graph E. The equation of graph E is for both sexes combined.

markedly from mid-summer through autumn, resulting in pronounced differences in BM by late autumn (Fig. 19A). Except for a brief period at weaning, calves in the high nutrition group grew rapidly through autumn. Low-nutrition calves ceased growth by mid-September, and medium-nutrition calves ceased growth by mid-October.

The significant interaction among time, nutrition, and birth date reflected faster growth of some late-born calves. Late-born

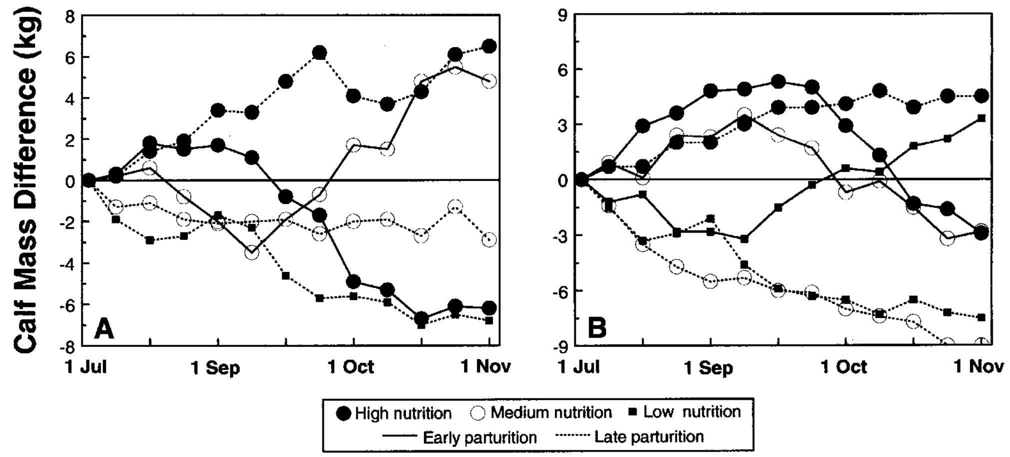

Figure 18. Differences in body mass (BM) between male and female elk calves (i.e., BM of males minus BM of females, within summer-autumn and parturition-date treatment groups each week) in 1996 (A) and 1997 (B), northeastern Oregon. Positive values indicate male calves grew more rapidly than females. These data indicate little evidence of a consistent gender effect on calf growth either year.

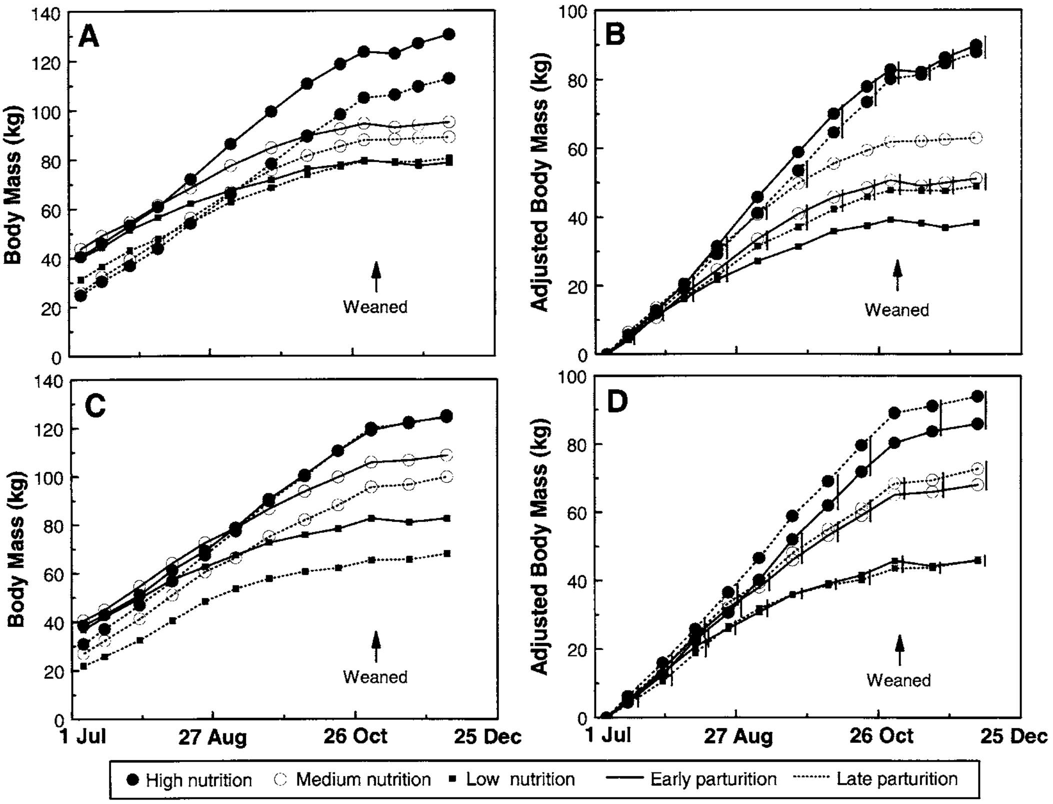

Figure 19. Growth of elk calves during summer and autumn 1996 (A,B) and 1997 (C,D) across 3 levels of nutrition and 2 periods of parturition date, northeastern Oregon. Actual body mass is presented in graphs A and C. In B and D, body mass was adjusted to remove effects of birth date and birth mass occurring during the neonatal period, by subtracting mass at the start of the time period (3 or 4 July) from all subsequent mass estimates. Data values not connected by vertical lines differ significantly ($P \leq 0.05$) within weekly periods.

calves in the low and medium nutrition groups weighed as much by late autumn as did their early-born counterparts. However, late-born calves in the high nutrition group did not catch-up (Fig. 19A,B). Thus the 10–15 kg advantage for early born calves lasted through late autumn only in the high nutrition group.

A final 5-way ANCOVA on unadjusted BM of calves at weaning in mid-November indicated significant effects of nutrition ($P < 0.001$), birth date ($P < 0.001$), birth mass ($P < 0.001$), and insignificant effects of gender ($P = 0.24$) and cow age ($P = 0.75$). The interaction of birth date and nutrition also was significant ($P = 0.014$) (because of the large number of possible interaction terms and moderate sample size, we could not include all possible interactions in the analysis, so we included the primary term of interest, i.e., the birth date × nutrition term). This interaction confirms a similar result from the repeated measures ANOVA described previously that late-born calves in the low and medium nutrition groups tended to grow faster than early-born calves. The residuals analysis for these variables further illustrates an important birth mass effect (Fig. 20). Birth mass of late-born calves in the low and medium nutrition groups was 1.1–1.4 kg greater than that of their early-born counterparts (Table 5), and may explain why late-born calves in the low and medium groups grew faster than early-born calves in the low and medium groups. Differences in gender (Table 5) evidently did not account for their faster growth (Fig. 20).

Thirty-six calves were born in 1997. Birth mass averaged 16.1 ± 0.3 kg, and mean birth date was 6 June (±1.8 days; range was 20 May–4 Jul); thus, calves tended to be heavier and born later in 1997 than in 1996. Twenty-two (61%) were females. Six of the 36 calves were either abandoned (3) or died because of diseases that caused severe diarrhea, fever, and loss of appetite. All of these calves were reasonably large at birth ($\geq$15.4 kg), suggesting that low birth mass did not predispose to death or abandonment (e.g., Thorne et al. 1976). Mean birth mass among treatment groups used in the summer experiments ranged from 15.3–17.1 kg, and mean birth date ranged from 31 May–25 June (Table 5).

Calf size attained by the time nutrition treatments were implemented again was a significant function of birth date ($P < 0.001$) (Fig. 17C) and birth mass ($P < 0.001$): $y = 114.24 - 0.66x_1 + 1.51x_2$, where y = calf mass on 4 July, x_1 = calendar day of birth, and x_2 = birth mass (kg). Including birth mass into the equation increased r^2 from 0.75 to 0.87, again indicating an appreciable effect of birth mass on early growth. Results of ANCOVA indicated no significant influences of calf gender ($P = 0.94$), cow age ($P = 0.19$), or previous-year summer-autumn nutrition level of their mothers ($P = 0.71$). However, the residuals analysis of birth mass effects indicated about 7 anomalous data values (Fig. 17D). Six calves were observed sick (diarrhea, reduced activity that typically lasted 4–7 days), including 5 of the 7 calves whose data include the anomalous points (Fig. 17D). We eliminated these 7 points from the data set and reran the ANCOVA and multiple regression. Birth mass and birth date remained highly significant ($P < 0.001$), gender became significant (i.e., males were larger) ($P = 0.035$), and previous-year nutrition remained insignificant ($P = 0.19$). The multiple regression equation for this subset of data was: $y = 113.3 - 0.66x_1 + 1.71x_2$, where y = calf mass on 4 July, x_1 = calendar day of birth, and x_2 = birth mass (kg), $r^2 = 0.95$).

The initial repeated measures ANOVA of calf growth after early July 1997 indicated an insignificant 5-way interaction between time, nutrition, birth date, mother's previous-year nutrition, and calf gender ($P = 0.13$). Both 4-way interactions also were insignificant ($P = 0.11$ for the time × birth date × nutrition × gender interaction; $P = 0.07$ for the time × birth date × nutrition × previous-year nutrition interaction). From these results, we concluded that calf gender (Fig. 18B) and previous-year nutrition were not likely to confound our test of birth date and summer/autumn nutritional influences on calf growth.

Dropping gender and previous-year nutrition, the ANOVA indicated an insignificant ($P = 0.54$) 3-way interaction between time, nutrition, and birth date and an insignificant interaction between time and birth date ($P = 0.15$). Only the interaction between nutrition and time was significant ($P < 0.001$). Thus, from early July through early December, nutrition levels over summer and autumn had the greatest influence on calf

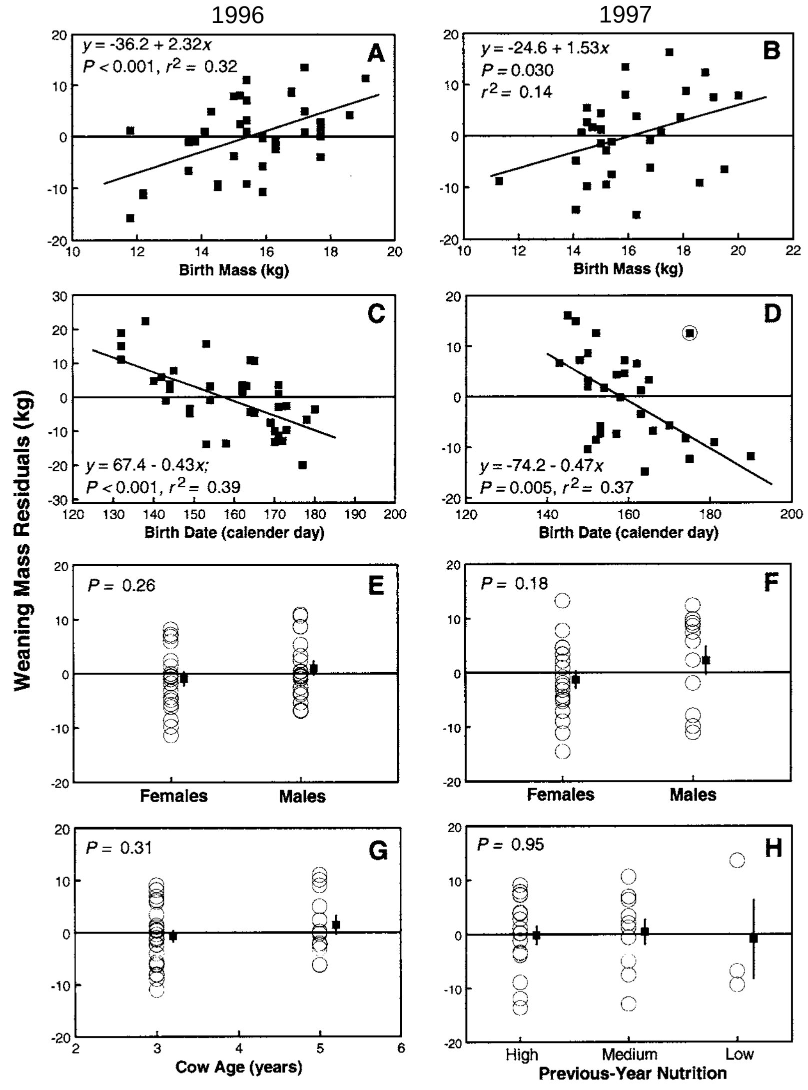

Figure 20. Residuals analyses of variables (birth mass, birth date, calf gender, cow age, and previous-year summer-autumn nutrition) potentially contributing to mid-November weaning mass of elk calves in 1996 and 97, northeastern Oregon. Relations between each variable and weaning-mass residuals are presented with the effects of all other variables removed (i.e., the analysis of covariance model was calculated with all but 1 variable included [summer-autumn nutrition was included in all ANCOVAs thereby removing the effects of nutrition from all analyses], and the residuals from that analysis were then regressed only with the excluded variable, once for each variable). The circled data point in D was excluded to calculate the regression coefficients, but was included to calculate significance levels. For graphs of categorical independent variables (E–H), solid squares and vertical lines indicate means and SEs.

growth of all variables measured (Fig. 19C,D). Calves in the low nutrition group ceased growth by late September, and growth of calves in the medium group lagged significantly behind that of calves in the high group by early October (Fig. 19D). Magnitude of nutritional influences increased from mid-summer through autumn.

The final 5-way ANCOVA on unadjusted BM at weaning in mid-November indicated significant effects of nutrition ($P < 0.001$), birth date ($P = 0.005$), and birth mass ($P = 0.030$); neither gender ($P = 0.18$) nor pervious-year nutrition of the mother ($P = 0.95$) were significant. (Inclusion of any of the interaction effects into the model rendered all terms insignificant; thus, no interactions

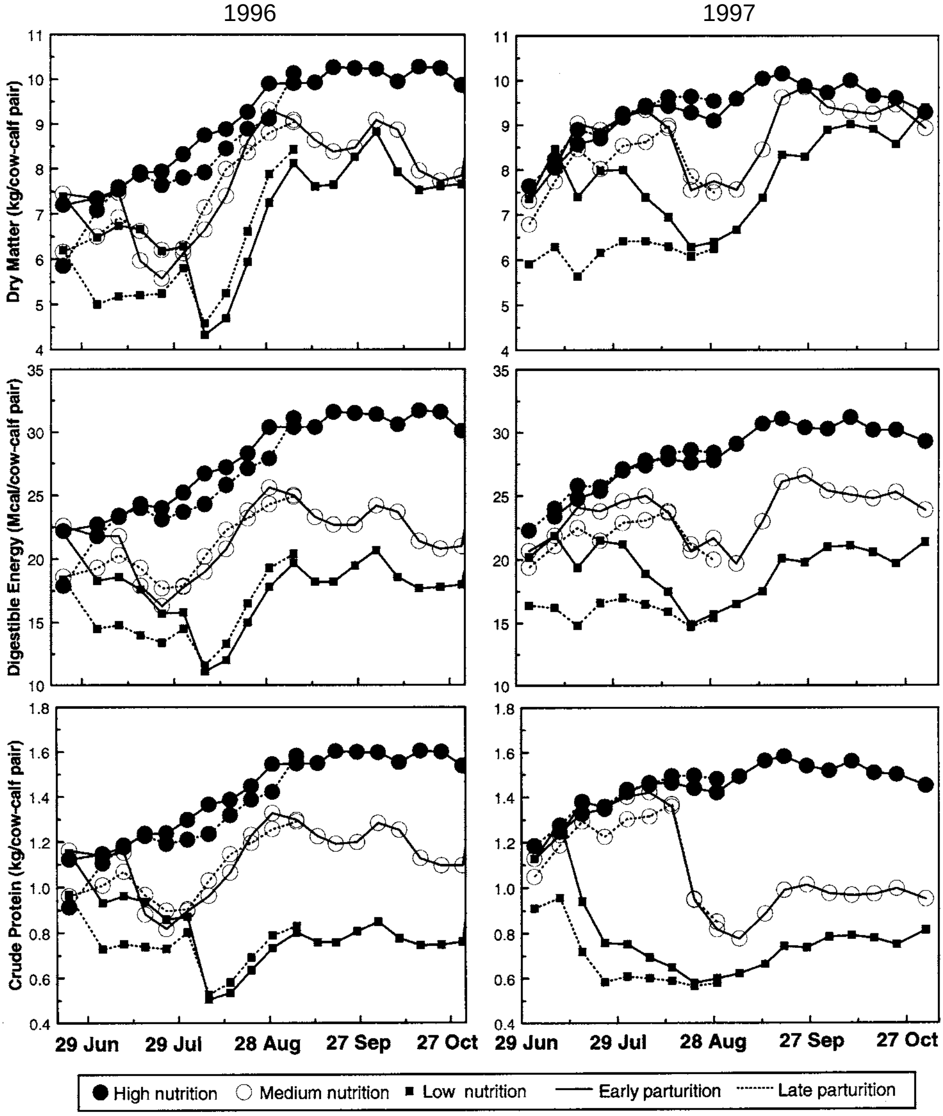

Figure 21. Weekly means of daily dry-matter, digestible energy, and crude protein intake of cow-calf pairs of elk by nutrition and birth date groups during summer and autumn in 1996 and 1997, northeastern Oregon. Because cow-calf pairs were combined within nutrition treatments across parturition-date treatments at the start of the rut in early September, intake estimates thereafter were combined across parturition-date treatments.

were included in this analysis). The advantage of early birth was again diluted by late autumn to some extent. Mass differences in mid-autumn of 1997 attributable to birth date were maintained by calves in the low and medium nutrition groups, but not in the high nutrition group (Fig. 19C), suggesting that late-born calves in the high nutrition group compensated late birth. This contrasts with apparent compensation patterns observed in the low and medium groups in 1996 (compare Figs. 19A,C). Faster growth of late-born calves in the high nutrition group again may be attributed to greater birth mass of late-born than their early-born counterparts (Table 5, Fig. 20).

Food intake by cows and calves.—Intake by cow-calf pairs showed marked differences between summer and autumn, among nutrition treatment groups, and, in early to mid-summer, between birth date groups (Fig. 21). In both years, cows giving birth late

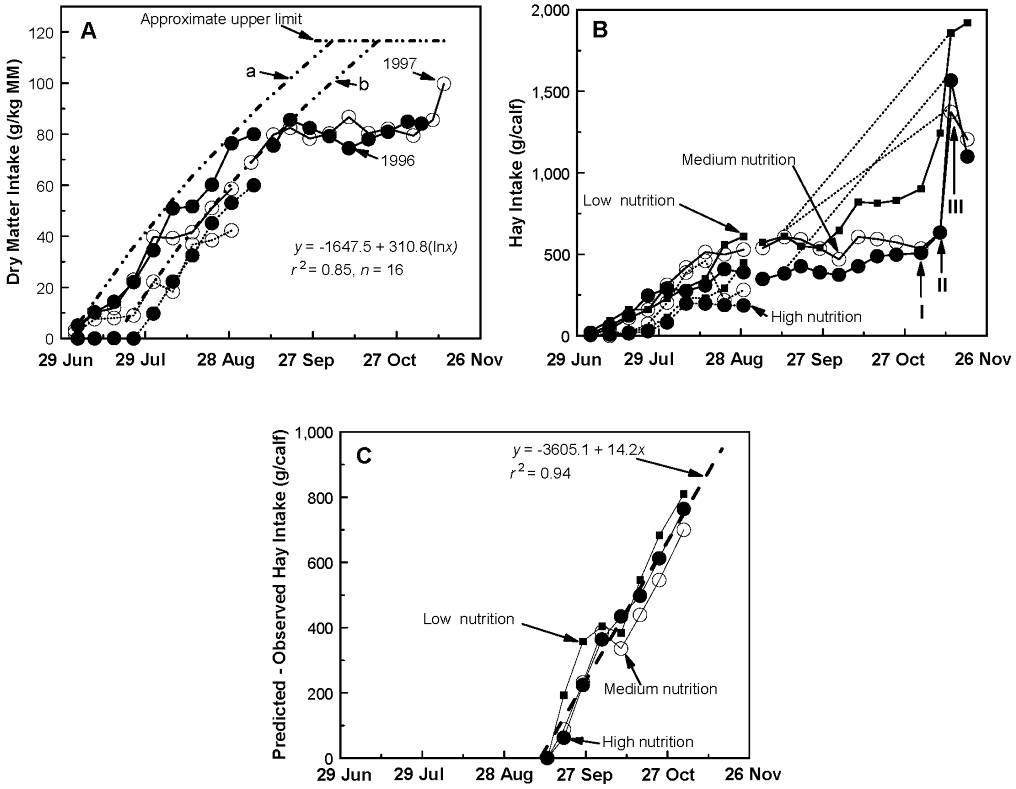

Figure 22. In graph A, observed daily dry-matter intake of solid food of elk calves, northeastern Oregon, fed high quality rations (high nutrition group) during summer and autumn in 1996 and 1997. Intake levels from our study were plotted with age- and metabolic-mass-specific (MM = body mass$^{0.75}$) solid food intake levels in other studies (summarized by Cook et al. 1996). Solid lines indicate data for our early-born calves; dotted lines indicate data for our late-born calves. The equation was derived from these summarized studies, and plotted as lines a and b (both lines are identical except both were date-shifted to correspond to our early and late parturition periods). This graph suggests that the plateau of solid food intake we observed in mid-September actually resulted from calves consuming hay intended for their mothers. In graph B, measured hay intake by calves in the 3 nutrition groups through the end of the autumn nutrition treatment period of 1997 (ending at I), the next 5 days when total hay offered to cows was reduced (II), and the next 4 days during which calves had no access to hay offered to the cows (III). Differences in intake between I and III provide an estimate of the amount of hay calves were taking from cows at the end of the experiment. Assuming that calves consumed very little hay intended for their mothers before mid-September, the dotted lines in graph B represent an approximate level of hay intake of the calves, and the difference between the dotted lines and observed intake (solid lines) provides an estimate of amount of the cow's hay consumed by the calves, plotted in graph C. The resulting equation (x = calendar day) was used to apportion hay intake initially attributed to cows to hay intake by calves.

consumed less food in July than cows giving birth early, particularly those in the low nutrition treatment. After mid-July, birth date differences gave way to differences induced by changing diet quality, despite ad libitum feeding. By late July, pairs in the low nutrition group consumed only 50–60% of that consumed by pairs in the high group in 1996 and 1997. However, cows in the medium and low nutrition groups subsequently began to increase intake by late August and early September. Nevertheless, intake of cow-calf pairs in the medium and low nutrition groups generally did not achieve intake levels by elk in the high group. Differences in intake of DE and crude protein were more pronounced among groups than differences in dry-matter intake, because of lower content of energy and protein in the food of elk in the medium and low groups (Fig. 21).

Measured intake by calves doubled when hay intended for cows was inaccessible to calves during the 4-day trial in November 1997 (Fig. 22B), indicating that calves had been consuming an appreciable portion of hay intended for their mothers by the end of the experiments. Plotting total dry-matter intake of solid food of our calves with that reported in

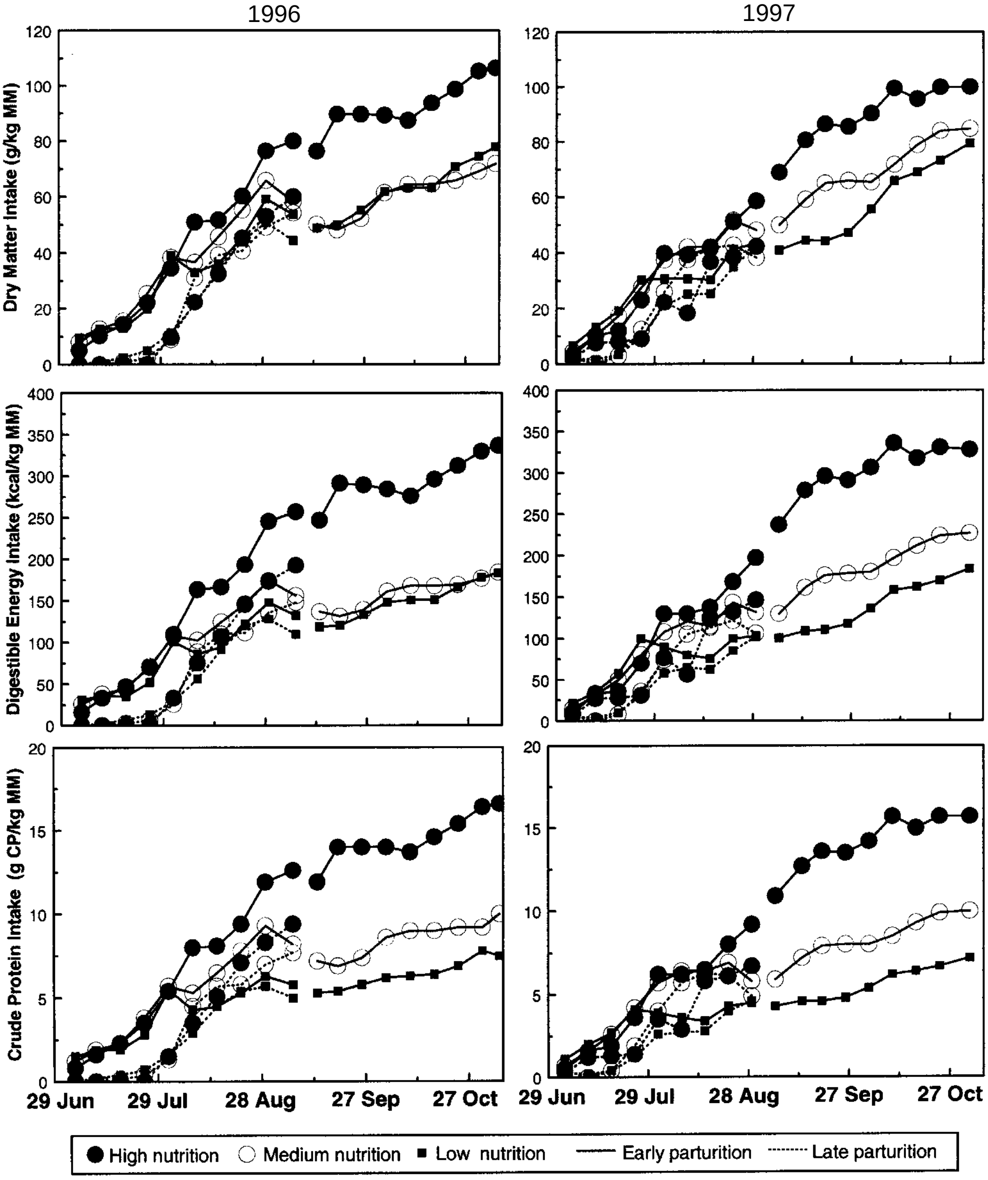

Figure 23. Estimates of dry-matter, digestible energy, and crude protein intake of solid food per kg of metabolic mass (MM = BM$^{0.75}$) for elk calves by nutrition and birth-date treatment groups in summer and autumn, northeastern Oregon. These estimates were adjusted to account for hay intended for cows that was actually consumed by calves as described in Fig. 22. Because cow-calf pairs were combined within nutrition treatments across parturition-date treatments at the start of the rut in early September, intake estimates thereafter were combined across parturition-date treatments.

other studies suggested that our calves began consuming cows' hay in early September (Fig. 22A). Based on this estimate of beginning bias and the estimate of hay calves were stealing based on the 4-day trial, we predicted how much total hay calves actually consumed between mid-September and early November (Fig. 22B). The difference between predicted and observed hay intake was consistent among nutrition treatment groups and was well-correlated to calendar day (Fig. 22C); we used this difference to adjust our estimates of cow and calf hay intake.

With this adjustment, intake of solid food by calves varied with nutrition and, to a lesser extent, with birth date (Fig. 23). Early-

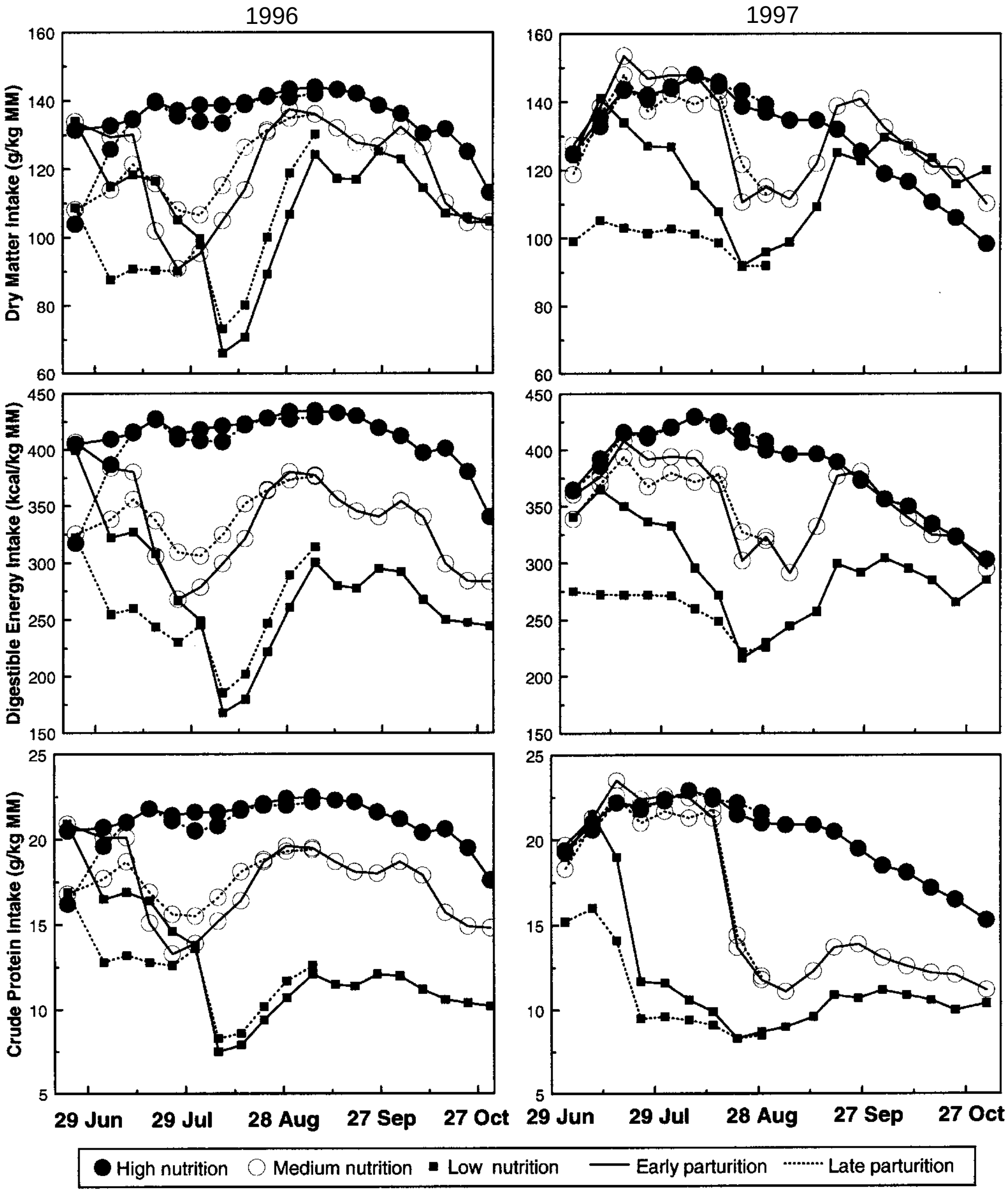

Figure 24. Estimates of dry matter, digestible energy, and crude protein intake for elk cows per kg of metabolic mass (MM = $BM^{0.75}$) by nutrition and parturition-date treatment groups in summer and autumn, northeastern Oregon. These estimates were adjusted to account for hay intended for cows that was actually consumed by calves as described in Fig. 22. Because cow-calf pairs were combined within nutrition treatments across parturition-date treatments at the start of the rut in early September, intake estimates thereafter were combined across parturition-date treatments.

born calves consumed appreciable amounts of solid food by late June, but late-born calves did not begin consuming solid food until mid-July. Differences caused by nutrition emerged by late July and increased thereafter. Digestible energy and crude protein intake by calves in the high nutrition group averaged about twice that by calves in the other nutrition groups by early October.

Parturition date and nutrition evidently affected dry-matter intake of lactating cows (Fig. 24). A declining trend in intake also was evident starting in early September in all nutrition groups. Dry-matter intake in the

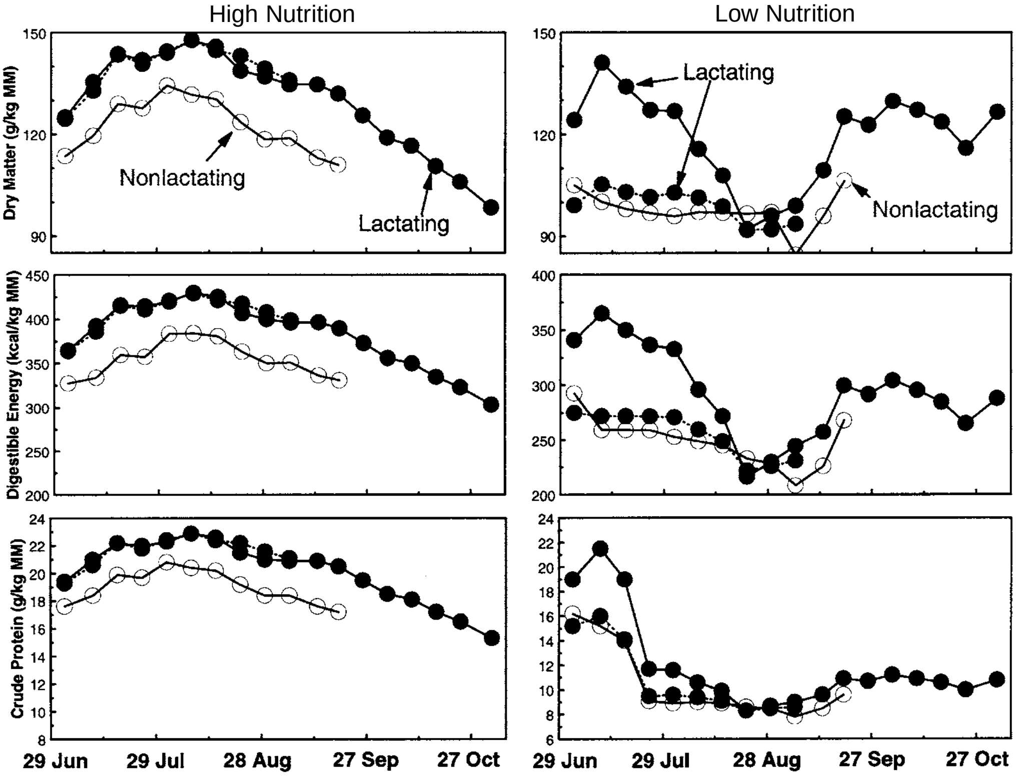

Figure 25. Estimates of dry-matter, digestible energy, and crude protein intake per kg of metabolic mass (MM = BM$^{0.75}$) for lactating and nonlactating elk cows during summer and autumn 1997, northeastern Oregon. We collected data on nonlactating cows until mid-September because they were placed at that time in a breeding pen without facilities to measure intake. Solid and dotted lines indicate data for cows in the early- and late-parturition treatment groups.

medium and low nutrition groups was similar both years, except that the mid-summer decline in intake was more acute in the first year than in the second. Also, dry-matter intake of the high nutrition group began a seasonal decline earlier in 1997 than in 1996, perhaps reflecting lesser intake needs for supporting their own growth.

Nonlactating cows in summer 1997 in the high nutrition group consumed less food than did lactating cows also fed the high nutrition ration (Fig. 25). More complex was the difference between lactating and nonlactating cows fed the low nutrition ration. Nonlactating cows consumed approximately the same amount of food as cows giving birth late, but both groups consumed less food than cows that gave birth early. However, by mid-August, food intake of all 3 groups converged, and no evidence of differences in intake existed by late August (Fig. 25).

Yearling growth, intake, and breeding.—Nine of the 19 yearling cows in this experiment were assigned to the high nutrition group and 10 were assigned to the medium nutrition group in late April 1997 (the medium nutrition treatment was implemented 1 Aug). Mean BM of both groups was virtually identical in late April (85.5 versus 84.9 kg with ranges of 67–130 kg and 61–110 kg in the high and medium groups, respectively). Yearlings grew rapidly over summer, doubling BM between early May and early September (Fig. 26A). The high nutrition group gained 90.6 ± 1.73 kg; the medium group gained 83.6 ± 2.60 kg (P = 0.039). Growth was virtually identical between the 2 nutrition groups over the summer until the nutrition level of the medium group was reduced in early August (Fig. 26A), corresponding to a substantial decline in DE intake (Fig. 26B). Intake of dry-matter and DE was high prior to August, equivalent to the highest levels of intake of lactating cows, when expressed on a $BM^{0.75}$ basis.

Ten of the 19 yearlings became pregnant during the rut of 1997, 5 in each of the 2 nutrition groups, suggesting that the 1-month (August) moderate reduction in DE content of food was insufficient to appreciably affect yearling pregnancy. All 5 yearling cows in the previous-year high nutrition group, 3 of 7 in the previous-year medium group bred, and only 1 of 7 in the previous-year low nutrition group bred. Yearlings with greater BM as calves the previous autumn were more likely to breed ($P < 0.001$) (Table 6). These data suggest that pregnancy probability as yearlings was established to a large degree during summer-autumn of their first year of life.

Logistic regression confirmed the importance of BM as a predictor of pregnancy for yearlings (Fig. 26C, Table 7). Yearlings <170 kg in early September had <50% chance of pregnancy, whereas cows >180 kg had >90% chance of pregnancy. Probability of pregnancy as yearlings also was related to BM the previous autumn of their first year of life (Fig. 26C). Differences in DE content of the 2 summer nutritional regimes may have been too small and implemented too late to affect yearling pregnancy probability ($P > 0.50$ for summer yearling nutrition when included in the logistic regression).

Carry-over Effects of Summer-Autumn Nutrition and Parturition Date

Winter survival of cows and fetuses.—This experiment was conducted with 40 pregnant cows in 1998: 9 cows in the SHWH treatment group, 10 in the SMWH group, 10 in the SNWM group, and 11 in the SNWL group. Although it was not the intent of the feeding regimes to reduce cows to dangerously low levels of condition, 1 cow died and 5 were removed from the study to prevent death. The mortality occurred on 27 February. She and 3 other cows removed from the study on the same day were in the SNWL group. The last 2 cows, from the SMWH group, were removed on 28 February and 6 March. Both required intensive monitoring and extra care for 1–2 months to prevent death. The former of these 2 cows aborted 21 March, 2 weeks after ad libitum feeding started, whereas the latter aborted in mid-May, over 2 months after ad libitum feeding started. The fetus of the cow that died appeared normal and viable upon post-mortem examination.

Cows fed high nutrition in winter (SHWH, SMWH) lost 7–11% of their BM, 3–5 percentage points more than did pregnant cows in the 2 previous winters, despite receiving what was intended to be the same diets each winter. Subsequent nutrient analysis of the pellets fed this winter (1998) suggested the manufacturer inadvertently switched pellet formulations, such that we fed a pellet of substantially lower quality in winter 1998 than in previous winters (Table 1). Although this complicates comparisons among winters, the within-winter comparisons of 1998 are unaffected because only quantity was varied among the treatment groups of elk.

Winter nutrition significantly affected changes in condition during winter ($P < 0.001$). Cows receiving the lowest winter diet lost the most mass, whereas mass loss by cows in the SMWH and SNWM groups was moderate (Fig. 27A). All cows except those in the SMWH group began winter in good condition (16–18% body fat, 1.5–2.7 Mcal/kg of gross energy), whereas cows in the SMWH group began winter in substantially poorer condition (Fig. 27B,C). Condition of cows in the SNWL group plummeted, and by the end of winter, their condition was significantly less than that of the SHWH and SNWM groups and equivalent to that of the SMWH group (Fig. 27B,C). Mid-February characteristics of the cow that died and the others removed from the study differed significantly from cows that completed the experiment: 190 ± 8.1 versus 216 ± 2.7 kg of BM, 4.4 ± 0.73 versus 10.5 ± 0.51% fat, 1.63 ± 0.06 versus 2.13 ± 0.35 Mcal of gross energy, 4.24 ± 0.163 versus 5.04 ± 0.08 cm of loin thickness ($P \leq 0.001$ for all comparisons based on individual *t*-tests).

Loin muscle thickness, an alternate index useful at low levels of condition (Cook 2000), provided a slightly different perspective of changes in condition during winter than LIVINDEX (Fig. 27D). Loin thickness of cows in the SMWH declined precipitously between February and March, indicating acute muscle catabolism of the 2 cows removed from the study, despite refeeding 2

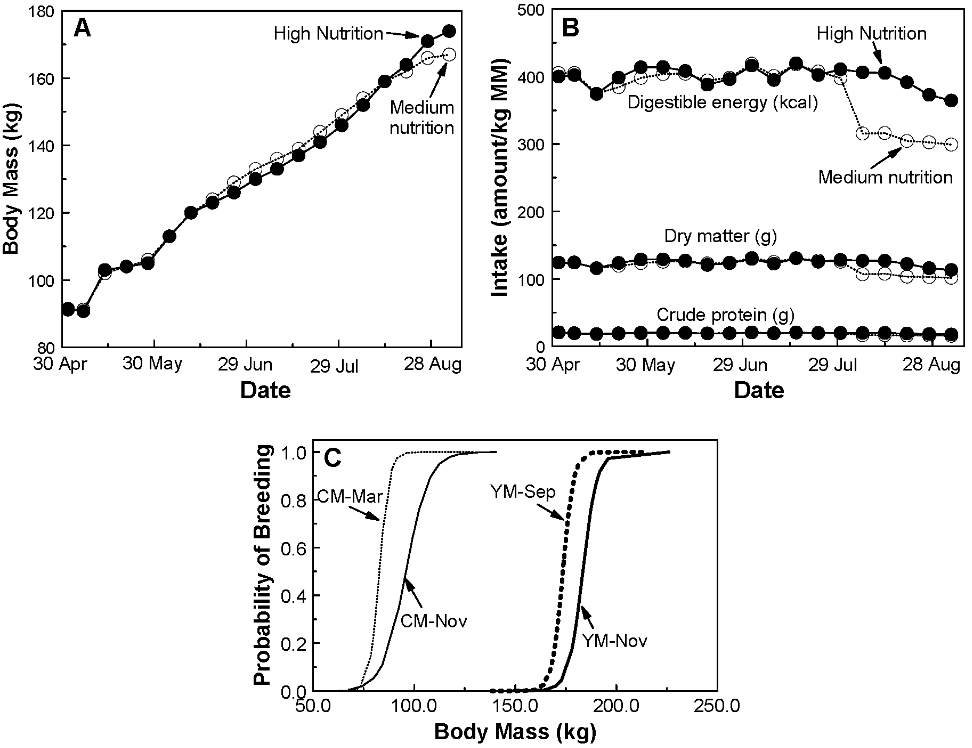

Figure 26. Body mass of yearling cow elk during summer 1997, northeastern Oregon (A) and estimates of daily intake of DE, dry matter, and crude protein per kg of metabolic mass (MM = $BM^{0.75}$) of these yearling cows (B). Cows in both nutrition groups received identical food through July. Starting 1 August, digestible energy (DE) was shifted from 3.2 to 2.9 kcal/g for elk in the medium nutrition group. Hay was fed ad libitum to both over the entire summer period. Graph C illustrates the probability that these yearling cows became pregnant as yearlings (autumn 1997) as a function of their body mass as (1) calves in late November 1996 (CM-Nov), (2) calves in late March 1997 (CM-Mar), (3) yearlings in early September 1997 (YM-Sep), and (4) yearlings in early November 1997 (YM-Nov) (see Table 7 for logistic regression equations).

Table 6. Body mass (kg) of pregnant (*n* = 10) and nonpregnant (*n* = 9) yearling cow elk before and after the rut of autumn 1997, northeastern Oregon.

			Nonpregnant		Pregnant		
Age class	Month	Year	Mean	Range	Mean	Range	*P*[a]
Calf	Nov	1996	81.5	67–99	113.2	84–140	0.001
Calf	Mar	1997	73.7	61–83	98.0	78–129	0.001
Yearling	Sep	1997	160.7	137–174	184.8	169–215	0.001
Yearling	Nov	1997	172.0	146–191	193.2	181–226	0.001

[a] Probability level of *t*-test comparisons for each age class (*n* = 19 cows).

Table 7. Logistic regression equations for predicting probability of pregnancy of yearling elk in autumn 1997 ($Pr(p_{97})$), northeastern Oregon, based on their body mass (BM)(kg) at different growth stages.

Age class	Month	Year	Equation	*P*[a]
Calf	Nov	1996	$Pr(p_{97}) = exp(–17.099 + 0.178BM) / (1 + exp(–17.099 + 0.178BM))$	0.031
Calf	Mar	1997	$Pr(p_{97}) = exp(–34.339 + 0.415BM) / (1 + exp(–34.339 + 0.415BM))$	0.091
Yearling	Sep	1997	$Pr(p_{97}) = exp(–65.813 + 0.379BM) / (1 + exp(–65.813 + 0.379BM))$	0.079
Yearling	Nov	1997	$Pr(p_{97}) = exp(–52.688 + 0.287BM) / (1 + exp(–52.688 + 0.287BM))$	0.037

[a] Level of significance of slope coefficient of logistic regression (*n* = 19 cows).

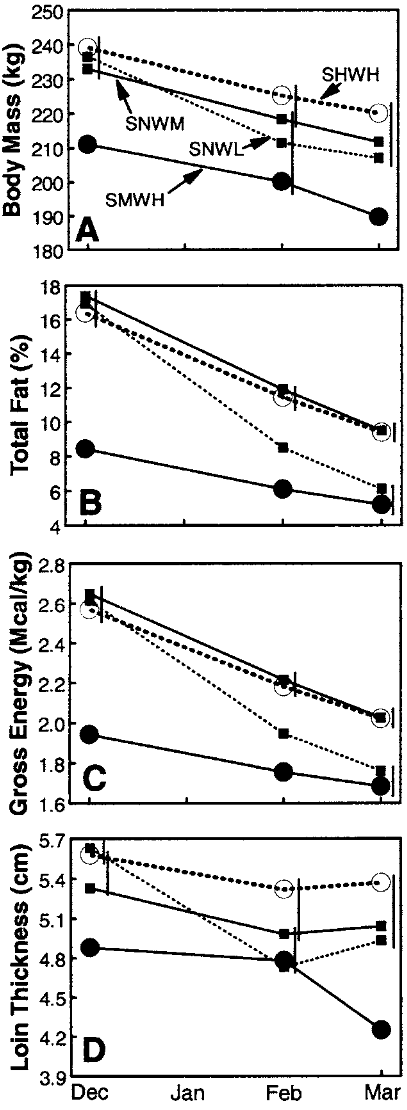

Figure 27. Body mass and nutritional condition of cow elk during winter of 1997–98, northeastern Oregon. Data are presented for 4 treatment groups: SNWM = high nutrition and nonlactating in summer, medium nutrition in winter; SNWL = high nutrition and nonlactating in summer, low nutrition in winter; SHWH = high nutrition and lactating in summer, high nutrition in winter; SMWH = medium nutrition and lactating in summer, high nutrition in winter. Total fat and gross energy content of the ingesta-free body were calculated from LIVINDEX (Cook et al. 2001*a*,*b*). Loin muscle thickness provides a measure of muscle catabolism most useful at low levels of condition (Cook 2000). Within time periods, data values connected with vertical lines do not differ ($P \geq 0.05$).

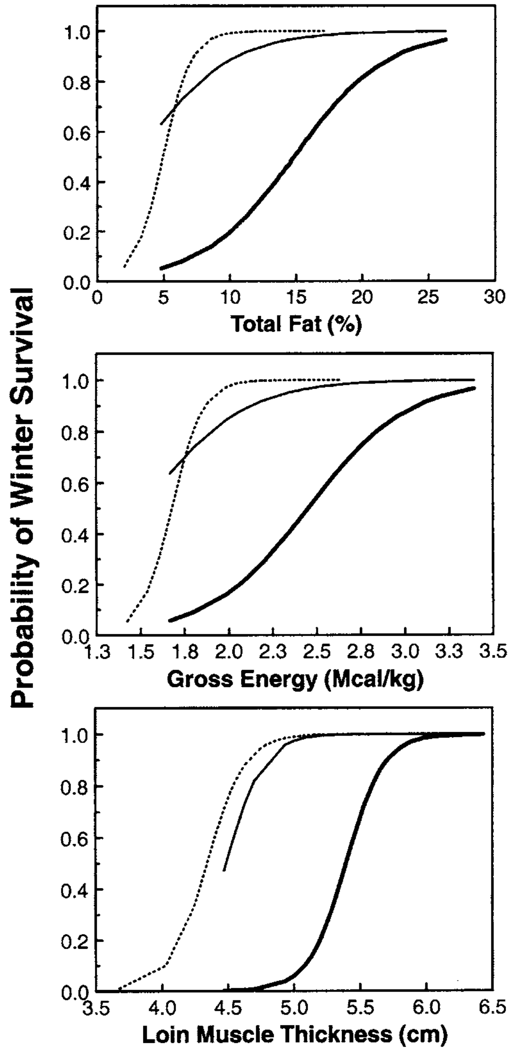

Figure 28. Logistic relations between probability of winter survival (1998) of pregnant elk cows, northeastern Oregon, and nutritional condition (see Table 8 for logistic equations) in 3 situations: (1) severe winter nutritional restriction equivalent to that fed to the winter-low-nutrition group (thick, solid lines); (2) moderate winter nutritional restriction equivalent to that fed to the winter-high-nutrition group (thin, solid lines); and (3) probability of surviving from mid-February through early March based on nutritional condition in mid-February and any of the winter nutrition treatments fed in this experiment (narrow, dotted lines). Total fat and gross energy content of the ingesta-free body were calculated from LIVINDEX (Cook et al. 2001*a*,*b*). Loin muscle thickness provides a measure of muscle catabolism most useful at low levels of condition (Cook 2000).

weeks before the loin measurement was taken for 1 cow and 1 week for the other.

Treating all animals removed from the study as "dead," we developed logistic regressions to predict probability of winter survival as a function of autumn condition, mid-winter condition, and winter nutrition (Fig. 28, Table 8). We first regressed survival on autumn condition and winter nutrition.

Table 8. Logistic regression equations for predicting probability of winter survival during winter 1997–98, northeastern Oregon, of adult cow elk based on (1) nutritional condition in December 1997 and winter nutrition and (2) condition in mid-February 1998. Probabilities are for survival over a 3-month winter season of nutritional deprivation for the former (S_{Win}) and for survival from mid-February through late winter (S_{Lwin}) for the latter.

Dependent variable[a]	Equation[b]
Estimated fat (%)	
	$S_{\mathrm{Win}} = \exp(-7.763 + 0.290\mathrm{FAT} + 3.455\mathrm{WNUT}) / (1 + \exp(-7.763 + 0.290\mathrm{FAT} + 3.455\mathrm{WNUT}))$
	$S_{\mathrm{Lwin}} = \exp(-4.717 + 0.955\mathrm{FAT}) / (1 + \exp(-4.717 + 0.955\mathrm{FAT}))$
Estimated gross energy (Mcal/kg)	
	$S_{\mathrm{Win}} = \exp(-12.07 + 3.555\mathrm{GE} + 3.353\mathrm{WNUT}) / (1 + \exp(-12.07 + 3.555\mathrm{GE} + 3.353\mathrm{WNUT}))$
	$S_{\mathrm{Lwin}} = \exp(-19.14 + 11.41\mathrm{GE}) / (1 + \exp(-19.14 + 11.41\mathrm{GE}))$
Loin thickness (cm)	
	$S_{\mathrm{Win}} = \exp(-44.41 + 7.047\mathrm{LOIN} + 6.403\mathrm{WNUT}) / (1 + \exp(-44.41 + 7.047\mathrm{LOIN} + 6.403\mathrm{WNUT}))$
	$S_{\mathrm{Lwin}} = \exp(-30.54 + 7.033\mathrm{LOIN}) / (1 + \exp(-30.54 + 7.033\mathrm{LOIN}))$

[a] Independent variables were: (1) total fat (FAT) of the ingesta-free body, (2) gross energy (GE) of the ingesta-free body, (3) loin muscle thickness (LOIN), and (4) winter nutrition levels (WNUT), an ordinal variable with values of 1 for low nutrition and 2 for moderate nutrition. FAT and GE were calculated from LIVINDEX from equations of Cook et al. (2001*a*).

[b] Coefficients of FAT ($P = 0.073$) and GE ($P = 0.078$) in the S_{Win} equations approached significance; all other slope coefficients in all equations were significant ($P < 0.050$).

Data for elk in the winter-high and winter-medium nutrition treatments were combined, because performance of elk in these groups was virtually identical (Fig. 27). Both winter nutrition and autumn condition were significantly related to probability of over-winter survival (Fig. 28, Table 8). Our data indicated that during harsh winters of marked nutritional restriction, equivalent to that fed elk in the winter-low nutrition group, winter survival primarily is a function of fat levels at the beginning of winter.

From mid-February through the end of winter, survival was significantly related to condition in mid-February but unrelated to the winter nutrition levels we implemented (Table 8), suggesting that fate of the elk was determined to a large extent by mid-February and was a significant function of their condition at this time. Probability plots with mid-February condition indicated steeper slopes than those of autumn condition, and suggest a threshold level occurring at about 3–5% body fat and 4.2–4.4 cm of loin thickness, below which survival probability was low. This by no means indicates that probability of mortality was irreversible by mid-February, only that probability was set as long as either of the 2 winter feeding levels remained unchanged until early March.

Calf Winter Survival.—In winter 1996–97, data from 22 female and 18 male calves were available to evaluate factors that influenced winter survival. Average mass at the beginning of the experiments in early December was 96.3 kg and ranged from 61–140 kg. Male calves averaged slightly larger than females (92.8 ± 4.44 kg versus 100.6 ± 4.94 kg).

The first winter experiment was conducted from 11 December–20 March. Over this time, all except 4 calves were removed (i.e., simulated death) from the study, most in February and March (Fig. 29A). Three calves died during this winter. One was the first removed from the study (4 Jan). She was ill with elevated temperature, had lost only 10% of her BM, and had peritonitis of unknown causes, based on veterinary necropsy. The second calf failed to recover after removal from the study (10 Feb); the third calf died during the night (8 Mar), probably from hypothermia.

At the time calves were removed from the study, they had lost an average of 18.6 ± 0.62% (range = 10–26.6%) of their starting BM. They lost an average, from 11 December–20 January, 0.09 kg per day or 0.11% of their beginning BM per day, and lost 0.24 kg per day, or 0.26% of their beginning mass per day, from the beginning to the point at which they were removed. Males lost 18.8% overall and 0.27%/day and females lost 18.3% overall and 0.26%/day, indicating virtually identical mass loss between sexes.

Mass lost by calves and timing of "mortality" strongly reflected calf mass at the beginning of winter. Number of days of winter

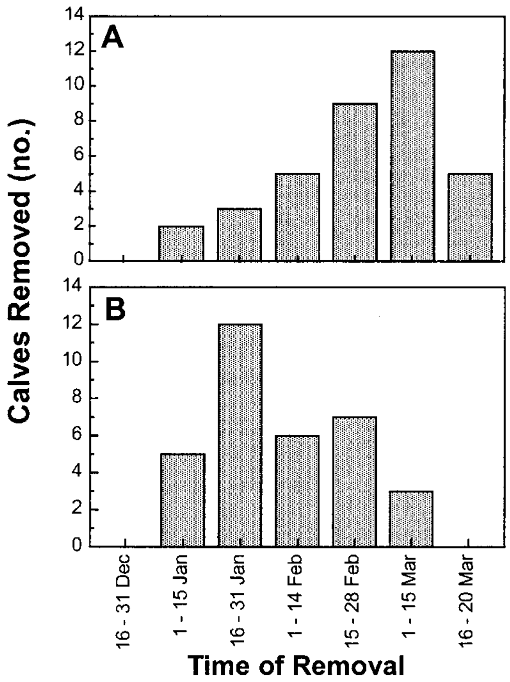

Figure 29. Timing of removal (i.e., simulated mortality) of elk calves from winter survival experiments in 1996–97 (A) and 1997–98 (B), northeastern Oregon.

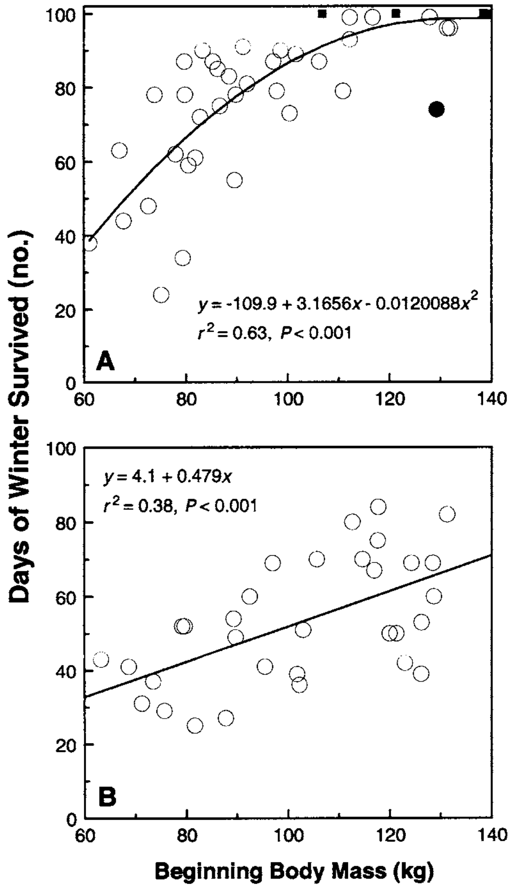

Figure 30. Relations between number of days of winter survived by elk calves and their body mass at the start of winter in 1996–97 (A) and 1997–98 (B), northeastern Oregon. Both winter experiments were conducted from mid-December to mid-March. In graph A, the 4 solid squares are data for calves that survived the entire winter experiment, and the solid circle indicates a data point treated as anomalous and excluded from calculation of the regression equation. Differences in regression relations between years reflect differences in feeding regimes between years.

survived was a significant ($P < 0.001$), nonlinear function of BM at the beginning of winter (Fig. 30A). The nonlinear relation for 1996–97 approached an asymptote; calves at least 105 kg at the beginning of winter had a high probability of surviving at least 90 days of winter. Number of days survived diminished markedly as BM declined below 105 kg. The 4 calves that survived winter averaged 126.6 ± 7.8 kg at the beginning of winter. By comparison, calves that died or were removed averaged 92.9 ± 3.13 kg. Survival was marginally affected by calf gender ($P = 0.11$).

Longer survival of larger calves apparently resulted from greater tolerance of nutritional deficiencies and winter weather. The smallest calves began losing appreciable mass early in winter, despite only moderate nutritional deficiencies, whereas the largest calves lost little mass until after mid-February (Fig. 31), when feeding levels were reduced appreciably (Table 3). The amount of mass lost daily to the time of removal was a nonlinear function of beginning BM ($P < 0.001$) (Fig. 32A). Additionally, larger calves were capable of losing more mass as a percent of their beginning BM (evident only when influences of day of the experiment were controlled using multiple regression): $y = -20.9 + 0.134x_1 - 0.1229x_2$, where y = total mass loss (%) to the time of removal, x_1 = mass at beginning of winter ($P = 0.008$), x_2 = number of days past 11 December ($P = 0.027$) ($r^2 = 0.18$, $P = 0.026$). Nonetheless, daily rate of mass loss, which ultimately determined the number of days of winter survived, was most affected by beginning mass.

Finally, the 2-way ANOVA, to identify influences of nutrition the previous summer

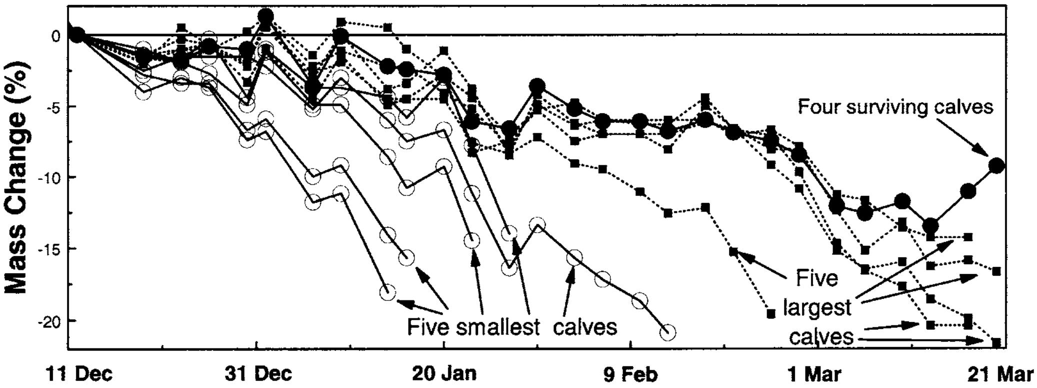

Figure 31. Body mass changes of elk calves during winter 1996–97, northeastern Oregon. Data are presented for the 4 calves that survived the entire winter (weekly averages of the 4), and the 5 smallest and 5 largest calves that "died" during winter.

and autumn, birth date, and their interaction, on winter survival of calves, indicated a strong effect of nutrition ($P < 0.001$), little or no effect of birth date ($P = 0.18$), and no interactive effect ($P = 0.60$). An initial 3-way ANOVA (summer-autumn nutrition, birth date, and calf gender) with all interactions indicated no influences of gender on winter survival ($P \geq 0.47$).

Thirty-three calves were available for the second winter experiment (1997–98). Three of these calves were abandoned soon after birth and bottle-raised (were not used in the summer-autumn experiments); all others were dam-reared and used in the summer-autumn experiment. Data from the 3 calves were included to evaluate relations between starting BM and winter survival, but were excluded from ANOVA tests of effects of birth date and summer nutrition on winter survival. The 33 calves averaged 100.7 ± 3.80 kg (range = 56.5–131.3 kg) at the beginning of the second winter experiment. The 20 females averaged 97.8 ± 5.3 kg and the 13 males averaged 105.2 ± 5.14 kg, but were not significantly different ($P = 0.33$, $t = -0.95$, df = 31). During the second winter, calves were removed earlier (Fig. 29) and lost mass about 50% faster compared to the first winter, and none of the 33 calves "survived." These differences probably were caused by greater nutritional restriction induced early in the second winter (Table 3). Even so, percent of mass lost at the time calves were removed from the study was virtually identical to that of the previous year (18.6 ± 0.56%; range = 13–24%).

"Mortality" and rate of mass loss again were significantly related to mass at the start of winter ($P \leq 0.004$). Beginning BM accounted for less variation (38%) in number of days of winter survival than in the first winter, and this relation was linear rather than nonlinear (Fig. 30B). Calves lost 0.39 ± 0.025% daily (no gender differences were evident, e.g., 0.39% versus 0.39% for males and females). Rate of mass loss was significantly

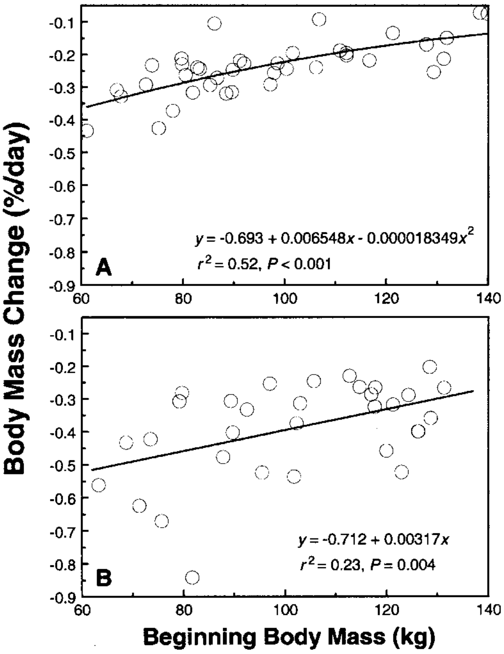

Figure 32. Daily rate of mass loss of elk calves from the start of the calf winter survival experiments in mid-December until time of removal (simulated "death") during 1996–97 (A) and 1997–98 (B), northeastern Oregon.

correlated to BM at the start of the experiment, but to a lesser extent than during the first winter experiment (Fig. 32). In contrast, larger calves were not capable of losing more mass, expressed as a percent of starting BM, than smaller calves. Thus, larger calves survived longer because their rate of mass loss relative to their total BM was lower.

The final 2-way ANOVA indicated a strong effect of nutrition (P = 0.001), no effect of birth date (P = 0.63), and no interaction effect (P = 0.74). An initial 3-way ANOVA (summer-autumn nutrition, birth date, and calf gender) with all interactions indicated no influences of gender on winter survival ($P > 0.11$).

Calf birth characteristics and gestation length.—Failure of most elk in the low nutrition group to become pregnant in both summer-autumn experiments indicates a marked carry-over effect of summer-fall nutrition on reproduction the subsequent year. However, it also reduced our sample to evaluate carry-over effects of summer-autumn nutrition and parturition date on subsequent year's calf birth characteristics. We therefore combined our 2 years of data, added "year" as a predictor variable, and included calf gender to account for this potentially confounding factor. Based on a total sample of 44 cows, calf gender (P = 0.001), year of the study (P = 0.001), and the cow's previous-year parturition date (P = 0.033) accounted for significant variation in birth mass (Fig. 33A). Neither previous-year summer-autumn nutrition (P = 0.77) nor the interaction of previous-year nutrition and previous-year parturition date (P = 0.30) (nor any other interaction of interest) were significant. Replacing previous-year summer-autumn nutrition and previous-year parturition date with body fat in autumn, the ANCOVA also suggested that gender and year primarily accounted for variation in birth mass (P = 0.079 and 0.012); autumn body fat was no more related to birth mass (P = 0.77) than previous-year nutrition. Finally, replacing previous-year autumn body fat with body fat in March in the ANCOVA failed to indicate that condition during the first 2 trimesters of gestation significantly influenced birth mass (P = 0.56). Winter nutrition of these cows was approximately constant each year, so winter nutrition was excluded from these analyses.

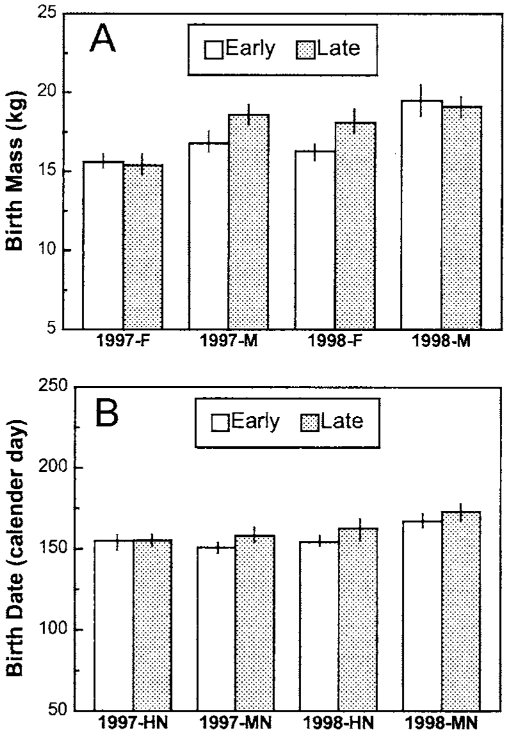

Figure 33. In graph A, influences of year, fetal gender (M = males, F = females), and the mother's parturition date the previous spring (early, late) on birth mass of elk calves born in 1997 and 1998, northeastern Oregon. In graph B, influences of year and previous-year nutrition treatment of the mother (HN = high nutrition, MN = medium nutrition) and previous-year parturition date of the mother on birth date of calves in 1997 and 1998. Vertical lines denote SEs. All graphed effects exhibited significant influences ($P \leq 0.05$) on birth mass and birth date.

The winter experiment examining survival of cows and fetuses provided a limited basis to evaluate winter nutrition's influence on birth mass. Birth mass of calves born to cows in the winter medium and winter low nutrition treatments (SNWM and SNWL groups) ranged from 13–16.8 kg across both treatment groups of cows, and average birth mass was similar (14.7 versus 15.5 kg). Birth mass was unaffected (P = 0.84) by change in body fat levels from autumn through early March, even though condition of 3 cows in the SNWL group reached critically low levels in late February. Neither fetal gender nor the interaction of gender and change-in-fat influenced birth mass ($P \geq 0.63$).

Current-year parturition date, in contrast, varied in response to previous-year summer-autumn nutrition (P = 0.010), which was expected because of the effect of previous-year nutrition on breeding date (Figs. 12 and 13). The effect of previous-year nutrition (i.e., higher nutrition, earlier birth) was evident mainly during the second year (Fig. 33B) ($P = 0.027$ of the year × nutrition interaction). Replacing previous-year nutrition with autumn body fat confirmed the carry-over effect of autumn condition ($P = 0.004$). The interaction of autumn body fat with year was not significant ($P = 0.98$). However, the simple linear regression relating autumn body fat to subsequent parturition date accounted for a small portion of the variation in parturition date ($y = 169.7 - 0.93x$; $r^2 = 0.14$; $P = 0.003$; $n = 63$, where x = autumn body fat).

Previous-year parturition date also was related to current year parturition date ($P = 0.004$). Cows giving birth earlier the previous year also tended to give birth earlier the current year. Effect of previous-year parturition date was similar across years and nutrition treatments ($P > 0.269$ for both 2-way interactions: previous-year parturition date × year and previous-year parturition date × previous-year nutrition) (Fig. 33B).

Breeding observations in 1997 permitted direct evaluation of factors influencing gestation length ($n = 16$ cows). Gestation length was 250.9 ± 2.28 days (range = 240–271). Current-year parturition date was only weakly related to previous-year breeding date ($P = 0.074$; $r^2 = 0.21$; $y = 0.606x - 4.8$, where y = calendar day of birth and x = calendar day of breeding). Neither previous-year nutrition nor previous-year autumn body fat, body fat in March, or calf gender ($P > 0.23$) were significantly related to gestation length. Only timing of birth the previous year was significantly related to gestation length (i.e., earlier births the previous-year corresponded to shorter gestation length in the current year) ($P = 0.021$), corresponding to findings of previous-year parturition date influences above (Fig. 33B). This suggests that those cows that give birth early do so because they tend to have shorter gestation lengths, assuming all else (e.g., nutrition) being equal.

However, of the 21 cows that were nonlactating in autumn 1997 and fed the medium and low diets during winter 1998 (the SNWM and SNWL treatment groups), parturition dates ranged over a 45-day period in spring 1998. Given the excellent condition of all these nonlactating cows during the breeding season (Fig. 16), differences in parturition date probably resulted from differences in winter nutritional regimes (Fig. 34). Change in nutritional condition from autumn to early spring accounted for 50–60% of the variation in parturition date ($P < 0.001$). Thus, for those cows beginning winter with 15–25% body fat, depletion of 90% of their reserves extended parturition date 34 days on average, if dietary conditions ceased to be limiting beginning by mid-March (Fig. 34).

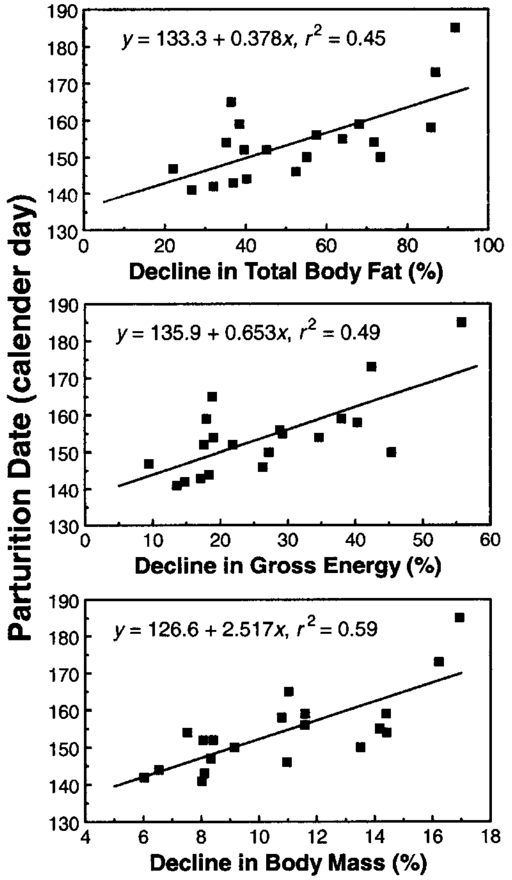

Figure 34. Influences of over-winter declines in nutritional condition and body mass of elk cows during winter 1996–97 on their parturition date in spring 1997, northeastern Oregon. Cows in this experiment were pregnant and in excellent condition in autumn and nonlactating and well-fed the previous summer (see Fig. 27). These results suggest elk cows can markedly extend gestation to compensate for relatively severe winter nutritional deficiencies.

DISCUSSION

Our data indicate that relatively small differences in DE content of food consumed by elk in summer and autumn have strong effects on fat accretion, timing of conception, probability of pregnancy of lactating cows, growth of calves, yearling growth, and yearling pregnancy rates. Effects of summer-autumn nutrition on fat accretion of cows and growth of calves significantly influenced their survival probability during winter under the harsh winter nutritional conditions that we mimicked. Earlier birth resulted in larger BM of calves in late autumn, but we were unable to document significant, consistent effects of parturition date on any other reproductive or survival attribute we estimated. Neither summer-autumn nutrition nor the cow's parturition date had biologically meaningful effects on birth mass of calves the following year.

Direct Effects

Calf responses.—Earlier work on elk suggested that breeding is delayed ≤3 weeks (Noyes et al. 1996) when yearling bulls dominate the breeding. Delayed parturition, whatever its cause, can reduce calf survival over summer (Guinness et al. 1978*b*, Clutton-Brock et al. 1982, Keech et al. 2000), over winter (Guinness et al. 1978*b*, Singer et al. 1997), and can reduce fitness of those that do survive (Festa-Bianchet et al. 2000).

A biologically relevant effect of birth date on winter survival depends on a key assumption–that late-born calves have little capability to catch up by late autumn with their early-born counterparts, thereby reducing or eliminating the "head-start" benefit of early birth. Additionally, the potential for an interaction between summer-autumn nutrition and birth date on late-autumn BM reflects the supposition that optimal birth date arises from the synchrony between the peak in forage quality and the peak in nutritional demands of the lactating mother. Hence, calves may have reduced ability to catch-up if they are born well after forage quality begins to decline and may lag behind calves that are born earlier, if nutritional restriction has a greater negative effect on very young calves than on older calves.

Our data failed to support this interaction hypothesis between birth date and summer-autumn nutrition. In 1996, we found a significant interaction between birth date and nutrition on calf growth. But this interaction resulted from faster growth of late-born calves (Fig. 19B). In 1997, the interaction between birth date and nutrition was not significant, nor did it approach significance. Our analysis also suggested that potential confounding by gender, cow age, and, in 1997, previous-year nutrition levels of the mother, probably do not account for these results and inconsistencies between years. Therefore, our data provide little evidence that (1) late-born calves are more disadvantaged, as summer nutrition becomes increasingly deficient, than are early-born calves and (2) elk calves are physiologically capable of accelerated growth to compensate for late birth.

The primary benefit of early birth in respect to calf BM by late autumn was simply due to a longer period of time for growth. But this head-start advantage was diluted to some extent before winter because some late-born calves grew faster. Understanding causes of this dilution is key for understanding whether early birth of about 3 weeks is truly an advantage.

Faster growth of these late-born calves was evident in the low and medium nutrition groups in 1996 and the high nutrition group in 1997 (Fig. 19A,C). Their faster growth probably resulted from complex interactions among birth date, gender, and birth mass. Even though Hudson et al. (1991) reported that male elk calves grow more rapidly than females, our data suggest that greater birth mass probably was more responsible than was gender for faster growth of late-born calves. Across both years, in each of the 3 nutrition groups where late-born calves caught up, (1) larger calves at birth grew faster (Fig. 35) and (2) late-born calves on average were larger at birth (Table 5). Conversely, (1) male calves grew faster and (2) there was a greater proportion of males in the late-born groups, but only in 2 of the 3 nutrition groups where late born calves caught up (Fig. 35, Table 5). Finally, in the low nutrition group of 1996, the tendency for faster growth by calves that were heavier at birth was more evident in males than females, and males predominated in the

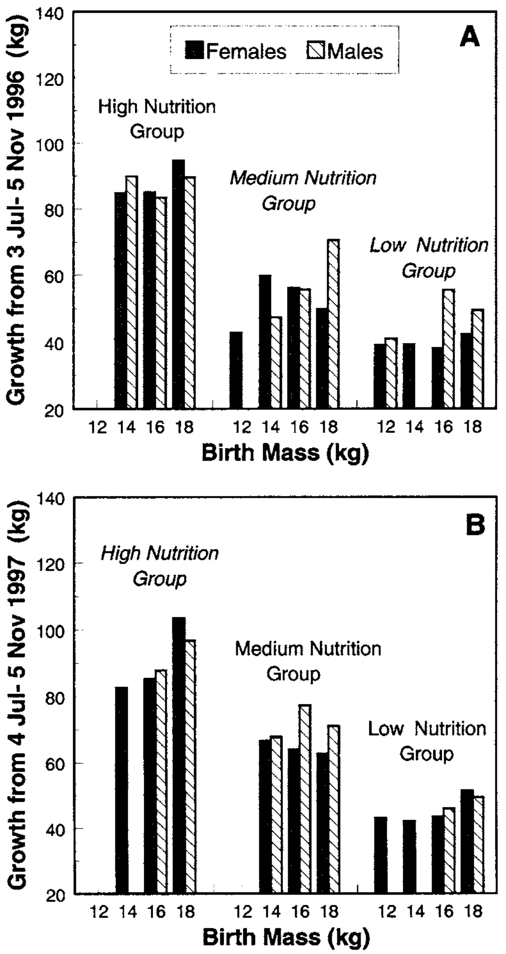

Figure 35. Relations between birth mass, gender, and growth from early July until weaning in early November, 1996 (A) and 1997 (B), by nutrition treatment groups of elk calves, northeastern Oregon. Late-born calves exhibited faster growth and caught up with their early-born counterparts in the italicized nutrition groups.

late-born group (Fig. 34, Table 5).

This qualitative evaluation (Fig. 34) is not conclusive. Nevertheless, it suggests that the early-birth advantage, and its dilution over summer and autumn, depends on the distribution of birth mass and perhaps gender across the parturition period. If larger calves at birth, particularly if they are male, occur more frequently late during the parturition period, then the advantage of early birth will wane before winter. On the other hand, if larger birth mass and male births are more frequent early in parturition, then calves born late may fall further behind their early-born counterparts over summer and autumn. Of our 3 calf crops (*n* = 118 calves), we found no evidence that heavier birth mass or males were more common early in parturition. In contrast, in 2 of the 3 years, birth mass, within gender, increased significantly as parturition progressed. Further, males comprised 36% of 73 early births (born on or before 10 June) and 52% of 45 late births (born after 10 June). Smith et al. (1997) reported that male elk calves were born later than females and were larger at birth, although they found no evidence that birth mass, within gender, increased as parturition progressed. We conclude that as long as birth mass and gender are relatively constant across the parturition period, the head-start advantage of early birth will be maintained through autumn. But if calves are heavier or males are relatively more abundant later in the parturition period, the head-start advantage of early birth will diminish by late autumn.

Nutrition during summer and autumn had marked influences on calf growth that overshadowed effects of all other variables we measured, and demonstrated once again (Holter and Hayes 1977; Verme and Ozoga 1980*a,b*; Cook et al. 1996) the sensitivity of growth to nutrition. Digestible energy content of food affected growth by influencing daily intake levels of solid food by calves and probably by influencing milk yield. The effect of nutritional deprivation on milk yield can be rapid, substantial, and independent of nutrition prior to the onset of lactation (Barnicoat et al. 1949, Peart 1968, Loudon et al. 1984, Oftedal 1985). Loudon et al. (1984), for example, reported that milk production in red deer was 1.6 times greater in females maintained on pastures with 1,800 kg/ha at 69% digestibility than in females using forages of "low density" with 60% digestibility.

Of the other influences on calf performance we investigated, birth mass was most important. Larger newborns grew more rapidly through early summer than did smaller newborns. A calf of 18 kg at birth would grow 3–5 kg more over the first month of life and weigh 7–8 kg more after 1 month than a calf weighing 13 kg at birth, a 20% difference in BM at 1 month. This probably occurs because absolute growth (kg/day) is greater in large calves, despite similar incremental growth (%/day) (Bailey and Mears 1990). Advantages of heavier birth mass remained through weaning in both years (Fig. 20). Enhanced growth due to larger birth mass was reported at least to 6 months of age for fallow deer (*Cervus dama*) (Pelabon 1997), at least to 10 months of age for moose (*Alces alces*) calves (Keech et al. 1999), and to 2.5 years of age for white-tailed deer (Schultz and Johnson 1995).

Influences of calf gender, cow age, and in 1997, previous-year nutrition level on growth were mixed. Gender significantly influenced growth from birth to early July in the second, but not the first year. Influences of gender on growth indicated no biological relevant pattern we could discern over summer and autumn and was unrelated to BM at weaning in mid-autumn in either year. We were unable to find significant effects of cow age or previous-year nutrition of the mother on calf growth over summer and autumn.

Cow responses.—As with calves, we expected that parturition date and nutrition would interact to affect fat accretion, conception date, and pregnancy rates of cows (i.e., cows giving birth earlier would be less affected by summer-autumn nutritional deficiencies than late-birthing cows, because nursing demands and thus nutritional demands placed on cows diminish starting when calves are about 4 weeks old [Robbins et al. 1981]). However, we found no significant interactions of parturition date and nutrition on BM, nutritional condition, or breeding dynamics over summer and autumn in either year. Yet each factor had significant, separate effects.

Seemingly small differences in DE content of food during summer and autumn had pervasive effects on every response variable measured for cows over the summer-autumn period. Significant differences in BM appeared by mid-July, only 3 weeks after nutrition treatments were initiated and before strong divergence in DE levels occurred (Figs. 6B and 8B). Even at the point of greatest divergence of forage quality, DE for the medium and low nutrition groups was reduced only 10% and 20% below that of cows in the high nutrition group. Yet, fat levels varied about 75% and 300% between cows on high nutrition versus those on medium and low nutrition.

These results demonstrate a "multiplier" effect (White 1983) regarding forage quality effects on animal performance. In our study, the effect resulted from differences in DE content of food and the reductions in daily food intake as DE content of food declined. Positive relations between forage quality and daily dry-matter intake have long been recognized (Spalinger et al. 1986, Ketelaars and Tolkamp 1991, Minson and Wilson 1994, Grey and Servello 1995). Our results further demonstrate that ruminants cannot substantially compensate for appreciably low forage quality simply by eating more.

The moderate level of nutrition significantly delayed conception date, and the low level effectively precluded pregnancy of most cows. Neither failure to implant nor early embryonic mortality were responsible for these low pregnancy rates; these cows simply failed to enter estrus (Cook et al. 2001*c*).

Significant relations of nutrition, condition, and BM with pregnancy rates and timing of conception have been presented for red deer and caribou (e.g., Guinness et al. 1978*a*, Hamilton and Blaxter 1980, Thomas 1982, Cameron et al. 1993). In elk, significant correlation has been reported between BM and pregnancy rates (Hudson et al. 1991), kidney fat and pregnancy rates (Trainer 1971, Kohlmann 1999), and between kidney fat and timing of conception (Trainer 1971). Nutritional condition is probably more related to pregnancy probability than BM. In our study, estimates of nutritional condition indicated thresholds that may be used for monitoring nutritional status of wild herds. Pregnancy rates declined precipitously as body fat declined below ≤9%, and fat ≤5% precluded pregnancy. Timing of breeding was early and unaffected when fat exceeded 13%, but was increasingly delayed as fat declined below 13%. Of the few cows with 5–7% body fat that bred, timing of breeding was delayed ≤1 month.

Our logistic curves of pregnancy probability as a function of body fat (Fig. 14) differ from that of Kohlmann (1999) (Fig. 36) (we converted his estimates of kidney fat to a body fat basis using equations of Cook et al. 2001*a*). Kohlmann's logistic regression equation, developed using a large sample ($n > 1{,}000$) of elk in Oregon, predicts pregnancy rates ≥40%, no matter how low the

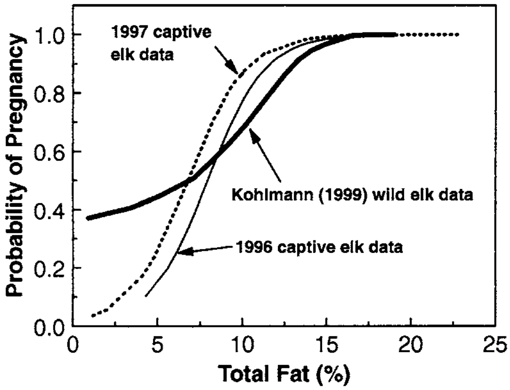

Figure 36. Comparison of pregnancy probability of captive cow elk, as a function of total body fat levels, in our study, northeastern Oregon, and hunter-killed wild elk collected 2 to 4 months post-rut throughout Oregon as presented by Kohlmann (1999). Differences between studies perhaps reflect differences in timing of collection of fat data (i.e., Oct in our study, Nov–Jan in Kohlmann's study).

level of body fat, despite empirical evidence to the contrary (e.g., Gerhardt et al. 1997, Heard et al. 1997, Testa and Adams 1998). Kohlmann's prediction of moderate pregnancy rates at very low levels of condition probably is an artifact of when samples were collected; samples were obtained from hunter-harvested elk from November through January, 2–4 months after the normal breeding season. Elk in his study probably had more fat during the breeding season in September and early October than when they were harvested.

Parturition date's influence on BM and condition of cows in late autumn was significant in only 1 of 2 years and was substantially weaker than that of summer-autumn nutrition. On average, early parturition increased body fat of cows by 1–3 percentage points in autumn, an effect evident only in 1996. We can only speculate about the differences between years, but, in 1996, two-thirds of the cows were in the younger cohort (3 years old) and probably still growing. The additional demands of their growth may have increased their sensitivity to parturition date. We were unable to find a significant influence of parturition date on timing or probability of pregnancy in either year.

Cow age, calf gender, and previous-year nutrition had some influences on cow performance over summer. In 1996, the 3-year-old cows tended to gain more mass or lose less mass than their 5-year-old counterparts. This tendency mirrored mass changes of the previous winter and spring (1995–96) (J. Cook, unpublished data) and probably was caused by an ongoing propensity to grow. We saw no evidence of this tendency during the subsequent winter and spring (1996–97) (J. Cook, unpublished data) or the summer-autumn period of 1997. Thus, this tendency to grow waned after 3.5 years of age. Male calves significantly reduced mass gain, or increased mass loss, of their mothers only in 1996 and only during early July of this year (Fig. 7A). We found no significant gender effect on body mass changes of their mothers in summer-autumn of 1997.

The carry-over effect of summer-autumn nutrition in 1996 on cow BM dynamics in 1997 was surprising. We hypothesized a priori that this carry-over effect would be manifested as a reduction in cow or calf performance caused by nutritional restriction the previous year. However, our findings suggested that cows compensated for previous-year nutritional limitations despite raising a calf (Fig. 9), but this compensation waned by late July. The ability to compensate while lactating for prior nutritional deprivation may reduce the frequency of reproductive pauses. However, Cameron (1994) noted that caribou raising a calf across successive years lost about 13% of their endogenous body reserves each year, eventually inducing failure to conceive. Relations between summer compensation and reproductive pauses undoubtedly depend on levels of forage quality and quantity during summer and the magnitude of nutritional deficiencies occurring in winter.

Finally, our experiment in 1997 to compare influences of nutrition on condition of nonlactating versus lactating cows provided insights about interactions between lactation status and summer nutrition. The low nutrition level that was responsible for poor condition, poor calf growth, and low pregnancy rates of lactating cows nevertheless allowed nonlactating cows to accrue fat and muscle tissues at nearly the same rate as lactating cows fed high nutrition (Fig. 16). Thus, autumn fat levels of nonlactating cows in free-ranging settings are probably less affected by variations in forage quality and quantity than are lactating cows.

Further, lactating cows in mid-autumn typically have lower BM and lower fat levels than nonlactating cows, a lactation increment that can depress pregnancy rates (e.g., Lowe 1969, Trainer 1971, Mitchell and Lincoln 1973, Guinness et al. 1978*a*, Hudson et al. 1991). Although it is tempting to conclude that such a differential is an inevitable cost of lactation, our data indicated that lactating cows can satisfy the costs of raising a calf and simultaneously accrue as much fat by mid-autumn as nonlactating cows, as long as forage quality is adequate. This evidently occurs simply because lactating cows consume more food (Fig. 25). But our data indicated that fat accretion by lactating cows diminishes to a greater extent, as DE content of food declines, than does that of nonlactating cows. Clutton-Brock et al. (1983) showed that pregnancy rates of lactating red deer cows declined significantly (presumably because of declining nutritional condition), but remained high for nonlactating cows, as population density increased. Thus, knowledge of summer forage quality may be important to explain alternate-year breeding or low pregnancy rates given its influence on cow recovery of body fat during lactation.

Yearling responses.—Summer growth of yearling cows was sensitive to DE content of their food. Reducing the DE content of diets from 3.2 to 2.9 kcal/g of the medium nutrition group in early August initiated a slight decline in dry-matter intake (from 125 to 110 g of DM/kg BM$^{0.75}$), and a substantial decline in total DE intake (from 405 to 310 kcal/kg BM$^{0.75}$) and growth rate (0.78 kg/day versus 0.46 kg/day over 28 days in Aug) (Fig. 26A). Growth of yearling cows reported by Cook et al. (1998) was 0.40 kg/day at 300 kcal/kg BM$^{0.75}$ in 1994 and 0.36 kg/day at 280 kcal/kg BM$^{0.75}$ in 1992 (DE content was about 2.9 kcal/g of food; feeding rate was held below ad libitum). These data provide a preliminary equation linking DE intake and growth rate of yearlings (Fig. 37) that is remarkably similar to that for elk calves (Cook et al. 1996).

Onset of puberty of females varies appreciably and usually is considered to be a function of BM (Hamilton and Blaxter 1980, Verme and Ullrey 1984, Sæther and Heim 1993). Hudson et al. (1991) indicated that cow elk must achieve 65–70% of their adult BM before they will breed. The percentage of yearling elk cows pregnant has been reported to be as low as 0–7 (Murie 1951, Cheatum and Gaab 1952, Trainer 1971, Noyes et al. 1996), and as high as 50 (Hudson et al. 1991). Statewide estimates for Oregon were <20% (Kohlmann 1999). Greer (1968) reported that no yearling cows ≤152 kg were pregnant; 10% weighing 152–163 kg were pregnant; and 25% weighing 163–169 kg were pregnant. These data support our observation of BM-specific yearling pregnancy rates (Fig. 26C).

Our data indicate that if summer nutrition is adequate to avoid limitations on calf and yearling growth, then yearling pregnancy rates should typically approach 100%, even in years following severe winters. Yet, the low pregnancy rates typical of yearlings in free-ranging herds suggest that forage on summer-autumn ranges routinely fail to support growth rates necessary for most yearling cow elk to breed. However, there are examples of high yearling pregnancy rates. Buechner and Swanson (1955) reported that 19 of 30 2-year-old cows were lactating in autumn of 1954 in Northeast Oregon, indicating a minimum yearling pregnancy rate of 58%. Hancock (1957: cited by Taber et al. 1982) reported 66% of yearling's ovulating following a mild winter in a Utah herd. Our data indicated that probability of pregnancy as yearlings is to a large extent set by autumn when these animals are calves (Fig. 26C). There may be little opportunity for yearlings

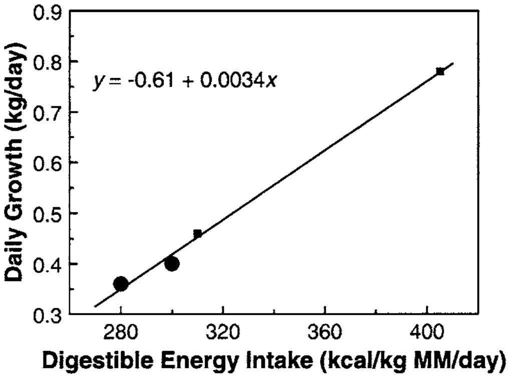

Figure 37. Relation between growth rate of yearling cow elk and digestible energy consumption, northeastern Oregon. Data points represented by squares are from this study (Fig. 26B, in Aug); data points represented by circles are for captive yearling cows during summer presented by Cook et al. (1998). MM = metabolic mass (BM$^{0.75}$).

to sufficiently compensate during their second summer and autumn of life for inadequate nutrition during their first summer and autumn.

Food intake patterns.—Despite our inability to statistically compare differences in food intake among summer-autumn nutrition and parturition-date groups, it was clear the DE treatments influenced dry-matter intake rates and, in turn, DE and protein intake. But the magnitude of the effect was time-specific. Cows adjusted to some extent to the lower DE levels and increased dry-matter intake by late summer. Increasing adaptation of rumen microbes may have contributed, although this should not require more than 2 weeks (Yokoyama and Johnson 1988). Also, elk on the lower quality diets may have increased gut fill by increasing rumino-reticular capacity, such that they were able to process a greater volume of food each day (Hofmann 1988, Owen-Smith 1994). Elk in the low nutrition group developed a more "round" appearance when viewed from the rear by early autumn, compared to a more "elliptical" appearance of elk in the high nutrition group, suggesting gut capacity and content increased in the low nutrition group. Baker and Hobbs (1987) observed this adaptation in mule deer, whereas elk failed to do so in their study. They used nonlactating, nonpregnant animals fed winter forages, and thus their animals did not have the nutritional demands of ours. Differences in nutritional need resulting from differences in production stage or fat levels greatly alter appetite and intake (Ketelaars and Tolkamp 1991, Romsos 1998), so it is not clear that results of Baker and Hobbs (1987) apply to our experimental setting.

Declines we observed in intake of dry matter, DE, and protein as dietary quality declined were greater the first year compared to the second (Fig. 24). The pellet:hay ratio in May and June, before the summer-autumn nutrition trials began, was changed from 55:45 in 1996 to 40:60 in 1997 to better adapt our cows to hay-dominated diets before the nutrition treatments were implemented. This may have accounted for the reduced mid-summer decline in intake observed in 1997. Nevertheless, the negative influences of the low and medium nutrition treatments on cows and their calves were as great or greater in 1997 than they were in 1996.

Additionally, dry-matter intake by cows on the high nutrition treatment began to wane earlier in summer in 1997 than in 1996. Cows in 1996 consumed $\geq$140 g dry matter/kg BM$^{0.75}$ from mid-July through late September, whereas cows in 1997 maintained this only through mid-August. This difference may reflect greater nutritional requirements of the younger cows to maintain their growth in 1996. The late-summer decline in intake during 1997 is congruent with the set-point concept as applied to large ungulates (Renecker and Samuel 1991). That is, as body fat approaches some upper physiological threshold, appetite and daily intake diminish (Bines and Morant 1983, Price and White 1985). A negative feedback between plasma leptin, originating from adipose tissue, and hypothalmic regulation of appetite (Romsos 1998) may have been responsible.

Our ability to determine the effects of parturition date on intake was limited. Nevertheless, some trends were clear. During early summer, parturition date seemed to interact with nutrition to affect daily food intake, particularly in 1996. Cows giving birth late consumed less food in early July than did early-birthing cows, particularly cows in the low nutrition group. This suggests that dry-matter intake by cows soon after giving birth (<3 weeks) may be suppressed to some extent, particularly if forage quality is relatively poor. The effect seemed transient and of little relevance to cow performance in our data, but if our nutrition treatments had been implemented earlier in the year (e.g., late May versus late June), we may have observed greater negative influences of late parturition on cows in this study.

The dry-matter intake levels we observed (140–150 g/kg BM$^{0.75}$, Fig. 24) by lactating cows are some of the highest reported for elk (Cook 2002). A slightly higher estimate of 150–155 g/kg BM$^{0.75}$ was reported for subadult nonlactating cows during early summer (Jiang and Hudson 1994). Robbins et al. (1981) reported intake of approximately 125 g/kg BM$^{0.75}$ for noncompensating elk cows (i.e., cows not compensating from winter mass loss) fed high quality alfalfa hay. Intake of the high nutrition group of cows in our study was nearly double that of nonlactating, noncompensating cows fed similar diets in other studies (70–80 g/kg BM$^{0.75}$) (Cook 2002). This large difference merely reflects the considerable nutritional cost of lactation (Oftedal 1985), particularly when combined with the nutritional costs of recovery from winter mass loss (Cook 2002).

Summer-autumn nutritional influences on solid-food intake by calves also were considerable in both years. By mid-September, calves in the high nutrition group consumed 50–100% more than did calves in the medium and low treatment groups. Birth date also influenced intake through most of summer. Our calves began consuming solid food about 40 days after birth, as did those reported by Robbins et al. (1981). Late-born calves started consuming solid food 2–3 weeks later than did early-born calves, a difference about equal to the difference in birth date between the 2 groups.

Digestible energy requirements.—Our data identify general DE requirements for lactating cow elk and their calves during summer and autumn. Here, we emphasize cows because such estimates for calves were identified in a study focusing entirely on calves (Cook et al. 1996). All estimates we present are expressed on a daily, dry-matter basis.

Identifying requirements depends on prior identification of target performance levels and nutritional condition (e.g., see National Research Council 1984). Based on body fat levels, cows in the medium nutrition group were nearly able to maintain their condition across the summer-autumn period (Fig. 16A), and thus their DE level should provide a reasonable estimate of maintenance requirement. After mid-summer, DE was 2.65–2.75 kcal/g (about 60% in vitro digestible DM), and they consumed from 325–375 kcal of DE/kg BM$^{0.75}$/day or about 21,000 total kcal/elk/day (assuming BM of 235 kg), matching estimates calculated for maintenance using a factorial approach by Cook (2002) and those of Haigh and Hudson (1993). But if cows enter the summer period in substantially lower condition than ours did following winter, this level of DE (2.65–2.75 kcal/g) apparently is inadequate for recovery of fat and muscle catabolized during winter (Cook 2002) and will not provide adequate energy for rapid growth of calves during summer and autumn.

Our data for cows in the high nutrition group indicate DE of 2.9–3.0 kcal/g (about 65% in vitro digestibility) satisfies DE requirements to replace winter mass loss of 10%, support lactation, enter winter at ≥15% fat, and provide for rapid calf growth. Cows on this diet consumed 400–425 kcal of DE/kg BM$^{0.75}$/day, or about 25,000 total kcal/elk/day, slightly greater than that calculated by Cook (2002) for elk losing 10% BM over winter (i.e., 385 kcal of DE/kg BM$^{0.75}$/day and 23,000 kcal in mid-July). Declining intake by cows in the high nutrition group after early August in 1997 (Fig. 24) also suggests that slightly lower DE content (e.g., 2.85–2.90 kcal/g, ~63% in vitro digestibility) will support those fat levels we observed in the high nutrition group (although it might take slightly longer to achieve these levels). Digestible energy content ranging above 2.9 kcal/g through mid- to late summer and 2.65–2.7 kcal/g through mid-autumn also may permit equivalent fat accretion, because DE requirement for lactation wanes at this time (Robbins et al. 1981). But such a decline probably would reduce calf growth, and may preclude full recovery of winter mass loss if it is appreciably >10% (Cook 2002).

Only our highest DE level in this study (2.9–3.0 kcal/g) sustained growth approaching the highest levels reported for elk calves (e.g., Hudson and Adamczewski 1990, Cook et al. 1996). It agrees closely with that for the solid food component of diets consumed by elk calves calculated by Cook (2002). Calves in our study consumed 325–350 kcal of DE/kg BM$^{0.75}$ from solid food by the end of the experiments (early November). Cook et al. (1996) reported that rapidly growing calves required 350–370 kcal/kg BM$^{0.75}$ (from milk and solid food combined). The difference probably is accounted for by milk's contribution to DE intake (which we did not measure). Food DE levels required by calves to maintain rapid growth through early November begin to exceed that required by their lactating mothers after early September (assuming winter mass loss of cows is about 10%).

Calf growth ceased in the low and medium groups in mid-September and early October. Food DE levels of 2.3–2.6 kcal/g resulted in DE intake of 125–175 kcal/kg $BM^{0.75}$/day at this time. Cook et al. (1996) reported that calves stop growing at about 150 kcal of DE/kg $BM^{0.75}$.

Digestible energy needs of rapidly growing yearlings are as high as those for calves. Yearlings receiving diets averaging 3.2 kcal of DE/g of food consumed nearly as much dry matter per day (125–130 g/kg $BM^{0.75}$) as did lactating cows. Their DE intake averaged about 400 kcal/kg $BM^{0.75}$/day, slightly higher than that of calves (perhaps not if DE intake from milk were taken into account). This high level of DE intake supported daily growth of 0.75 kg/day and was similar to growth of calves in the high nutrition group (0.70 kg/day), from late May through late August. Hence, growth potential of yearlings and calves, and DE requirements to support this growth, was similar.

In the context of pregnancy probability, however, summer DE requirements of yearlings also probably depend on BM acquired before this summer period. If yearlings face mild to moderate winter conditions as calves, then summer DE requirements might be lower. However, if growth rate was moderate when these animals were calves, then mild winters probably would not reduce the need for forage of very high quality during summer when these animals are yearlings (and so on). Our data clearly show that if these animals face harsh winter conditions, then forage quality during summer and autumn of both the first and second year of life must be high (>2.9 kcal of DE/g) to provide for high rates of yearling pregnancy.

Carry-over Effects

Winter calf survival.—The carry-over effect of greatest initial interest to us was that of summer-autumn nutrition and birth date on the ability of calves to survive their first winter. The hypothesis that delayed breeding and birthing influences juvenile survival during winter assumes that larger body size at the start of winter appreciably enhances survival probability in winter. However, smaller animals might compensate by accumulating considerable fat reserves in autumn (partition less dietary energy for growth and more to accrue fat) and by reducing activity in winter (Verme and Ozoga 1980*a*).

In both winters, calf BM exerted the dominant effect on calf survival. Differences in the relation between starting BM and survival between the 2 years probably reflects differences in our winter feeding regimes. The nonlinear, or perhaps asymptotic relation, between survival and starting BM in the first winter (Fig. 30A) suggests a threshold, above which increasing BM provides little additional advantage. But this threshold is probably an artifact of the experiment's design. Substantially reducing feeding level after mid-winter increased rate of mass loss of the large calves still alive in late-winter (e.g., after 15 Feb, Fig. 31). This feeding regime probably accounts for the nonlinear relation of Fig. 32A as well. Without this reduction, most of the calves that were removed in the last several weeks probably would have "survived" the entire experiment, and probably would have continued to survive if the experiment had been conducted for several more weeks. The latter in particular would eliminate the nonlinear, or asymptotic nature of the first winter's data. In other words, the length of winter and timing and magnitude of negative energy balance over winter will determine the specific relation between BM and number of days that the animals survive. Nevertheless, our data demonstrate a considerable advantage of large body size for surviving harsh winters.

Varying the severity of winter nutritional restriction between winters, from gradually declining to abruptly declining (Table 3), provided some insight regarding how robust the body size-survival relation might be across different winter nutritional regimes. Through mid-January of the 1996 winter experiment, the lowest DE level fed was only about 30% below that normally considered maintenance (e.g., 180 kcal/kg $BM^{0.75}$, Cook 2002). Through the end of January, the largest calves in the study lost only about 5% of their BM and thus appeared resilient to this nutrition level. Yet BM of the smallest calves plummeted, and 5 were removed from the experiment by late January. Not until we reduced DE levels to half of maintenance (mid-Feb) did the larger calves begin to lose appreciable mass ($\geq$10% by late Feb). If the first winter experiment had been terminated in late February, and thus mimicked better winter forage conditions, 16 of 22 calves weighing <95 kg would have "died," whereas only 4 of 18 that were >95 kg would have "died."

With abruptly declining feeding regime in winter of 1997, calves were removed earlier, and starting BM accounted for less variance (38% versus 63%) in the number of days of winter survived, than in 1996. Nevertheless, our results from both winters indicated greater vulnerability of small calves than large calves to winter conditions over a wide range of simulated winter conditions. Although the nutritional conditions we imposed on these calves were extreme, overwinter mortality rates of ≥75% have been reported for elk calves (Houston 1982).

Why small calves are more vulnerable is not immediately clear, particularly in an experimental setting in which predation, competition for food, and other factors are eliminated or held constant. All calves received equal amount of food in relation to $BM^{0.75}$. Converting to a whole body basis ($BM^{1.0}$), smaller calves actually received more food per kg of mass than did large calves. Smaller calves may have less fat relative to total BM and may have relied more on protein, rather than fat, as a source of endogenous energy. Thus, they would have to catabolize body tissues at a faster rate to provide metabolic energy requirements than would larger calves, because catabolism of protein reaps less useable energy for metabolism than does fat. However, Verme and Ozoga (1980*a*) showed that smaller white-tailed deer fawns accrued substantial fat before winter, despite levels of under nutrition that effectively stunted growth.

Additionally, surface area relative to volume, and thus heat loss, increases with decreasing body size. Small calves on sub-maintenance diets, therefore, must catabolize more muscle and fat to maintain body temperature than do large calves, and this effect can be substantial (Parker and Robbins 1985). If this is an important cause of differences between small and large calves, then the susceptibility of small calves to winter conditions may be greater in areas appreciably colder or wetter than we encountered (see Cook et al. 1998 for a review of winter temperature and precipitation on western elk winter ranges). Greater difficulty traveling in snow, because of shorter stature, less ability to access and compete for food, and greater susceptibility to predation all might increase winter mortality of small calves in the wild relative to that observed in our study.

Although we found that calf BM at the start of winter significantly influenced winter survival, and birth date was significantly related to BM at the start of winter, we failed to find a significant relation between birth date and winter survival. Only summer-autumn nutrition was significantly related to winter survival. This result does not prove that birth date is unimportant. Rather, it demonstrates that the magnitude of differences in early winter BM resulting from a birth-date difference of about 3 weeks was insufficient to influence calf winter survival under the conditions we simulated. Our data should facilitate modeling calf survival under conditions of more delayed birthing and different nutritional regimes.

Winter cow survival.—This experiment provided an initial evaluation of the relative influence of body condition in autumn versus winter nutrition on winter survival of pregnant cows and their fetuses. The "high" winter nutrition treatment averaged 65% of maintenance and induced about 10% loss in BM (about 15% when adjusted for products of conception), which we assumed to be representative of mass loss of cows in "moderate to normal" winters. The low winter nutrition level ranged from 30–50% of maintenance from late December through early March and was intended to represent severe nutritional conditions during relatively harsh winters. By mid-February, the low nutrition level caused the death of 1 cow, and 3 others had to be removed prematurely (4 of 11 elk). On average, these cows depleted body fat at a rate of 0.83% of beginning fat daily, whereas cows in the high winter nutrition group lost fat at 0.5%/day. Cows in the high group ended winter with about 10% body fat, still in relatively good condition.

Overwinter performance also differed between cows fed medium and those fed high nutrition diets during summer and autumn. Reduced rate of fat loss of the thinner elk (the medium group) suggested some ability to conserve endogenous body reserves compared with the fatter cows. Nevertheless, body fat by late winter was significantly lower, and 2 of the 10 cows fed medium nutrition diets during summer were removed to prevent death. Further, these cows subsequently aborted despite intensive care and refeeding.

The abrupt decline in loin muscle thickness (Fig. 27D) of these cows also attests to the greater overwinter vulnerability of elk that enter winter in relatively poor nutritional condition. This decline was most evident in the 2 cows removed from the study, despite refeeding 1–2 weeks before the loin was measured. Rapid loin depletion is indicative of advanced catabolism of muscle tissue, and may result in death, perhaps via "mass organ failure" syndrome described by Saltz and White (1991) for mule deer.

Graphs of survival probability (Fig. 28) illustrate the interplay between winter nutrition and late-autumn condition. Under the harshest of our winter nutritional regimes, only cows with at least 15–17% body fat in late autumn had a 50% chance of surviving the winter. Cows entering winter with 7–8% body fat had virtually no chance of survival on this winter nutrition level and had only an 80% chance of survival on our highest winter nutrition level. Thus, vulnerability to nutritional deprivation in winter increases markedly as late-autumn fat levels decline. These results empirically demonstrate for elk what Hobbs (1989) modeled for mule deer.

Birth characteristics and gestation length.—A primary assumption of the hypothesis that skewed sex ratios (i.e., young bulls predominate in the herd) reduces calf survival is that differences in conception date do, in fact, cause similar differences in parturition date. But considerable variation has been reported for gestation length in elk (Taber et al. 1982, Haigh 2001), and the strength of the relation between breeding and parturition date, on which this hypothesis rests, may be weak. Differences in breeding date imposed in 1995 resulted in approximately equal differences in parturition dates of our cows the following spring. But over the next 2 years, the relation was diluted across winter. First, influences of nutrition and body condition on subsequent parturition date were significant only the second of the 2 years, despite being highly related to breeding date both years. Second, autumn condition accounted for 50% of the variation in breeding dates (Fig. 15), but only 14% of the variation in parturition date. Finally, breeding date in 1997 accounted for only 21% of the variation in parturition date the following spring for the 16 cows for which breeding date was known. Berger (1992) reported that late-breeding bison (*Bison bison*) in good condition shorten gestation by up to 15 days, evidently to synchronize births with other females. Our study did not rigorously test the assumption of a strong relation between conception date and parturition date, but our data nonetheless suggest caution regarding this key assumption.

Surprising was our finding that parturition date of the previous year had significant effects on current year's parturition date, gestation length, and birth mass (Fig. 33). This result seems spurious because parturition date did not affect subsequent breeding date and autumn cow condition. The significant relation between parturition date and subsequent gestation length (i.e., cows that gave birth earlier had shorter gestation lengths the following gestation period) possibly suggests a genetic component that would explain the significant relation between previous-year parturition date and current-year parturition date. We documented no carryover effects of summer-autumn nutrition or autumn condition on gestation length or birth mass the following spring.

Parturition date after the cow survival experiment of winter 1998 was correlated to extent of winter nutritional deprivation during this experiment (Fig. 35). Despite severely stressing cows in the low winter nutrition treatment, nutrition did not affect birth mass. These data therefore indicate elk have considerable ability to compensate for winter nutritional deprivation and produce calves with viable birth mass (mean of 15 kg, range of 13–17 kg in our case) by extending gestation length. Moderate extensions (≤15 days) in gestation to compensate for winter starvation were reported for white-tailed deer (Verme 1965, Johannesen 1984). Schwartz and Hundertmark (1993) reported that cow moose fed at 70% of ad libitum and losing 281 g/day in

BM over winter gave birth on average 27 days later than moose fed ad libitum through winter. This compares to about 34 days later on average for our cows that depleted the most fat (90%) overwinter (Fig. 35).

We expected to find evidence that summer-autumn nutrition and winter nutrition would influence birth mass the following spring. For example, Blaxter and Hamilton (1980) reported that, for every 10 kg increase in the mother's mass during the rut, red deer calves weighed 0.5 kg more at birth. However, Hudson et al. (1991) reported that birth mass of elk calves was unrelated to mass of their mothers the previous autumn. Schwartz and Hundertmark (1993) found, as we did, that birth mass of moose calves was unaffected by extent of winter undernutrition.

Nutrition and fat levels after the rut probably have greater influence on birth mass than fat levels during rut. Keech et al. (2000) reported that birth mass of moose calves was positively correlated to body fat levels of their mothers in late winter. Smith et al. (1997) reported temperature in December and January was positively correlated to birth mass of elk at the elk refuge in Jackson, Wyoming, USA. In cattle, Holland and Odde (1992) indicated that influences of nutritional restriction on birth mass remain unclear, but that fetal growth can be affected by severe energy deficiencies.

Additionally, there seems to be general agreement that nutrition during spring has a substantially greater influence on birth mass than does nutrition in winter (Clutton-Brock et al. 1982, Oldemeyer et al. 1993). Clutton-Brock et al. (1982), with red deer, and Smith et al. (1997), with elk, found that birth mass was positively correlated to ambient temperature in spring. Both indicated this was probably caused by effects of warmer temperature on growth of plants. Our decision to provide more than ample nutrition starting earlier (early to mid-March) than most wild herds typically may encounter (Cook 2002) may have masked any potential carryover effects of nutrition or nutritional condition the previous autumn.

MANAGEMENT IMPLICATIONS

Despite our findings of marked effects of summer-autumn nutrition on reproduction and survival, we did not directly test the hypothesis that forage conditions in summer and autumn do, in fact, exert strong limiting influences on free-ranging elk. The extent to which our findings are indeed relevant to management largely depend on how well our nutrition treatments represent the range of forage quality consumed by free-ranging elk. This caveat is particularly important for the low nutrition treatment because its effect was so debilitating. Cook (2002) summarized dietary DE estimates of free-ranging ungulates across much of the western U.S. and Canada (n = 20 studies). Deleting 3 extreme, possibly anomalous data sets, the studies reported ranges of 2.5–3.25 in early summer, 2.25–3.0 in mid-summer, 2.2–2.5 in late summer, 2.0–2.6 in mid-autumn, and 1.25–2.0 kcal/g in late autumn. If these studies provide reasonable estimates of actual diets for wild elk, then (1) the DE levels in our high nutrition group generally exceeded that of free-ranging elk by late summer, (2) our medium nutrition level generally mimicked the higher range of these estimates after mid-summer, and (3) our low nutrition level fell within these ranges by late summer. Thus, if we can assume that these studies collectively represent the range of summer-autumn nutrition of wild elk, we can conclude that all 3 of our summer-autumn nutritional treatments are relevant to wild elk during summer and autumn, at least in the areas reviewed by Cook (2002). It follows that forage quality on some elk summer ranges is inadequate to support rapid growth of calves and subadults or high levels of fat accretion in adults. These in turn may elevate mortality, delay onset of puberty, and induce occasional reproductive pauses.

Nutrition's influence, and particularly the relative importance of nutrition in summer versus that in winter, undoubtedly varies among ecological settings. Years ago, Verme (1969) proposed a classification system that reflected the differential role of nutrition on population demographics among regions for deer in the upper Midwestern U.S. Across the western U.S., plant community composition and plant phenology vary greatly as a function of climate, soils, and topography. Nutrition's influence undoubtedly varies as a result. Trainer (1971) noted significant differences in fat levels and herd productivity between coastal-Cascade environments and those of inland Oregon. Bomar (2000) reported that broad-scale patterns of recruitment in elk herds in Idaho were significantly related to patterns of climate and vegetative dynamics. Both concluded that nutrition probably was a fundamental mechanism linking biophysical attributes and elk population dynamics. Within a given ecological setting, nutrition's influence probably varies as a function of (1) large-scale changes in habitat that appreciably alter forage abundance and quality, such as from timber harvest (Hett et al. 1978, Gill et al. 1996, Cook 2002) or fire, and (2) herbivore density, because the balance between nutrient demand and nutrient availability is altered as density changes (Fowler 1987).

The key role of habitat for wildlife has long been recognized. But in the case of elk, nutrition's influence on population dynamics has been infrequently studied. Instead, habitat's influences have been examined mainly via radiotelemetry studies of habitat selection. As typically conducted, these studies are fundamentally incapable of accounting for influences of nutrition, or those of other potentially limiting habitat factors, on reproduction, survival, and carrying capacity. Without attendant data on limiting factors, some of the inferences derived from telemetry studies are being questioned (Hobbs and Hanley 1990, Morrison 2001). Probably as a consequence of habitat selection studies, most models developed for large-scale evaluation of habitat suitability for elk largely ignored nutrition or concentrated on variables that simply index forage supply without regard to forage quality (Edge et al. 1990, Cook et al. 1998).

One value of our research is to provide standards of performance with which to gauge the likelihood of nutritional limitation in natural settings (Table 9). Much of our criteria pertain to performance of pregnant or lactating cows. Our data (Fig. 16) indicated that estimates of body condition and breeding performance of nonlactating cows provide less inference of summer-autumn nutritional limitations. These data also illustrate an issue discussed by Verme and Ullrey (1984): as nutritional limitations increase and juvenile survival declines,

Table 9. Estimated levels of performance expected for elk in temperate ecosystems as a function of dietary digestible energy (DE) from mid-summer through mid-autumn[a]. Animal performance estimates are based on late-October and November measurements. For adults, we assume prime-age, roughly 3–12 years old. Adult cow fat levels pertain only to those that lactated over most of summer and autumn; our data indicate nonlactating cows will be fatter than lactating cows, particularly at the lower levels of DE.

Sum–aut nutritional status[b]	Dietary DE (kcal/g of food)[c]	Calf mass (kg)	Yearling cow mass (kg)[d]	Lactating adult cow fat (%)	Yearling pregnancy (%)	Adult pregnancy (%)	Adult cow breeding date
Excellent	>2.90	125 to 145	195 to 230	16 to 25[e]	≥90	≥90	≤30 Sep
Good	2.75 to 2.90	105 to 125	180 to 195	12 to 16	30 to 90	≥90	≤5 Oct
Marginal	2.40 to 2.75	90 to 105	160 to 180	8 to 12	0 to 30	≥70	≤10 Oct
Poor	<2.40	<90	<160	<8	<5	<70	>10 Oct

[a] Relations between nutrition and performance indicated here assume that direct extrapolation from captive to wild settings is reasonable and that the relations are robust across at least moderate variations in winter severity. Thus, these relations are preliminary and should be updated as per findings of additional research. These criteria were developed based on performance of individual elk; some mistakes may result if herd averages are applied to these criteria. For example, if mean fat of lactating cows in a herd in autumn is 14%, this table would predict pregnancy of this herd to be ≥90% and breeding to occur <5 Oct. However, if fat for this herd ranges from 7–20%, then predicted pregnancy rate may be <90% and some cows may bred >5 Oct. Thus, predicting pregnancy and breeding date should be based on fat levels of individuals, rather than on herd averages. Equations of Fig. 14 and 15 and Table 7 provide a means to do so.

[b] "Excellent" summer-autumn nutritional status refers to settings in which there are virtually no nutritional limitations in summer and autumn; therefore, these performance levels approximate the maximum for elk. "Good" is defined as summer-autumn nutrition levels that exert minor limitations on performance, but the magnitude of this effect probably is too small to be of practical relevance. "Marginal" pertains to nutrition levels that may influence reproduction or survival (e.g., enhanced probability of death in winter, delayed breeding, delayed puberty). "Poor" pertains to nutrition levels that markedly affect reproduction and reduce survival probability.

[c] These estimates of DE reflect requirements of captive existence. Energy expenditure of wild elk may be greater, and thus these DE levels should be considered minimum requirements for each level of performance.

[d] Based on our post-rut (Nov) body mass measurements.

[e] The higher levels (>22%) were observed in nonlactating cows.

pregnancy rates tend to remain high because an increasingly large proportion of females escape the nutritional demands of lactation. This may be particularly important where predation on juveniles in summer after birth is relatively high. Thus, high pregnancy rates do not necessarily indicate sufficient nutrition for the complete reproduction cycle (Verme and Ullrey 1984). Conversely, pregnancy rates of prime-aged cows with calves at heel below about 85% probably indicate important summer-autumn nutritional limitations. Similarly, we predict that overall fat levels might be greater in herds experiencing high levels of juvenile mortality in summer than in herds without high juvenile mortality, even if nutrition in both situations is identical. Such an effect might confound comparison of fat levels (Table 9) among herds that experience markedly different levels of juvenile mortality in summer or early autumn.

Our data also provide monitoring standards regarding evaluation of forage and dietary quality (Table 9). Our study adds to the growing body of literature (e.g., see Holter and Hayes 1977, Verme and Ozoga 1980*b*, Lyford and Hubert 1988, Cook et al. 1996, Parker et al. 1999) that indicates energy, at least as much as protein, should be emphasized in studies of forage and dietary quality. But our finding that seemingly small differences in DE content of forage have large effects on the performance of elk suggests some cautions. First, the ability of herbivores to select diets significantly greater in quality than generally available limits the value of general forage quality surveys, except perhaps for relative comparisons across space or time. Dietary quality evaluations that employ direct observations of food selection (Schwartz and Hobbs 1985) provide more reliable data. Second, field and laboratory techniques that cause even a small bias of estimated DE in forage (just 10%) might lead to important misinterpretations of nutritional adequacy. Finally, wild elk may have greater energy demands attributable to free-ranging existence compared to our cows. If so, then our estimates of DE requirements might be conservative.

In our study, influences of parturition date, where they occurred, were relatively minor. Our average difference in parturition date was 24 days in 1996 and 19 days in 1997, and we conclude that influences on breeding date that result in differences in parturition date of 3 weeks or less (Noyes et al. 1996) probably will not have much effect on nutritional condition and pregnancy rates of cows and growth and winter survival of calves. Therefore, productivity of populations probably will be little affected even if the preponderance of breeding is by yearling bulls. In a study of 3 Rocky Mountain elk populations in Washington where calf:cow ratios were declining and mature bull:cow ratios were low (<1.5 branched-antlered bulls:100 cows), Bender et al. (2003) reported that the increasing bull and branched-antlered bull ratios, resulting from changes in bull harvest strategies, failed to influence calf recruitment.

We mention 2 caveats, however. First, a span in parturition date greater than 3 weeks probably would increase parturition date's effect on reproduction and survival. Late breeding caused by either poor nutrition or few mature bulls, harsh winter weather that extends gestation, and late vegetative growth in spring present accumulating stresses that may greatly delay parturition, perhaps sufficiently to reduce reproduction and survival of calves. Second, our study precluded influences of other mortality factors, especially predation, that might interact with parturition date to influence survival. Clutton-Brock et al. (1982) reported that unusually early or late parturition reduces survival over the first several months of life. In predator-rich environments, the classical perception is that juveniles born during the peak period of parturition are less susceptible to predation, because of a "swamping" effect. The more synchronous the parturition period, the greater the degree of swamping. From a nutrition and growth perspective, the earlier the birth the better (to a point, of course), and so the 2 perspectives are not necessarily congruent. Keech et al. (2000) argued for moose in Alaska that the latter is of greater relevance even in predator-rich environments. Findings of other studies that focused on the effect of birth date on juvenile survival are mixed, further clouding the issue. Fairbanks (1993) reported birth date did not influence survival of pronghorn (*Antilocapra americana*) fawns. Guinness et al. (1978*b*) reported marked increases of mortality during summer and winter for red deer calves born very late (as late as August), but otherwise noted little effect of birth date on calf mortality. Singer et al. (1997) reported that birth date of elk calves in Yellowstone was unrelated to mortality from predation in summer ($P = 0.146$), was marginally related to mortality from all causes in summer ($P = 0.066$) and in winter ($P = 0.065$), and that birth mass had greater influences on survival than did birth date. We suspect that the magnitude of differences in birth date and differences in causes of mortality may account for different results among studies.

Our study implicates, but provides no direct proof of nutrition's contribution to declines of elk herds. Nor did it provide insights regarding the changing role of nutrition, i.e., if nutrition was adequate to support the growth of herds over most of the past century, why has it become inadequate in recent years? Density-dependence, an oft-cited mechanism of bottom-up population regulation (Fowler 1987), provides one explanation. Recent population declines following many years of growth support this concept, and evidence indicates increasing influences by elk populations on vegetative composition and successional trajectories (Kay 1995, Riggs et al. 2000) on summer-autumn ranges. Herbivore-induced changes in the value of the forage base over time could cause density-dependent feedbacks to be manifest over time at sequentially lower herbivore densities (Irwin et al. 1994, Riggs et al. 2000). Advancing plant succession that increases overstory canopy cover and decreases understory vegetation may have important effects on carrying capacity (Hett et al. 1978, Peek et al. 2001) and herd productivity (Gill et al. 1996), and has been implicated as a cause of declining ungulate herds in the Pacific Northwest (Bomar 2000, Peek et al. 2002). Interactions between herbivore density and episodic disturbance regimes (e.g., fire, logging) probably modify the influence of chronic herbivory on vegetative trajectories and stable states, and thus on herbivore carrying capacity over time (Riggs et al. 2000).

At the same time, cougars (*Puma concolor*) (e.g., Keister and Van Dyke 2002) and bears (*Ursus americana*), large predators capable of killing elk, apparently are increasing in the Northwest. Thus, the issue of how to manage elk productivity is developing into a classic top-down versus bottom-up controversy, as it has already regarding declines in western deer herds (Carpenter 1998). Such either-or explanations are likely to be unrealistically simplistic in most situations, particularly over the long term. Our data implicate a chronic nature of nutritional influence that in turn suggests an additive or interactive relation between nutrition and predation. Whereas reductions in predation rates may elevate herd productivity, particularly in the short-term, long-term vegetative trajectories and attendant density-dependent thresholds are more likely to function as ultimate limiting factors.

Considerably more knowledge is needed regarding influences of habitat, nutrition, and predation/hunting effects on ungulate populations. Nutrition is the habitat feature most likely to have a predominant influence on reproduction, survival, and thus population demographics (Cook et al. 1998). If nutrition's influences are to be understood, conventional studies of habitat selection must be augmented with innovative and rigorous designs that explicitly examine contributions of limiting resources. Referring to wildlife-habitat studies, Morrison (2001) observed that "We seem to be stuck in a revolving framework of endless site- and time-specific studies," and as a result, "our understanding of the causes of distribution, abundance, and performance are not advancing." Similarly, simple predation studies may document the occurrence of predation, but in many cases provide insufficient information to conclude predation's effect as a regulating or limiting factor. At least such studies should examine the effects of multiple regulating and interacting factors. Our study demonstrates that nutrition during summer and autumn is a key factor that should no longer be dismissed as inconsequential.

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CLEARWATER RIVER- SPRING/SUMMER CHINOOK SALMON HATCHERY PROGRAM REVIEW

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Introduction and background

The Clearwater River Chinook Salmon hatchery program funded through the Lower Snake River Compensation Plan (LSRCP) was established to provide mitigation for losses of spring/summer Chinook Salmon associated with the construction and operation of the four lower Snake River hydroelectric dams (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor). Hatchery production funded by LSRPC in the Clearwater River basin includes fish reared at Clearwater Fish Hatchery, Dworshak National Fish Hatchery, and Nez Perce Tribal Hatchery. Additional juvenile spring Chinook Salmon hatchery production in the Clearwater basin is funded through the Bonneville Power Administration's (BPA) Fish and Wildlife Program at Nez Perce Tribal Hatchery and through the US Fish and Wildlife Service (USWFS) at Kooskia National Fish Hatchery (Figure 1, Table 1). Clearwater Fish Hatchery is operated by the Idaho Department of Fish and Game (IDFG). The Dworshak, Kooskia, and Nez Perce Tribal facilities are all operated by the Nez Perce Tribe (NPT).

Table 1. Rearing facilities, funding source, and juvenile production targets for the spring and summer Chinook Salmon in the Clearwater River basin.

Rearing Facility	Funding Source	Juvenile Lifestage at Release	2010 Juvenile Release Target	Current Juvenile Release Target
Clearwater Fish Hatchery	LSRCP	Smolt	2,835,000	3,749,000
Dworshak NFH	LSRCP	Smolt	1,050,000	1,650,000
Nez Perce Tribal Hatchery	LSRCP	Smolt	0	400,000
Nez Perce Tribal Hatchery	BPA	Smolt	0	200,000
Nez Perce Tribal Hatchery	BPA	Parr and Pre-Smolt	625,000	225,000
Kooskia National Fish Hatchery	USFWS	Smolt	600,000	650,000

Total Juvenile Releases	**5,110,000**	**6,874,000**
Total LSRCP Funded Releases	**3,885,000**	**5,799,000**

Since the last Independent Scientific Review Panel (ISRP) program review in 2010, there has been a concerted effort among co-managers in the Clearwater River basin to operate all hatchery facilities in a more coordinated manner as more of a hatchery complex rather than as individual programs which is consistent with the programmatic recommendations from the Hatchery Scientific Review Group (HSRG) in 2009. These facilities include Nez Perce Tribal Hatchery, Dworshak National Fish Hatchery, Clearwater Fish Hatchery, and Kooskia National Fish Hatchery. This has resulted in a more effective and efficient use of trapping, spawning, and rearing capacity in the Clearwater basin and has allowed managers to increase the number of juveniles produced annually from 5,110,000 in 2010 to 6,874,000 currently (Table 1).

This high level of coordination between facilities and co-managers is maintained primarily through the development of Annual Operating Plans (AOPs) and weekly coordination calls (i.e., Webinars) that occur from April-November. The AOPs establish plans for hatchery operations and highlight any anticipated deviations from normal operations. All normal operations are captured in a Standard Operating Procedures (SOP) document that is reviewed annually. The weekly conference calls are used to track and update the adult returns (via PIT tags) for estimating allowable harvest shares for the tribal and non-tribal fisheries and to develop contingency plans if it appears we will not have sufficient adult returns at some or all trapping facilities to meet production targets. This process helps to maximize the beneficial use of adult Chinook Salmon that are in excess of broodstock needs, ensure that enough adults are trapped and spawned to meet production targets at all facilities in the Clearwater basin, and ensure a timely and coordinated response for unanticipated events or conditions.

While it is somewhat difficult to decouple all operations within the highly coordinated efforts that occur in the Clearwater program, this report, to the extent practicable, only includes information specific to the component of the program that occurs at Clearwater Fish Hatchery and its satellite facilities

The Clearwater Fish Hatchery and satellite facilities are operated by IDFG, and all production at Clearwater Fish Hatchery is funded by LSRCP. Infrastructure includes a rearing hatchery and three satellite facilities. The Clearwater Fish Hatchery is the rearing facility and is located on the North Fork Clearwater River in Ahsahka, Idaho. Construction of this facility was completed in 1992. The Powell satellite facility is located on the upper Lochsa River and was completed in 1989. It is used for adult trapping and spawning. All eggs from this facility are transferred to CFH for incubation and final rearing. The Red River satellite facility is located on Red River, a tributary to South Fork Clearwater River and was completed in 1976 as part of the Columbia River Fisheries Development Program and was updated in 1986 as part of the LSRCP mitigation program. This facility is used for trapping and temporary holding of adults. All adults trapped and held for broodstock are transferred to CFH for spawning, incubation and final rearing. The Crooked River satellite facility is located on Crooked River in the South Fork Clearwater River drainage and was completed in 1989. Historically this facility was used to trap adults associated with a juvenile release that occurred near the adult trap in Crooked River. This juvenile release was discontinued in 2013 due to poor conversion rates of returning adults back to the trapping facility. Facility locations for the hatchery and three satellite facilities are displayed in Figure 1.

The LSRCP adult mitigation goal for the Clearwater Fish Hatchery is 11,915 adult Chinook Salmon above the Project Area (Lower Granite Dam) and 47,660 adults available for downriver (Columbia and lower Snake rivers) harvest. The original smolt release target of 1.37 million yearling smolts was based on an assumed smolt-to-adult survival rate (SAR) of 0.87% back to the project area and a smolt-to-adult survival rate (SAS) of 4.35% back to the Columbia River mouth (Table 2).

Table 2. Adult return goals for LSRCP funded Chinook Salmon reared at Clearwater Fish Hatchery.

Run	Project Area Goal	Downstream of Project Area Goal	Total Adult Goal
Spring	9,882	39,528	49,410
Summer	2,033	8,132	10,165
Total	**11,915**	**47,660**	**59,575**

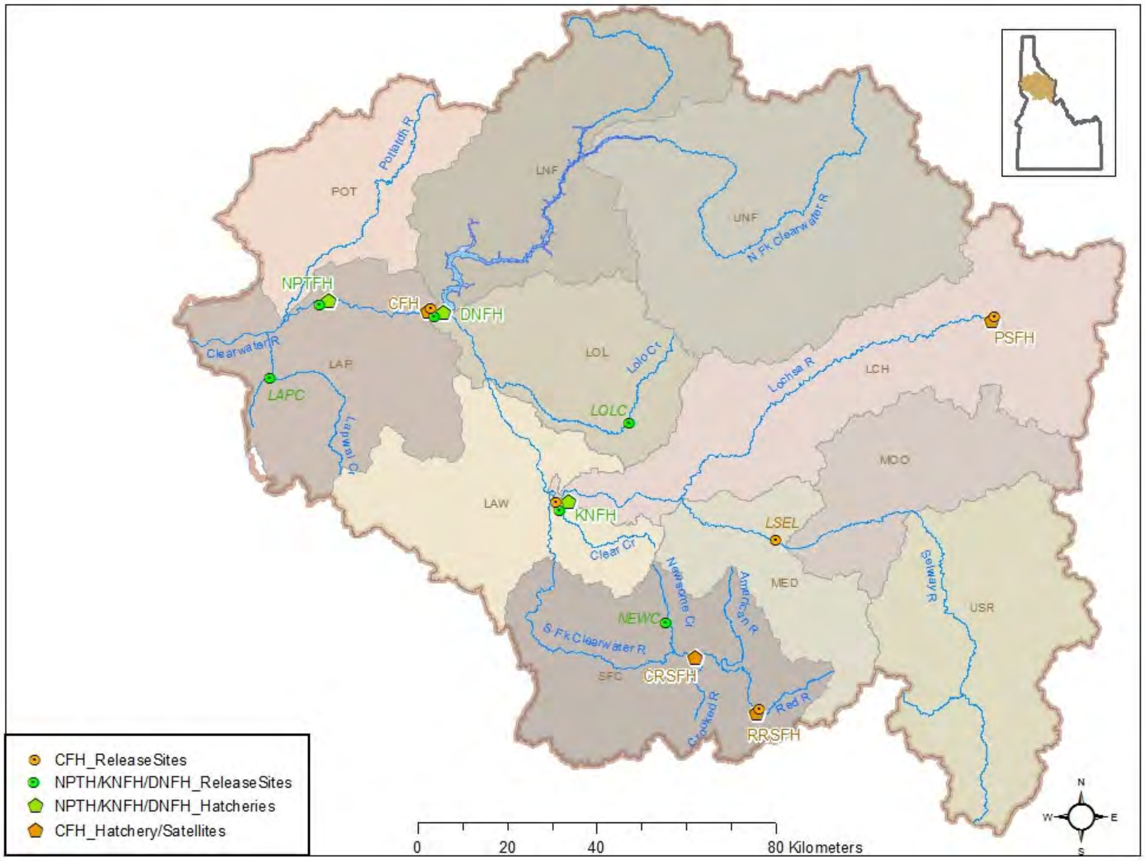

Figure 1. Map of the Clearwater River drainage and locations of fish hatchery facilities and juvenile release sites for spring/summer Chinook Salmon. Orange colored location markers are associated with Clearwater Fish Hatchery. Green markers are associated with The Nez Perce Tribal Hatchery, Dworshak National Fish Hatchery, and Kooskia National Fish Hatchery.

Production changes since last ISRP review

Since the last ISRP review, the total production target across all facilities for spring/summer Chinook Salmon juveniles increased from 5.11M to 6.87M in the Clearwater basin (Table 1). Production funded through the LSRCP program increased from 3.89M to 5.8M juveniles. Production at Clearwater Fish Hatchery increased from 2.84M in 2010 to 3.75M currently. This additional production is intended to help meet the LSRCP adult mitigation objective.

In addition to the spring Chinook Salmon hatchery mitigation that occurs in the Clearwater, in 2009 managers initiated the development of a summer-run Chinook Salmon program in the Clearwater basin. Historic run timing data collected while the Lewiston Dam was in operation indicated that some fish exhibited more of summer Chinook Salmon run timing. That coupled with a desire by mangers to provide additional fishing opportunity and diversity led to initiating the summer program. The initial smolt release target was set at 200,00 yearling smolts and has since increased to 640,000.

Current smolt production targets for Clearwater Fish Hatchery includes 3.11M spring Chinook Salmon and 640K summer Chinook Salmon (Table 3). Releases occur at five locations throughout the Clearwater basin with the intent to provide a diversity of fishing opportunities for both tribal and non-tribal fisheries (Figure 1).

Table 3. Smolt production targets and release locations for Clearwater Fish Hatchery spring and summer Chinook Salmon. All releases are yearling smolts.

Run	Release Site	Target Release Number
Spring	N.Fk. Clearwater River	709,000
Spring	Red River	1,280,000
Spring	Clear Creek	720,000
Spring	Selway River	400,000
Summer	Powell	640,000
Total		**3,749,000**

ESA status and consultation history

Natural populations of spring Chinook Salmon in the Clearwater River were extirpated and current natural spring Chinook Salmon are not part of the listed Snake River ESU.

Through consultation with NOAA fisheries and the USFWS, two Biological Opinions (WCR-2017-7303; 01EIFW00-2017-F-1143) were completed in 2017 that established take limitations for ESA listed species (including spring/summer Chinook Salmon, fall Chinook Salmon, steelhead, and Bull Trout) that are impacted by operation of the spring/summer Chinook Salmon hatcheries in the Clearwater basin. The non-tribal fishery is operated in accordance with IDFG's Fishery Management and Evaluation Plan (IDFG 2011).

Broodstock history

Spring Chinook Salmon

The construction and operation of the Lewiston Dam from 1927 to 1973 on the Clearwater River, four miles upstream of the mouth, led to the extirpation of natural populations of Chinook Salmon in the Clearwater basin. Lewiston Dam was removed in 1973. Reintroduction efforts began in the 1950's and ramped up in the 1970's. These reintroductions consisted primarily of Rapid River stock but also included some Dworshak, Kooskia, Middle Fork Salmon R., Carson, and Leavenworth stocks. Since the early 1990's, the majority of brood have been collected from Clearwater basin adult returns. Returns of spring Chinook Salmon adults to all trapping locations (NPTH, N.F. Clearwater R., Clear Cr., Red R., and Crooked R.) in the Clearwater basin are managed as a single stock. Adult returns to each trapping location are prioritized for the juvenile releases at those locations to take advantage of any local adaptation that may occur. However, in years when there are not enough returns to meet juvenile production targets at particular release locations, backfilling occurs from other trapping locations within the Clearwater basin and may also include fish from Rapid River Fish Hatchery. During the 1990s, the average percent of the broodstock for fish reared at Clearwater Fish Hatchery was 65%

from locally returning adults to the Clearwater basin with Rapid River making up the difference (Figure 2). Since 2000, the average broodstock composition has been 94% local returns to the Clearwater basin. In 2018 and 2019, production in the Clearwater basin included eggs from spring Chinook Salmon collected at Little White Salmon Fish Hatchery. For those two years, juveniles from the Little White Salmon were released into the Selway River where they are not expected to contribute to future brood collections. It is noteworthy that the present stock of spring Chinook Salmon at Little White Salmon FH is considered a derivative of Carson Stock (Little White Salmon HGMP, 2002). The Carson Fish Hatchery spring Chinook Salmon broodstock was founded from adult collections at Bonneville Dam from 1955-1964 and was believed to be a mixture of Snake River and upper Columbia River stocks (Carson FH HGMP, 2004).

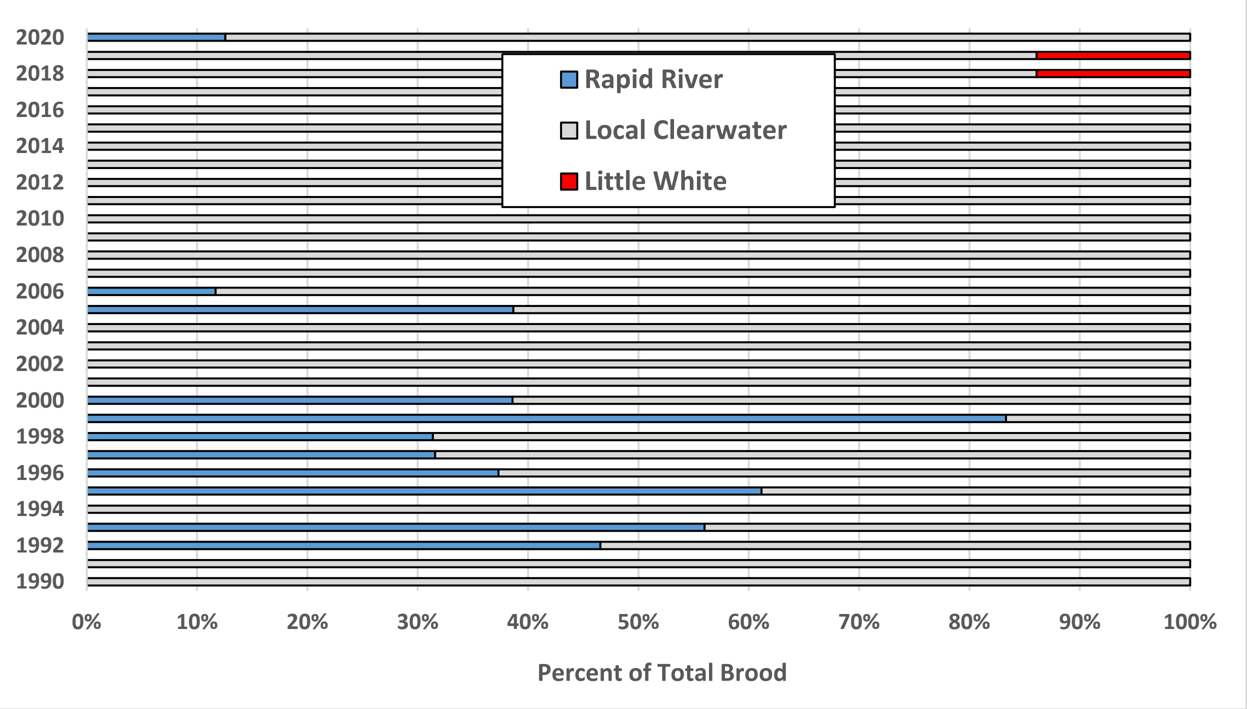

Figure 2. Broodstock composition of spring Chinook Salmon reared at Clearwater Fish Hatchery for brood years 1990-2020.

Summer Chinook Salmon

The summer-run hatchery program in the Clearwater basin was initiated in 2009 with the first juvenile releases occurring in 2011. Broodstock for this program was founded from hatchery-origin adults returning to the South Fork Salmon River (SFSR) that were in excess of brood needs for the South Fork program. The first locally returning summer-run adults in the Clearwater River occurred in 2013. Since then, locally returning summer run adults to the Clearwater Basin have been prioritized for brood but when returns are insufficient to meet production targets, adults from the SFSR are used to make up the shortage, when available. The composition (local vs. SFSR) of the summer brood has varied but since brood year 2014 has been composed of 74% from locally returning Clearwater adults (Figure 3).

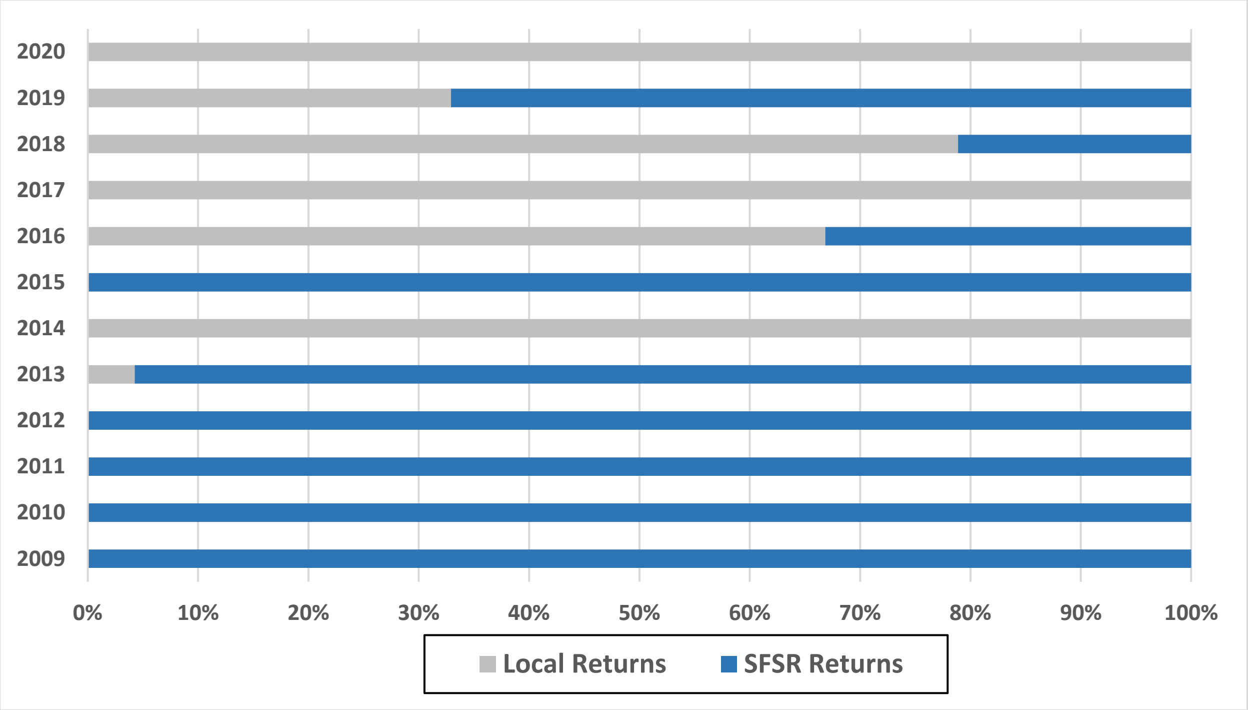

Figure 3. Broodstock composition of summer Chinook Salmon reared at Clearwater Fish Hatchery for brood years 2009-2020.

Broodstock goals

Broodstock collection targets are established annually through the AOP process for all facilities. A "Broodstock Calculator" is used to calculate the number of adults to be trapped and spawned based on a five-year running average of survival metrics (i.e. adult pre-spawn mortality, fecundity, eye-up rate, and eye-release survival). Current broodstock targets for the Clearwater Fish Hatchery include trapping 2,165 spring Chinook Salmon adults and 432 summer Chinook Salmon adults. All spring and summer Chinook hatchery production in the Clearwater basin utilize segregated hatchery broodstocks.

Management and monitoring and evaluation objectives

Management Objectives for the Clearwater River Chinook Salmon hatchery program are to meet the LSRCP adult mitigation objectives, to restore and maintain tribal and non-tribal fisheries in the Clearwater River basin, and reduce impacts of the hatchery program on the natural Chinook Salmon production in the Clearwater River.

The hatchery population in the Clearwater River basin is managed in a manner that reduces risk to the natural populations, and hatchery smolt release sites have been selected to allow for sanctuary areas which reduce hatchery and natural fish interactions. IDFG's Fisheries Management Plan (IDFG 2019) specifies tributary habitats within the Clearwater basin that are prioritized for natural Chinook Salmon conservation. Consequently, hatchery smolt release sites are located in mainstem habitats with trapping facilities to capture returning adults with the exception of the Selway River release where there is no trapping site and supplementation is intentional. IDFG will continue to work cooperatively in the

Clearwater basin to improve habitat quality and monitor productivity of natural Chinook Salmon populations while reducing impacts of the hatchery program.

Monitoring and evaluation (M&E) objectives for the Clearwater River program include monitoring production, productivity, and life history characteristics of the hatchery and natural populations and to evaluate broodstock and rearing strategies to increase and maximize adult returns. M&E activities in the Clearwater R. basin are a cooperative effort between the Idaho Department of Fish and Game (IDFG), the Nez Perce Tribe (NPT), and the U.S. Fish and Wildlife Service. The monitoring and evaluation of the natural population consists of a comprehensive fish-in, fish-out monitoring program that follows fish from the cradle to the grave via sampling at screw traps, snorkel surveys, and spawning ground surveys in addition to juvenile and adult sampling at Lower Granite Dam. For IDFG, monitoring of natural populations in the Clearwater basin is funded through the BPA Fish and Wildlife program under project 1990-055-00.

In-Hatchery and Post-Release Performance

Adult pre-spawning mortality

Average pre-spawn mortality rates for male and female spring Chinook Salmon at Clearwater Fish Hatchery are generally low, with most years recorded at <10% (Figure 4). The exception was for brood year 2007, when 17% of adults died as part of an accidental fish kill. The most recent 10-year mean is 4% and over the entire time series is 6%. Summer Chinook Salmon pre-spawn mortality rates varied widely between years. Between 2009 and 2013, summer Chinook Salmon brood for Clearwater Hatchery was sourced exclusively from the SFSR fish trap which experienced several years of unusually high pre-spawn mortality and is described more thoroughly in the report for the SFSR program. The average pre-spawn mortality rate for brood years from 2009-2020 is 8% and since 2013 is 2%.

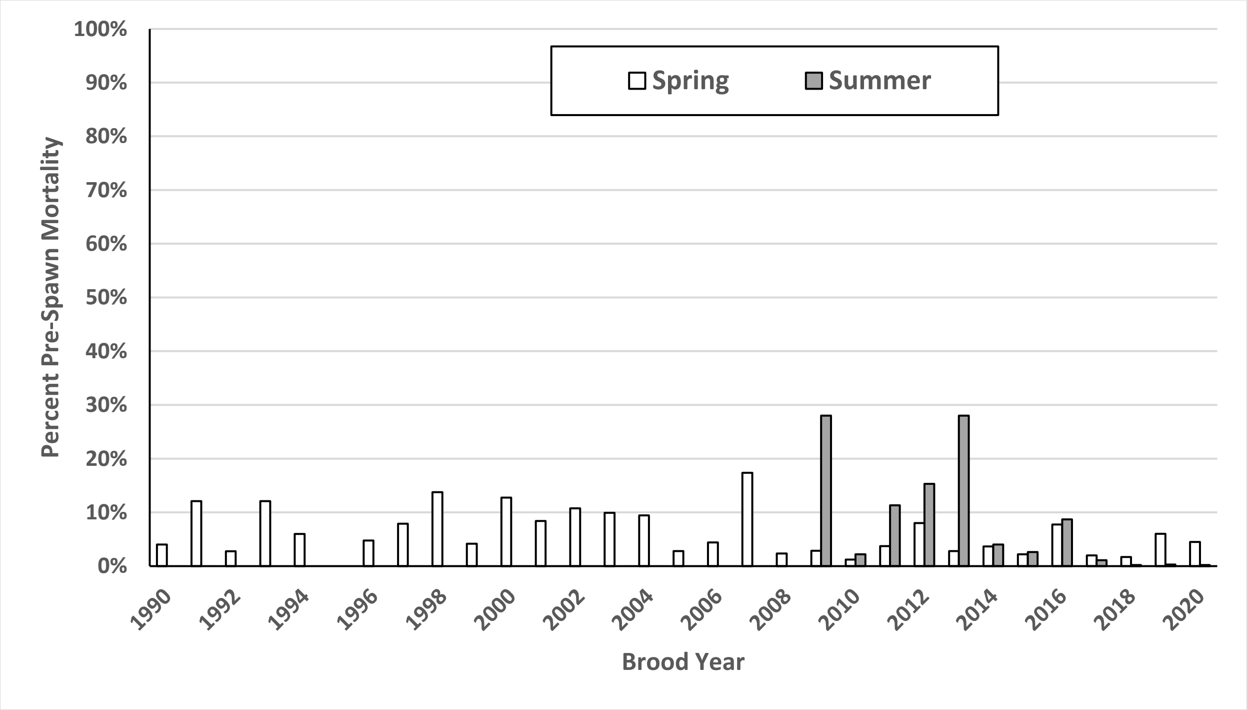

Figure 4. Pre-spawn mortality rate of spring and summer Chinook Salmon at Clearwater Fish Hatchery, 1990-2020.

Egg to smolt survival

Average survival from eyed-egg to release at Clearwater Fish Hatchery for spring Chinook Salmon is 85% over the entire time series and 86% for the most recent 10 years (Figure 5). For summer Chinook Salmon, the average survival for brood years 2009-2020 is 82%.

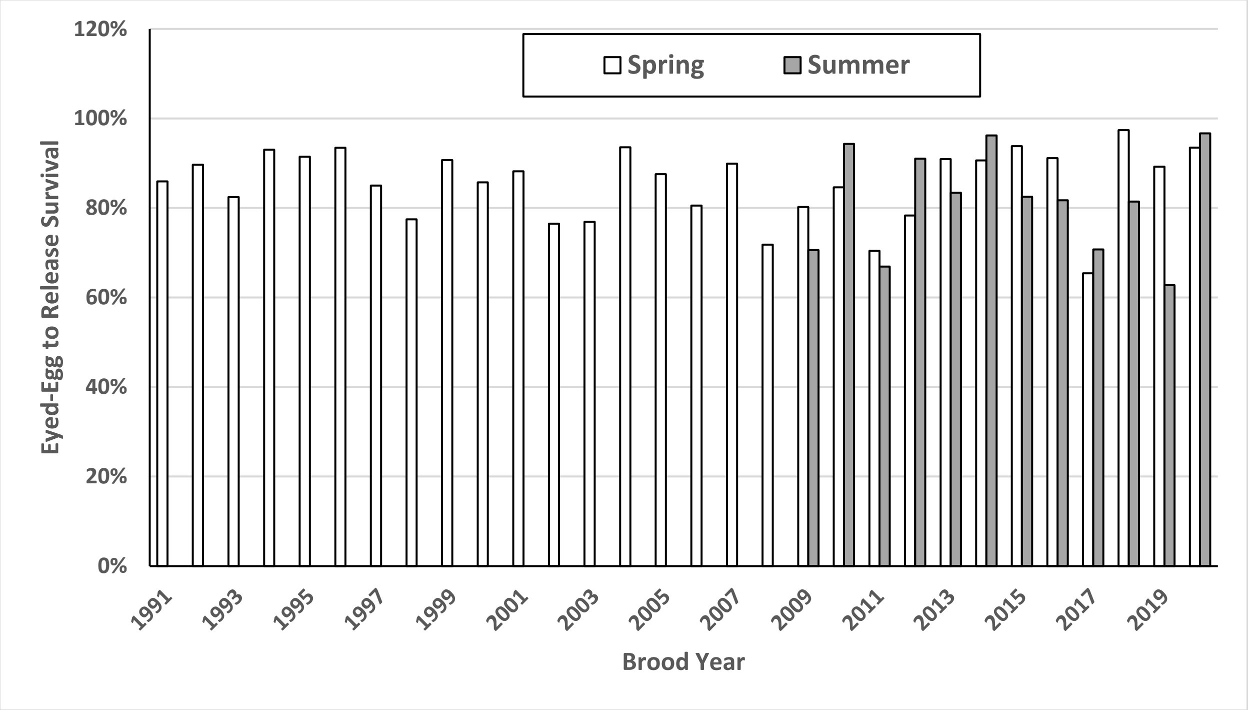

Figure 5. Eyed egg to release survival of Clearwater Fish Hatchery spring (1991-2020) and summer Chinook Salmon smolts, 2009-2020.

Juvenile releases

Production targets for juvenile releases of spring and summer Chinook Salmon from Clearwater Fish Hatchery have increased incrementally over the last twenty years in an effort to achieve the adult mitigation goals (Figure 6). Likewise, due to the relatively poor post-release performance of sub-yearling releases, all sub-yearling releases were phased out and since brood year 2012, all production at Clearwater Fish Hatchery has been composed of yearling smolt releases (Figure 7). Early in the Clearwater Fish Hatchery program, release targets were routinely underachieved due to low adult returns. Since 2000, juvenile release targets have largely been met (Figure 6).

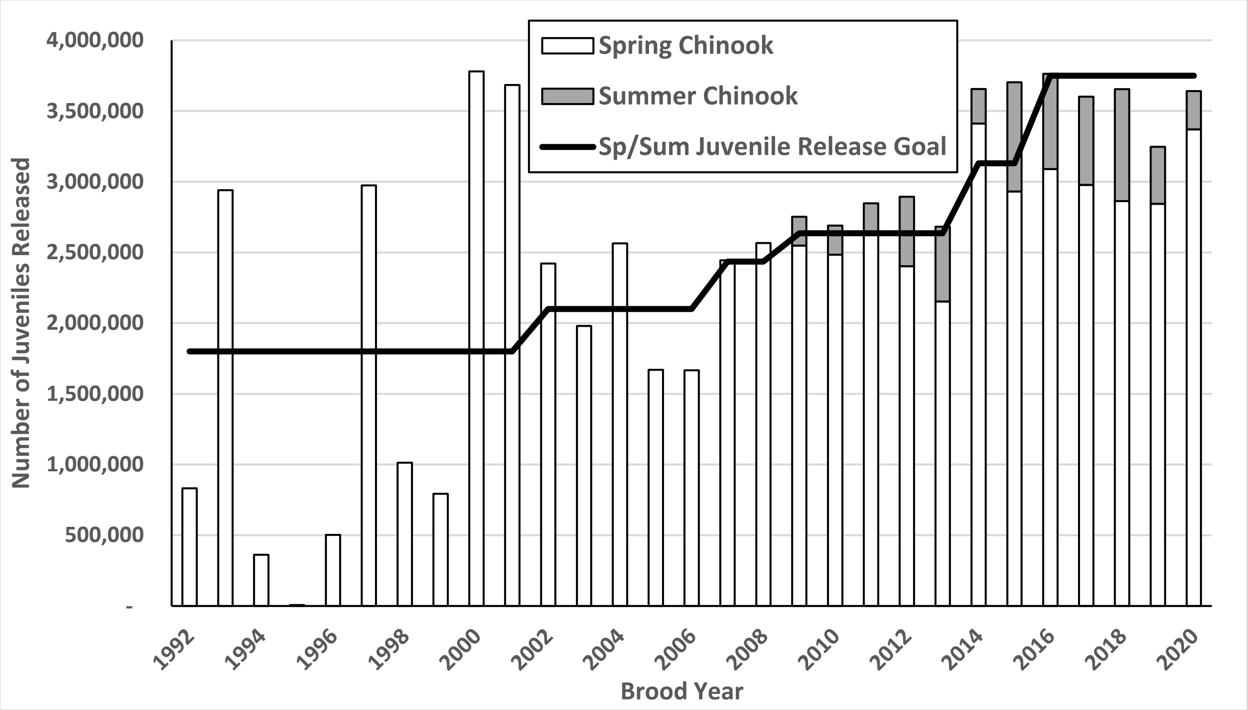

Figure 6. Release target and actual number of juvenile spring and summer Chinook Salmon released from Clearwater Fish Hatchery, 1992-2020.

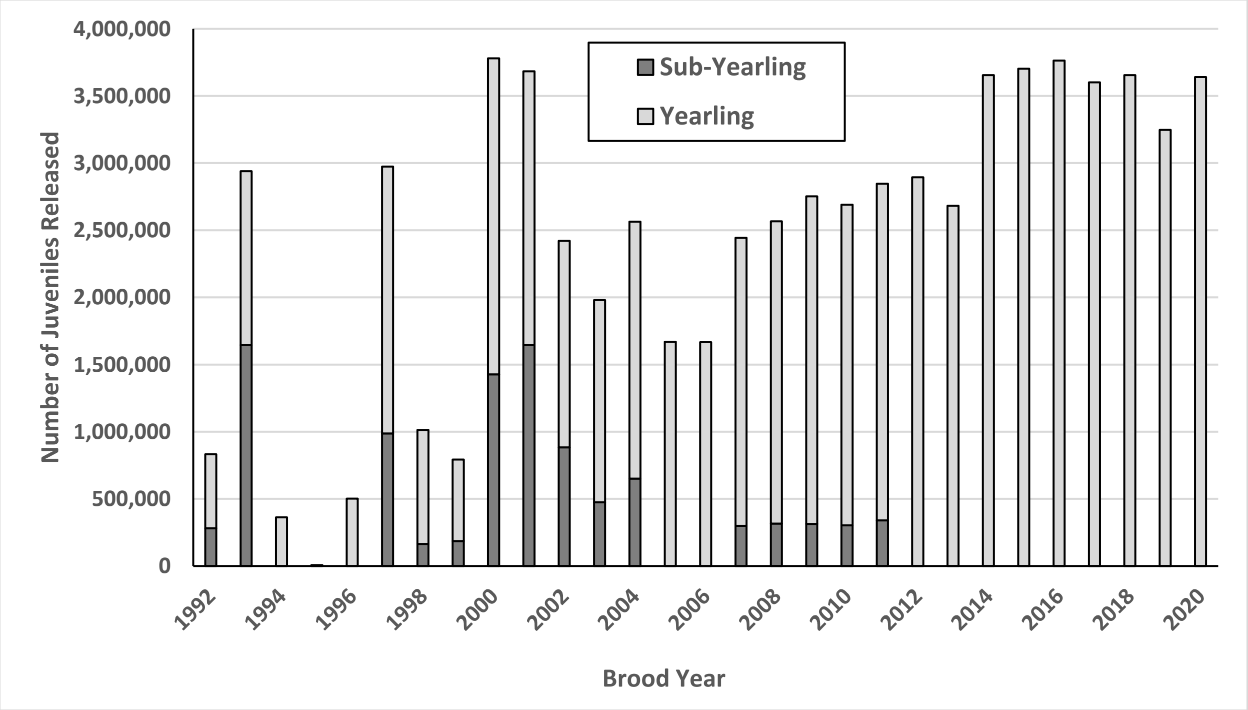

Figure 7. Number of sub-yearling and yearling spring/summer Chinook Salmon released from Clearwater Fish Hatchery, 1992-2020.

Juvenile survival from release to Lower Granite Dam

Juvenile release groups for spring and summer Chinook Salmon have been representatively tagged with Passive Integrated Transponders (PIT) tags since 1995 and are used to estimate juvenile survival from release to Lower Granite Dam. Since 2008, PIT tagging efforts increased (number tagged per release group) as part of a cooperative effort with the Comparative Survival Study (McCann et al., 2021) and to provide estimates of adult returns for survival analysis and for in-season fisheries management.

Estimated survival of juvenile spring Chinook Salmon from release to Lower Granite Dam has been stable over the time series and has averaged 67% across all release sites over the entire time series (Figure 8). Some of the highest survival observed has occurred in the most recent three years. During the years when both spring and summer juveniles have been produced (2009-2020) the average survival of spring Chinook Salmon is 70% and the average survival of summer Chinook Salmon is 63%.

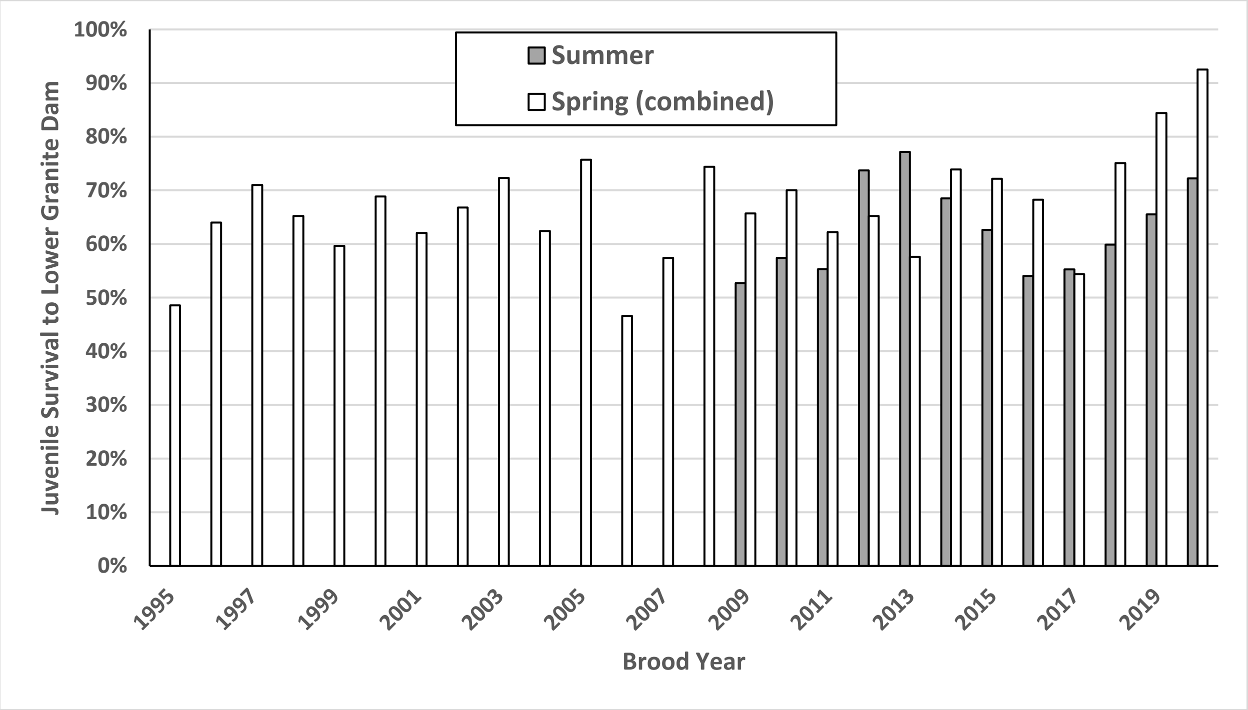

Figure 8. Estimated survival, from release to Lower Granite Dam, of juvenile spring and summer Chinook Salmon from released from Clearwater Fish Hatchery for brood years 1995-2020. The estimates for spring Chinook Salmon represent the weighted average across all release sites. There is a single release site for summer Chinook Salmon.

The data in Figure 9 represents the contemporary release site configuration for Clearwater Fish Hatchery (see Table 2 for release targets). We have observed considerable variation in juvenile survival between release sites annually and much of this variation is consistent across time. Except for the most recent few years, the Red River release has consistently had the lowest juvenile survival of all release sites.

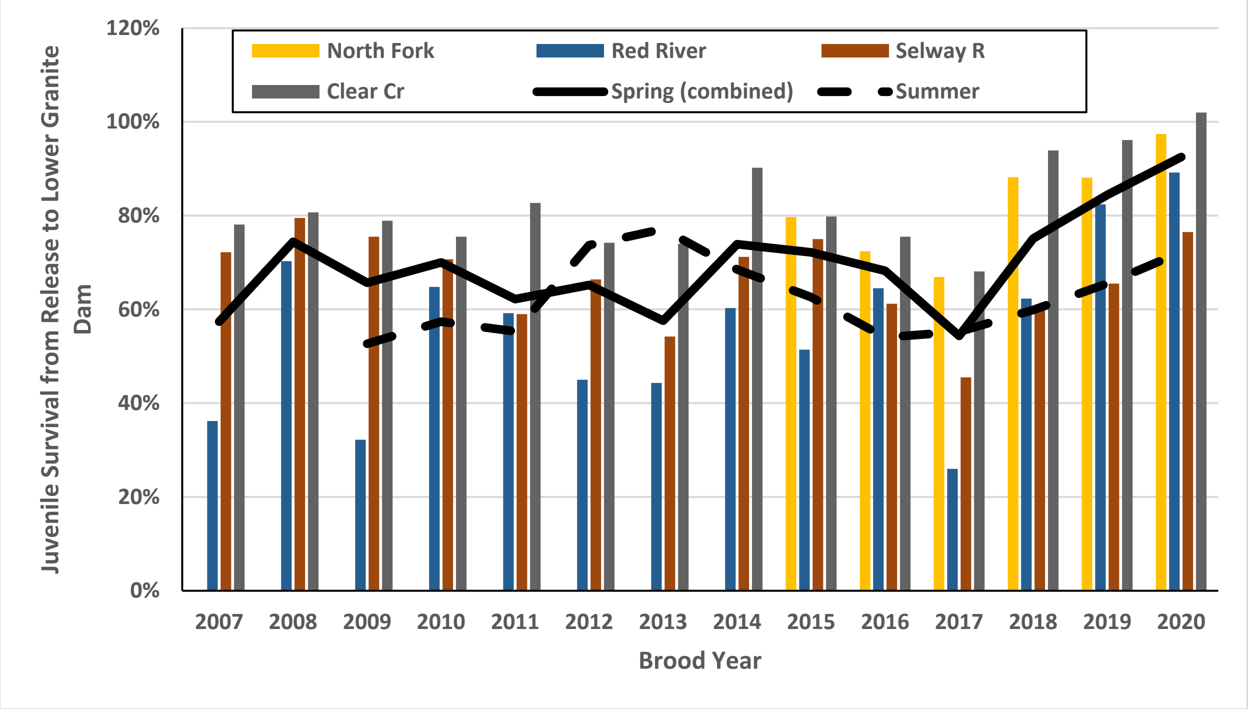

Figure 9. Estimated survival, from release to Lower Granite Dam, of juvenile spring/summer Chinook Salmon released from Clearwater Fish Hatchery for brood years 2007-2020. The solid black line represents the weighted average across all release locations for spring Chinook Salmon. The dashed black line represents the single release site for summer Chinook Salmon. The colored bars represent estimates from individual release sites for spring Chinook Salmon.

Adult returns to the Project Area (mitigation goal)

The LSRCP adult mitigation goals for programs in Idaho are measured as adult returns above the project area and are defined as returns to Lower Granite Dam. For Clearwater Fish Hatchery, the goal is to return 11,915 adults annually to Lower Granite Dam.

Prior to return year 2012, adult returns to Lower Granite Dam were estimated indirectly from a traditional run reconstruction. Adults were accounted for on the spawning grounds, returns to the trapping facilities, and estimates of harvest in the tribal and non-tribal fisheries upstream of Lower Granite Dam. All of these components were summed to estimate the return to Lower Granite Dam. Beginning in 2012, adult returns to Lower Granite Dam have been estimated directly from a systematic sampling program at the adult fish trap and use of Parental Based Tagging (PBT) to assign sampled fish to their hatchery, stock, and cohort of origin (Belnap et al., 2012).

Over the history of the Clearwater Fish Hatchery program, the Project Area adult goal has been met or exceeded in only three years (Figure 10). However, through improvements in fish culture, better coordination and efficient use of Clearwater basin facilities, post release survival, and increased smolt production, the Clearwater Fish Hatchery has averaged 74% of the Project Area mitigation goal for the last ten years (2012-2021) compared to 29% from the previous 22 years (1990-2011). Arguably, some of the apparent improvement is a result of the more thorough accounting that has resulted from the adult sampling program at Lower Granite Dam and the incorporation of the PBT tagging program.

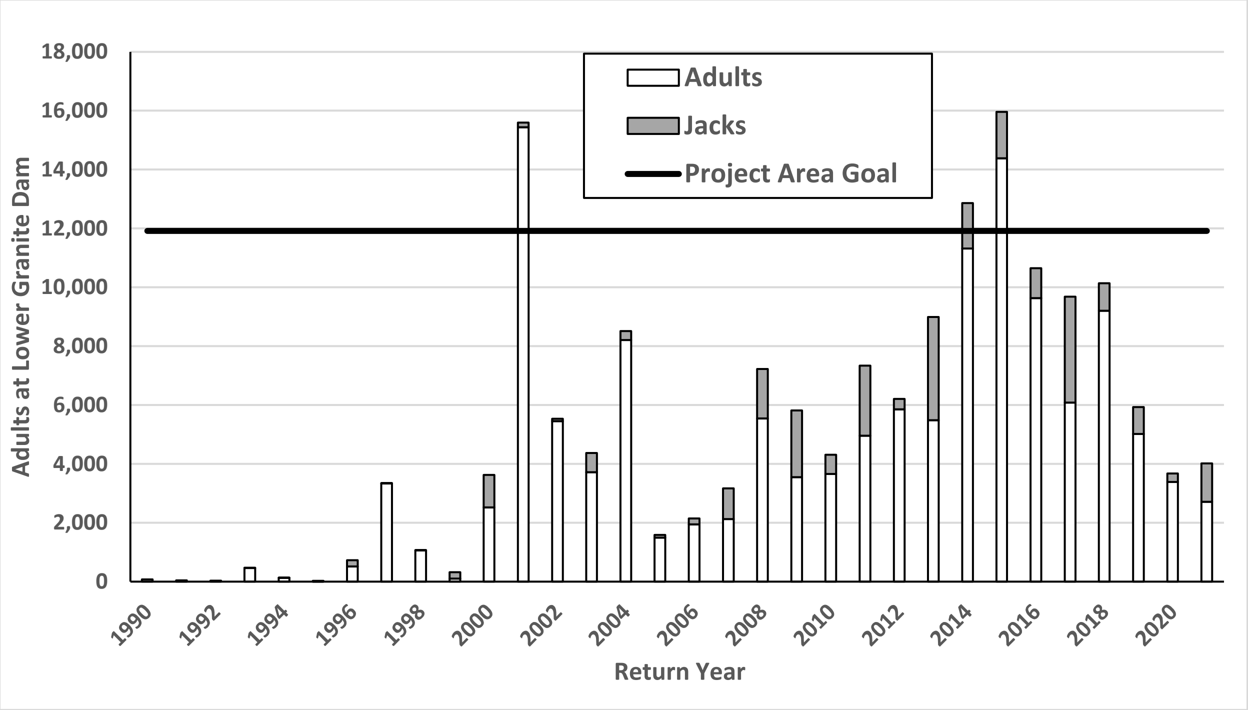

Figure 10. Estimated number of Clearwater Fish Hatchery adult Chinook Salmon at Lower Granite Dam 1990-2021. The black horizontal line represents the Project Area return goal for Clearwater Fish Hatchery.

Since the high adult return in 2015, returns from Clearwater Fish Hatchery have decreased precipitously and are reflective of the decline in overall returns of both hatchery and wild fish to Lower Granite Dam during the same time period (Figure 11).

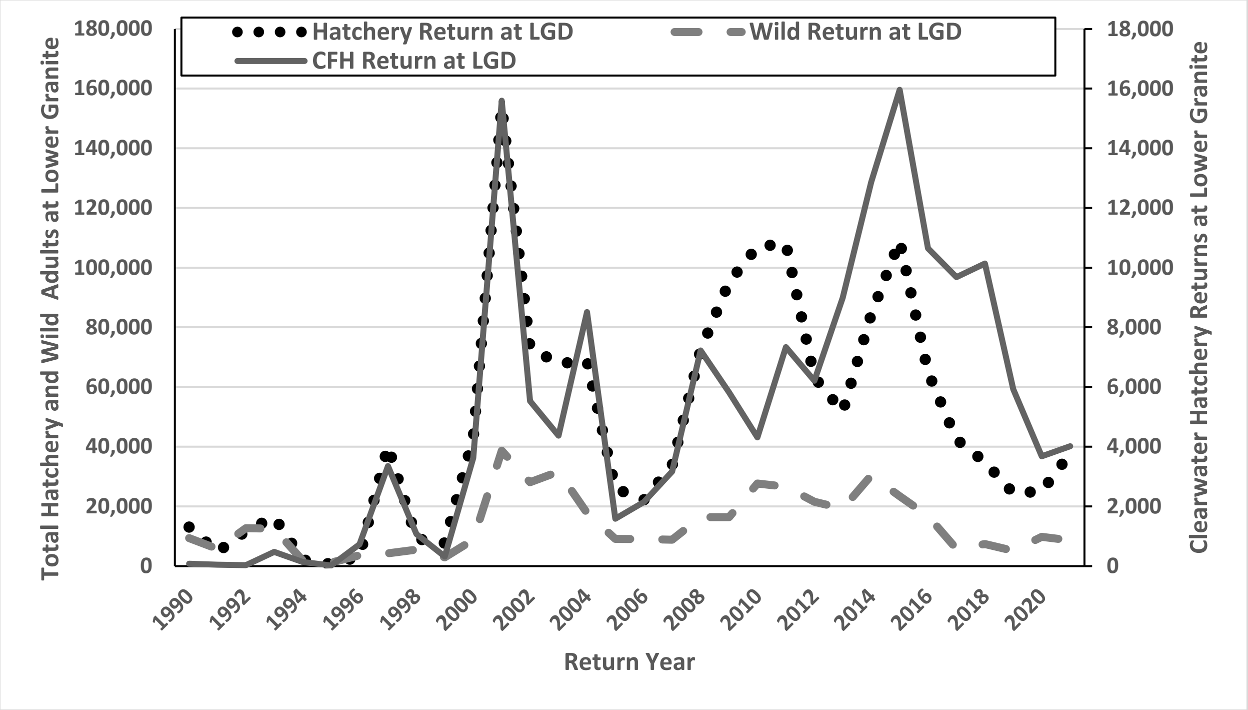

Figure 11. Number of hatchery-origin adults from Clearwater Fish Hatchery (CFH) and the total hatchery and wild return of spring/summer Chinook Salmon at Lower Granite Dam. 1990-2021.

Smolt-to-adult return (SAR)

Smolt-to-adult return rate (SAR) in this report is defined as the fraction of juveniles released that return to Lower Granite Dam as adults. Adults from a single cohort return over three years as one-, two-, and three-ocean adults. Stock and cohort specific estimates at Lower Granite Dam are determined based on PBT analysis described in the "Adult Returns to Project Area" section above. Based on the current smolt production target of 3.75M yearling spring/summer smolts at Clearwater Fish Hatchery, an SAR of 0.32% is necessary to achieve the adult mitigation goal to the Project Area (11,915 adults).

Smolt-to-adult return rates (SARs) for spring Chinook Salmon released from Clearwater Fish Hatchery have varied significantly over the program history (Figure 12). The mean SAR across all release sites is 0.35% indicating that, on average, the Project Area goal would be met under the current smolt release target. Within a year we have observed significant differences in SARs between release sites within the Clearwater basin for spring Chinook Salmon. Generally speaking, the Selway and Clear Cr releases have consistently had the highest SARs across the release sites and Red River has had the lowest. One of the primary management goals in the Clearwater River basin is to provide diverse fishing opportunities across time and space (IDFG 2019), even if it comes at a cost in terms of lower SAR's at some release sites. The current suite of release sites helps accomplish that goal, and co-managers are continuously balancing the costs and benefits of this approach.

Smolt-to-adult return rates for the summer Chinook Salmon program have also been variable and averaged 0.26% for brood years 2009-2016 (Figure 13). For reference, we compared SARs of the Clearwater summer Chinook Salmon with the South Fork Salmon River (SFSR) program that was used as the founding broodstock for the Clearwater program. For brood years 2009-2013 SARs for the SFSR program were 2.5 times higher on average. In all of these years, the broodstock for the Clearwater program was almost entirely from SFSR returns (Figure 3). For brood years 2014 and 2016, SARs for the two programs were similar and the majority of the broodstock for the Clearwater program were from locally returning adults to the Clearwater basin indicating that local adaptation to the hatchery environment in the Clearwater may happen rapidly. This is noteworthy because the SFSR program consistently has some of the highest adult return rates across the spring/summer Chinook Salmon hatchery programs in Idaho. Returns from the more recent broods (2017-2021) will be informative to see if this continues to hold true as the dependance on the SFSR for brood diminishes.

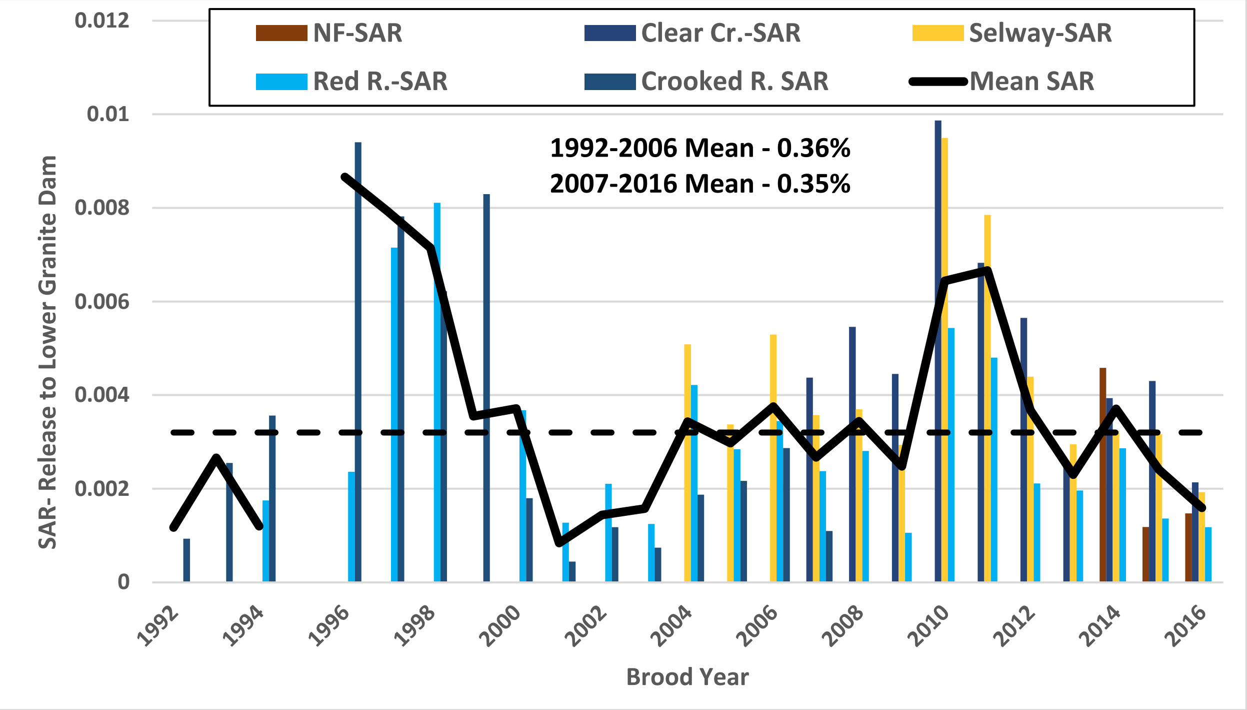

Figure 12. Smolt-to-adult return rate (SAR) of Clearwater River spring Chinook Salmon by individual release location and weighted mean SAR of all release sites by brood year, 1992-2016. For brood year 1995, only 7,000 smolts were released from CFH, so no estimate of SAR is provided for that year.

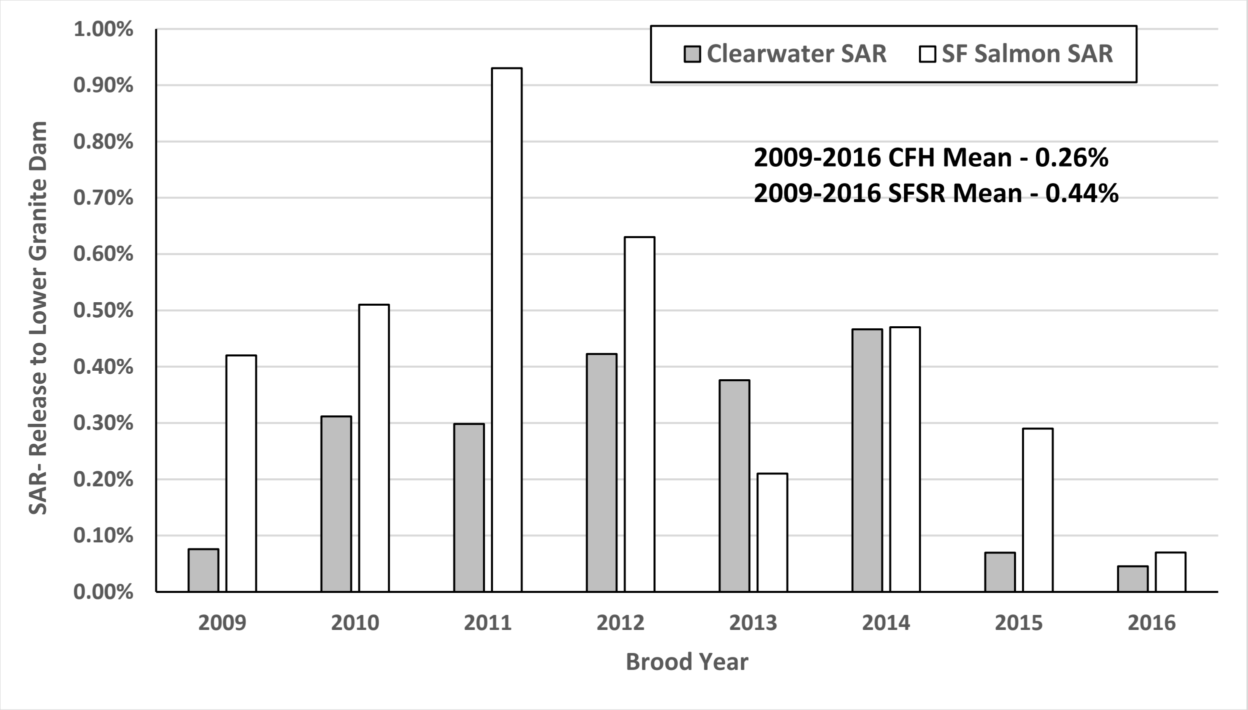

Figure 13. Smolt-to-adult return rate (SAR) of Clearwater River summer Chinook Salmon by brood year, 2009-2016. For comparison, SAR values for the summer Chinook Salmon hatchery program in the South Fork Salmon R. (founding stock for Clearwater summer program) is included.

Smolt-to-adult survival (SAS)

Smolt-to-adult survival rate (SAS) in this report is defined as the fraction of juveniles released that survive to adulthood back to the Columbia River mouth. Due to minimal harvest of spring/summer Chinook Salmon in the Pacific Ocean, returns to the Columbia River mouth represent the survival rates prior to any human exploitation. Estimates to the Columbia River mouth are derived by backing down the Lower Granite estimates (described above) to Bonneville Dam using the stock and cohort specific PIT tag conversion rates between Bonneville and Lower Granite dams. The Bonneville estimates are then backed down to the Columbia River mouth based on coded wire tag recoveries from fisheries sampled in the Columbia River downstream of Bonneville Dam. When the LSRCP program was developed, it was assumed that the catch to escapement ratio of fish harvested downstream of the project area was 4:1. As such, based on the smolt release target of 3.75M, an SAS of 1.6% is required to meet the total adult escapement goal of 59,575 to the Columbia River mouth.

Smolt-to-adult survival rate (SAS) for spring Chinook Salmon released from Clearwater Fish Hatchery has averaged 0.46% over the history of the program indicating that on average, only 29% of the total adult return goal would be achieved under the current smolt release target. (Figure 14). Similar to SAR, we observe significant differences in SAS between release sites within the Clearwater basin for spring Chinook Salmon.

Smolt-to-adult survival rate for summer Chinook Salmon from Clearwater Fish Hatchery have averaged 0.43% for brood years 2009-2016 (Figure 15).

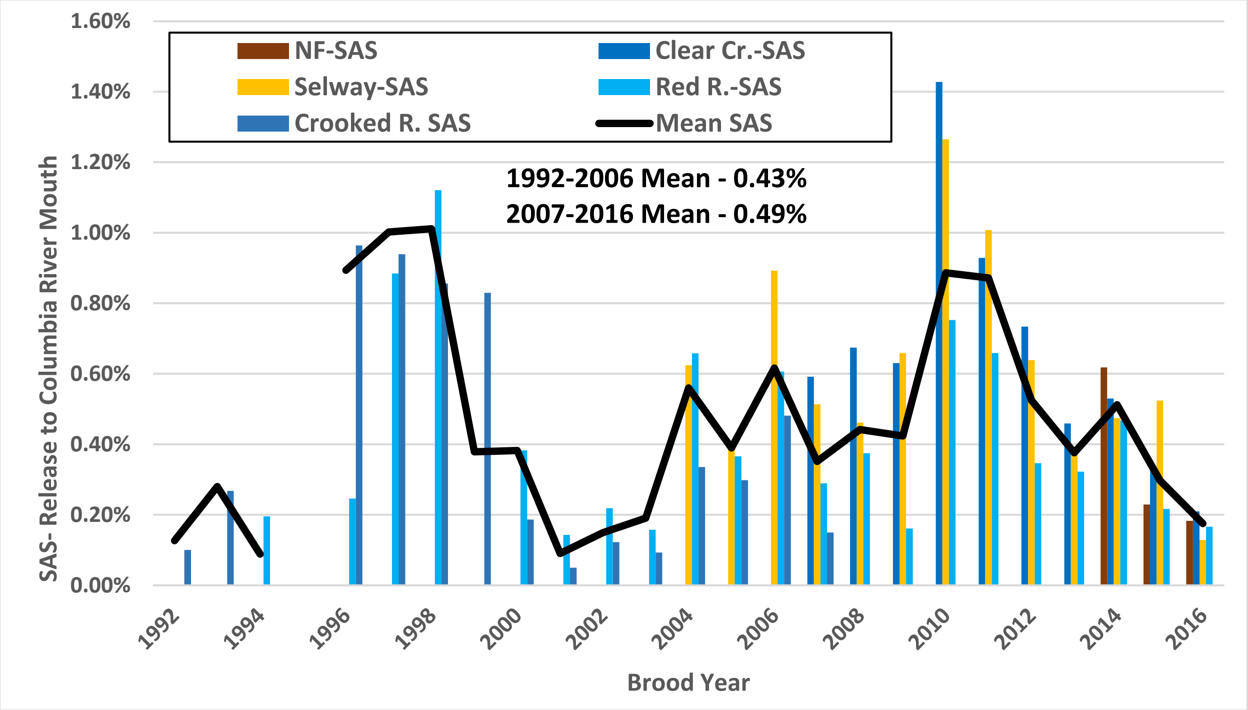

Figure 14. Smolt-to-adult survival rate (SAS) of Clearwater River spring Chinook Salmon by brood year, 1992-2016. For Brood year 1995, only 7,000 smolts were released from CFH, so no estimate of survival rate is provided for that year.

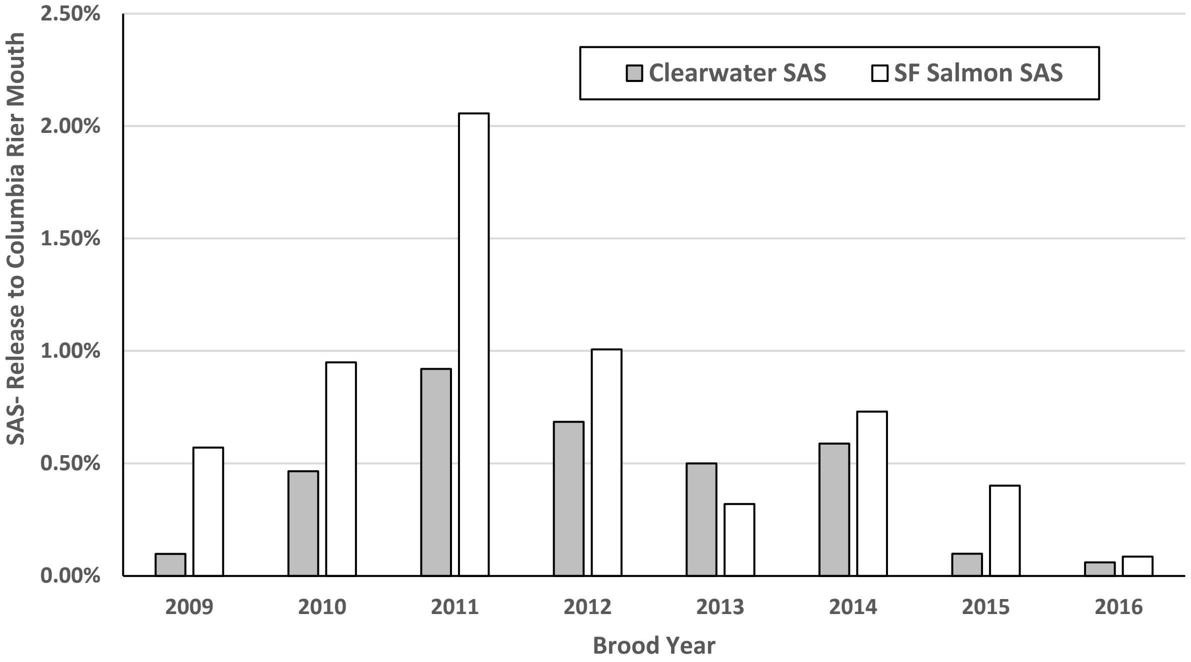

Figure 15. Smolt-to-adult survival rate (SAS) of Clearwater River summer Chinook Salmon by brood year, 2009-2016. For comparison, SAS values for the summer Chinook Salmon hatchery program in the South Fork Salmon R. (founding stock for Clearwater summer program) is included.

Recruits per spawner

The number of returning hatchery origin adults produced per adult spawned is a useful metric that captures survival over the entire lifecycle and highlights the survival advantage that occurs during the hatchery rearing phase of the lifecycle. In this report we provide the number adult recruits produced per spawner that is calculated as the number returning adults estimated at the Columbia R. mouth divided by the number of parents that were spawned for that particular cohort. The number of parents spawned includes those spawned, the number of adults that died prior to spawning, and parents whose eggs were culled at the hatchery for disease management purposes.

The average number of recruits per spawner for the spring Chinook Salmon reared at Clearwater Fish hatchery over the history of the program is 6.8 (Figure 16). The average for the most recent 10 years (BY2007-2016) is 6.9.

For the summer Chinook Salmon reared at Clearwater Fish Hatchery, the average number of recruits per spawner for brood years 2009-2016 is 6.3 (Figure 17)

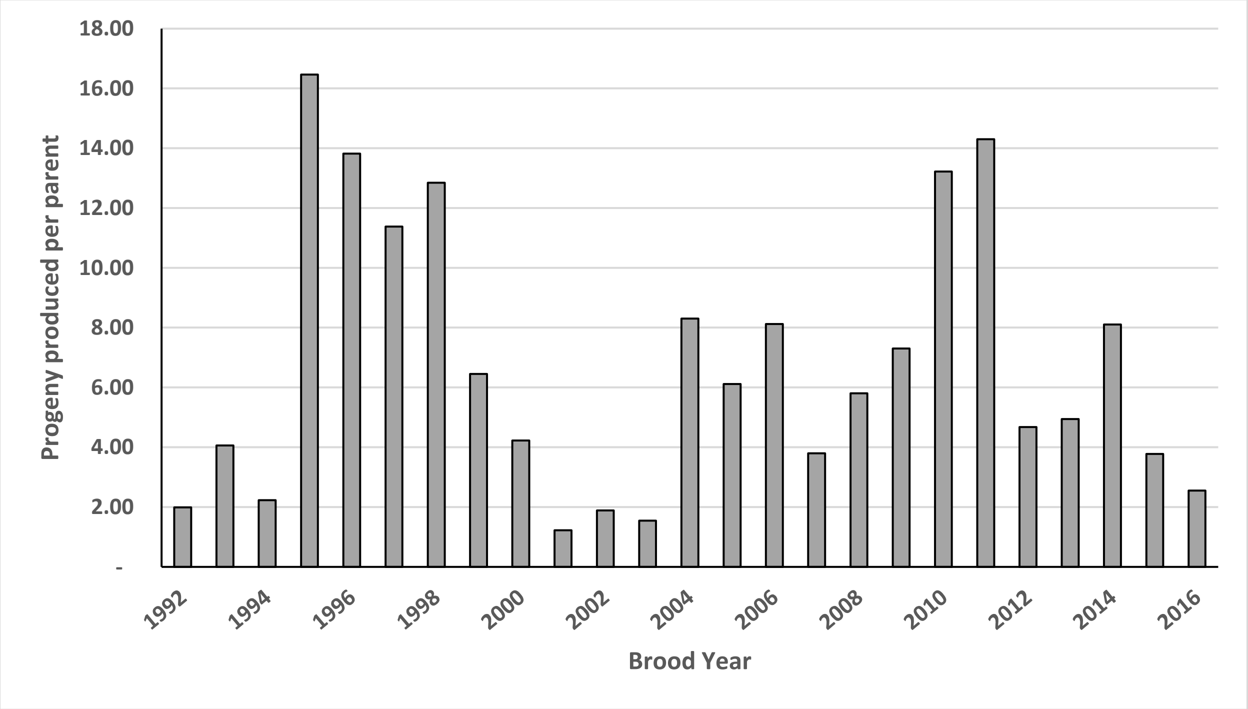

Figure 16. Adult progeny produced per parent for spring Chinook Salmon released from Clearwater Fish Hatchery, brood years 1992-2016.

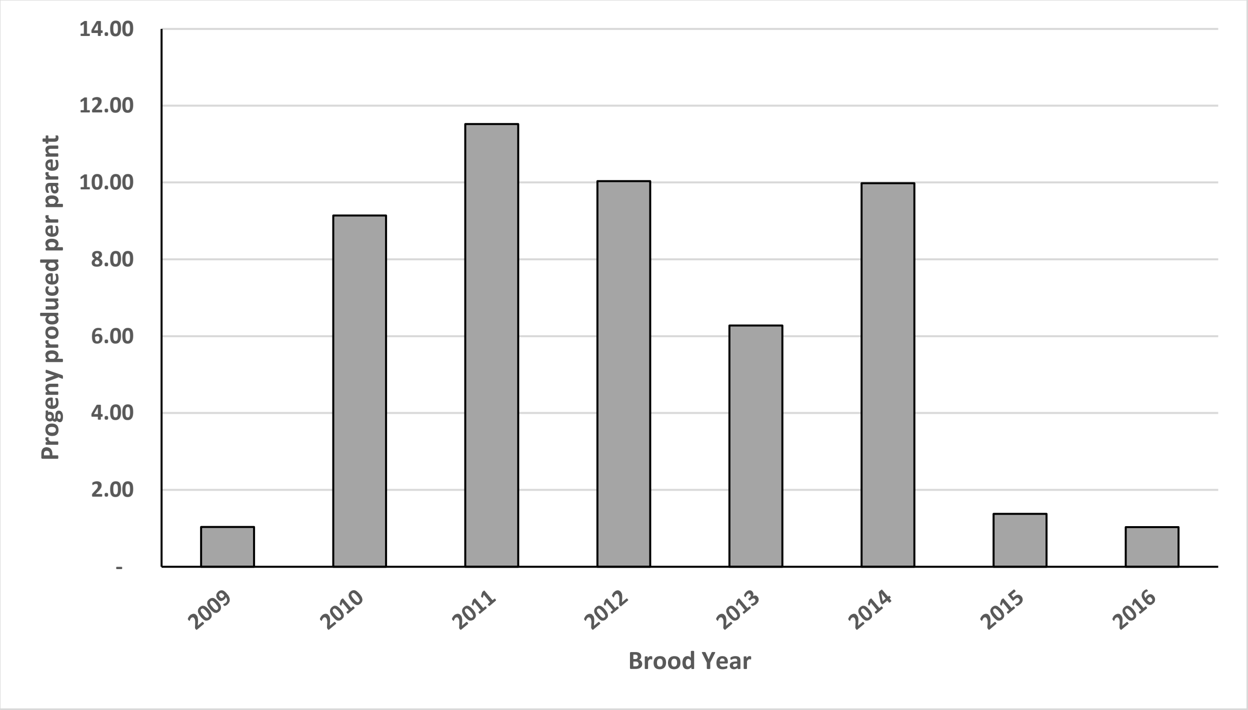

Figure 17. Adult progeny produced per parent for summer Chinook Salmon released from Clearwater Fish Hatchery, brood years 2009-2016.

Harvest **contributions**

The primary objective for the LSRCP funded fish produced at Clearwater Fish Hatchery is to provide for lost harvest opportunity associated with the construction and operation of the four lower Snake River hydroelectric dams.

Fisheries in Idaho

Both tribal and non-tribal fisheries occur in the Clearwater River basin but for the purposes of this report, only information from the non-tribal fishery is provided. Staff from the Nez Perce Tribe will provide data relevant to the tribal harvest in the Clearwater River basin as part of their written report and presentation.

Annually, non-tribal fisheries in Idaho are initially established based on pre-season forecasts of Chinook Salmon destined for return to the Clearwater basin from production at all of the rearing facilities (DNFH, CFN, KNFH, NPTH). In-season, the forecasted numbers are updated based on PIT tag detections at the Columbia River and Snake River dams. Fish returning that are in excess to brood needs are split evenly between the tribal and non-tribal fisheries. Weekly conference calls conducted during the fisheries are used to update the projected returns and numbers of fish harvested to date.

Between 1997 and 2022, non-tribal fisheries have been operated in the Clearwater River drainage every year except 1999. The number of fish harvested, and the amount of angler effort have varied over that timeframe with an average annual harvest of 3,963 (range: 11-21,883) spring/summer Chinook Salmon and an average of 70,669 (range: 1,756-307,681) hours of angler effort (Figure 18).

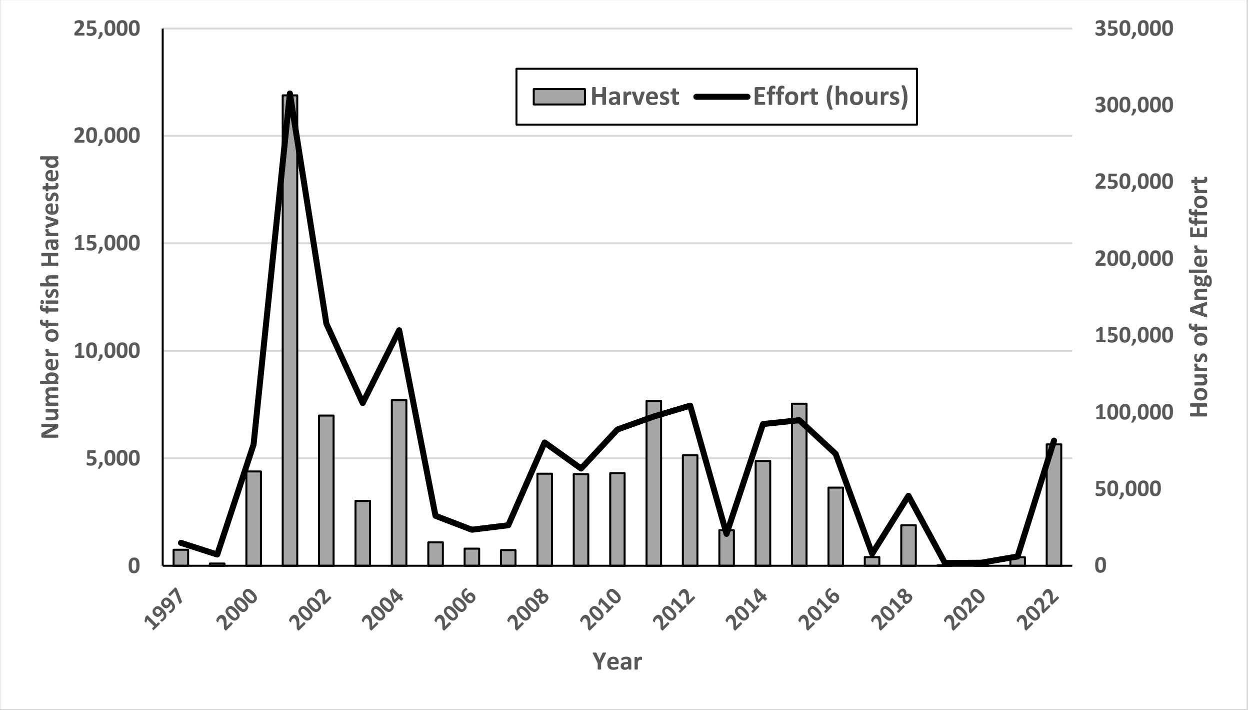

Figure 18. Annual harvest and hours of angler effort estimated from the non-tribal fisheries operated within the Clearwater River basin, 1997-2022.

Fish harvested in these fisheries resulted from production at all of the rearing facilities in the Clearwater basin. Figure 19 shows the composition of the harvest each year with respect to the facility the harvested fish were released from. Over the entire time series, the percent of the catch from Clearwater fish hatchery is 42%. In the most recent 10 years, fish from Clearwater Fish Hatchery represent 59% of the fish harvested. This is consistent with the fraction of the total juvenile releases in the Clearwater basin that come from Clearwater Fish Hatchery.

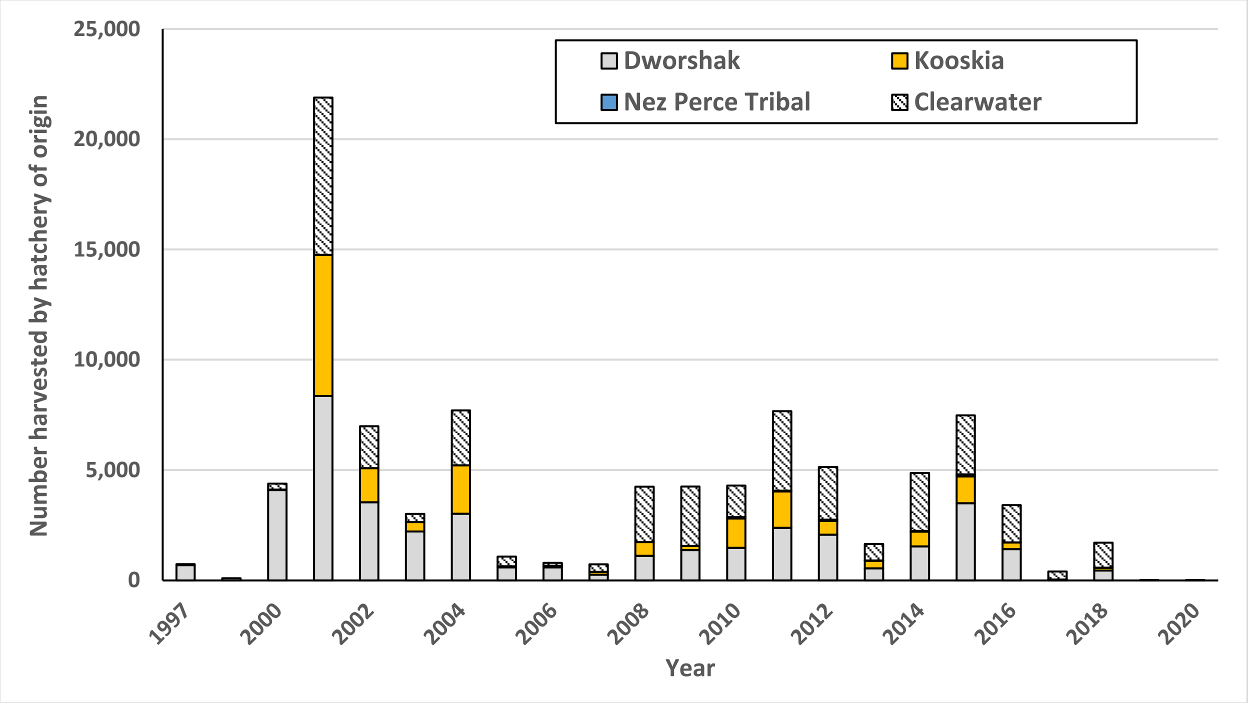

Figure 19. Catch composition (number harvested by hatchery of origin) of spring/summer Chinook Salmon from fisheries operated within the Clearwater River basin, 1997-2020.

Harvest downstream of Idaho

Between 1992 and 2019, harvest of spring/summer Chinook Salmon produced by Clearwater Fish Hatchery occurred in fisheries downstream of Idaho in all but four years (Figure 20). During this time period an average of 1,043 (range: 0-4,214) fish were harvested annually.

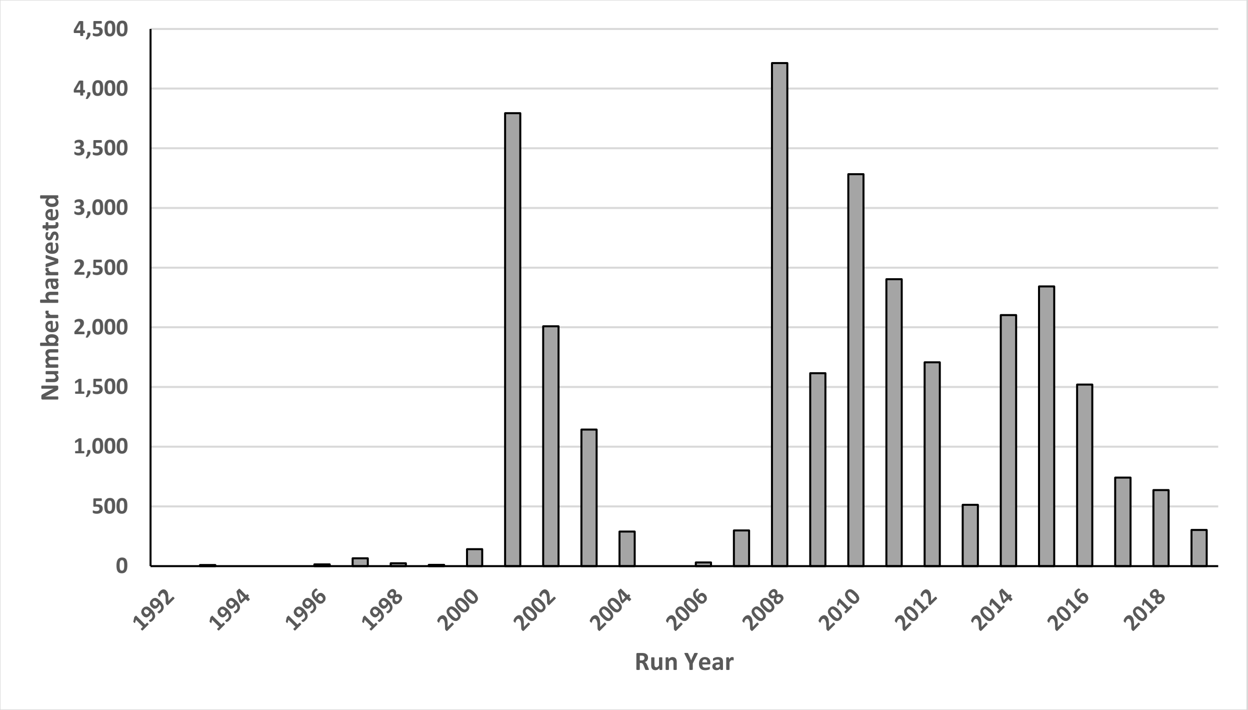

Figure 20. Number of spring/summer Chinook Salmon produced at Clearwater Fish Hatchery harvested in fisheries downstream of Idaho, 1992-2019.

Adaptive management

In order to move the needle closer to meeting the LSRCP mitigation objectives, managers in the Clearwater basin have taken advantage of increases of rearing capacity that resulted from efficiencies realized by managing the Clearwater basin hatchery facilities as more of a hatchery complex than as individual facilities. Managing the spring Chinook Salmon programs as a single stock has also ensured that the hatchery facilities have operated at full capacity during recent years. In addition to increasing the numbers of smolts released, managers are also evaluating alternative rearing practices to increase post release survival of program fish.

Baffle Study at Clearwater Fish Hatchery

A study was conducted at Clearwater Fish hatchery for brood years 2015-2019 looking at the response in adult returns rates for fish reared in baffled raceways compared to a traditional plug-flow configuration. The baffled raceways provided variable water velocities with the highest velocities near the bottom of the raceway in the gap between the baffle and raceway floor with velocities maintained at approximately 2.5 body lengths per second compared to the control raceways with uniform velocities at approximately 0.2 body lengths per second. While this study will not be complete until the final adults return in 2024, results to date show no significant differences in juvenile size or condition factor at release, or travel time or survival to Lower Granite Dam. Similarly, for the two completed brood years

(2015 and 2016) of adult returns, the SAR was not significantly different between treatment and control raceways.

Time of release evaluation

A cooperative effort across facilities in the Clearwater basin began in 2021 to look at the effect of release timing on outmigration timing and survival and ultimately on adult return rates. Treatment groups were released two week later than the traditional release dates (4/14 compared to 3/31) at Clearwater and Dworshak facilities. For the two years of juvenile outmigration (2021 and 2022), results show that even though the release dates were two weeks different, the median passage dates at Lower Granite and Bonneville dams were similar with the late release groups arriving 0-3 days later than the early release groups at Lower Granite and 1-3 days later at Bonneville (Table 4). Survival estimates to Lower Granite for the early and late release groups were within 1% for Clearwater Fish Hatchery releases and 6% for Dworshak Fish Hatchery releases. Point estimates for survival differences to Bonneville Dam were larger than for those to Lower Granite Dam but the 90% confidence intervals for all comparisons at Bonneville overlapped. Based on these two years of data it appears that the conditions each group experienced through the hydro system was likely similar based on passage dates. Survival to Lower Granite was very similar for early and late groups but it appears that survival to Bonneville may be lower for the early groups. The primary difference between the treatment and control groups is the amount of time each group spent at large prior to arriving at Lower Granite dam (10-14 days). Evaluation of the returning adults from these releases should provide insight on whether the difference in time spent in the environment prior to outmigration impacted survival to adulthood.

Table 4. Differences in outmigration timing and survival of early and late release groups of spring Chinook Salmon reared at Clearwater and Dworshak fish hatcheries, 2021-2022.

Facility	**Juvenile Migration Year**	**Difference in Release Date (days)**	**Difference in Median Passage Date at LGD (days)[a]**	**Difference in Median Passage Date at Bonn (days)[a]**	**Difference in Survival to LGD[a]**	**Difference in Survival to Bonn[a]**
Clearwater	2021	14	3	3	-1%	14%
Clearwater	2022	14	0	1	1%	13%
Dworshak	2021	14	3	2	4%	15%
Dworshak	2022	14	2	3	6%	1%

[a] Differences in passage and survival are calculated as (Late Group - Early Group)

90% confidence intervals overlapped for all survival comparisons to Lower Granite and Bonneville dams

Managers in the basin will continue to look for opportunities to refine rearing methods with the goal of increasing post release performance of hatchery reared fish.

Summary and outlook for the future

Since the last ISRP review in 2010, there has been a concerted effort among co-managers in the Clearwater River basin to operate all hatchery facilities in a more coordinated manner as a hatchery complex rather than as individual programs which has resulted in a more efficient use of facilities in the basin. High in-hatchery survival has remained consistent and juvenile production targets were achieved in most years. Production of hatchery-origin spring Chinook Salmon has increased at all rearing facilities and has resulted in a larger and more consistent return of adults despite the recent downturn in abundance of both hatchery and wild populations.

The adult mitigation goal to the project area (11,915) for Clearwater Fish Hatchery has been met or exceeded in only three years (2001, 2014, and 2015) over the history of the program, but in the last ten years has averaged 74% of the goal compared to 29% from the previous 22 years. The total return goal to the Columbia River mouth has never been achieved.

A summer-run program was initiated in the Clearwater to provide more diversity and opportunity for fisheries and potentially higher post-release survival of that stock. For the completed brood year returns to date, SAS of the summer stock has been equal to or greater than the spring Chinook Salmon from Clearwater Fish Hatchery in four of the eight years. Fishery opportunity and harvest provided by the summer stock to date has been modest and managers will continue to evaluate the performance of the summer stock as local adaptation of this stock to the Clearwater basin occurs.

In addition to increasing the number of hatchery smolts released, co-managers are also evaluating alternative rearing practices to increase the post release performance of hatchery fish. The baffle study at Clearwater Fish Hatchery will be completed in two years but the initial data does not indicate increased performance of the treatment groups reared with higher and variable water velocities. The time of release evaluation that is occurring in the Clearwater has just recently started and the first adult returns will be coming back starting in 2023.

Mangers have and will continue to look at performance of fish released at the various sites in the Clearwater Basin to ensure production is being allocated in a manner that maximizes adult returns while maintaining the diverse fishing opportunities available in the basin.

Looking ahead, managers will continue to seek ways to increase hatchery production and productivity while balancing the needs of the tribal and non-tribal fisheries across the landscape to provide in-kind, in-place mitigation for lost harvest opportunities. Additionally, major infrastructure investments are needed at Clearwater Hatchery including installation of a new water-supply pipeline to replace the existing one before a catastrophic failure occurs. A new pipeline would also allow vacant raceways at the hatchery to be watered-up and used for production of additional smolts which would contribute to more consistent returns in the future and move the program closer to regularly meeting its goal.

Literature Cited

Belnap, M., F. Bohlen, C. Dondero, R. Brown. 2021. IPC and LSRCP Monitoring and Evaluation Programs in the State of Idaho: Calendar Year 2018 and Brood Year 2012 Hatchery Chinook Salmon Reports. Idaho Department of Fish and Game, Report 21-14, Boise.

IDFG (Idaho Department of Fish and Game). 2011. Fisheries Management and Evaluation Plan for IDFG Recreational Fisheries for Spring/Summer Chinook Salmon. January 2011.

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McCann, J., B. Chockley, E. Cooper, G. Scheer, S. Haeseker, R. Lessard, T. Copeland, J. Ebel, A. Storch and D. Rawding. Comparative survival study of PIT-tagged spring/summer/fall Chinook, summer steelhead, and sockeye. 2021 annual report. CSS Oversight Committee and Fish Passage Center, BPA Contract 19960200, Portland, Oregon. Available: http://www.fpc.org/documents/CSS/2021_CSS_Annual_Report.pdf

United States Department of Agriculture | **Forest Service** | **Nez Perce NF** | **Rt. 2, Box 475**
Grangeville, ID 83530

Reply to: 1920
FP Amendment #7

Date: January 2, 1990

Dear Forest Planning Participant:

During the Forest Plan appeal period, the Nez Perce Indian Tribe raised a number of issues and requested changes to the Nez Perce National Forest Plan. Through negotiations we have reached a settlement agreement that results in the enclosed Forest Plan amendment and the withdrawal of the Forest Plan appeal by the Nez Perce Tribe.

The settlement agreement clarifies Forest Plan language surrounding issues raised in the Tribe's appeal. We have taken the content of the settlement agreement and re-worked it into the enclosed Forest Plan appeal.

have decided to amend the Nez Perce Forest Plan by clarifying direction found in the following sections:

Chapter II (Forestwide Management Direction)
Chapter V (Implementation)
Chapter VI (Summary of the Analysis of the Management Situation)
Appendix O (Forest Plan Monitoring)

These changes will not alter the multiple-use goals and objectives identified in the Forest Plan.

The Decision Memo and Forest Plan Amendment are enclosed. Please attach the amendment to your copy of the Nez Perce Forest Plan.

By working together, we can move forward keeping our Forest Plan current, useable, and responsive.

Tom Kovalicky
TOM KOVALICKY
Forest Supervisor

Enclosure

Decision Memo
Forest Plan Amendment No. 7
Nez Perce National Forest
Idaho County, Idaho

The purpose of Amendment No. 7 of the Nez Perce National Forest Plan is to clarify language found in the following sections:

Chapter II (Forestwide Management Direction)
Chapter V (Implementation)
Chapter VI (Summary of the Analysis of the Management Situation)
Appendix O (Forest Plan Monitoring)

The specific items modified provide clarification that will not alter the multiple-use goals and objectives as identified in the Forest Plan.

The need for changes and clarification in management standards was the result of negotiations with the Nez Perce Indian Tribe's appeal of the Nez Perce National Forest Plan. An interdisciplinary team was used in developing the settlement agreement that addressed the appellant's concerns and develop a proposal for correcting the Forest Plan. This amendment focuses on the following appeal issues:

Monitoring of impacts to elk and other species
Adequate mitigation for elk
Impacts of livestock grazing on elk
Cultural resource protection
Tribal treaty grazing rights
Impacts of budget flucuations on Forest Plan implementation
East Meadow Creek management
Second Decade ASQ

Forest Service policy permits Forest Plan amendments resulting from changes necessitated by the resolution of administrative appeals (FSM 1922.51). I have determined the proposed changes are not significant since they are minor changes in standards and guidelines and will not alter the multiple-use goals and objectives for long-term land and resource management.

Adoption of this amendment will not significantly change the forestwide environmental impacts disclosed in the Nez Perce Forest Plan Environmental Impact Statement (EIS). This amendment is categorically excluded from further documentation in an EIS or EA (ID No. 16, FSM 1950 and ID No. 2, FSH 1909.15)

Additional information can be obtained from:

Joe Bednorz, Staff Officer
Land Management Planning
Nez Perce National Forest
Route 2, Box 475
Grangeville, Idaho 83530

(208) 983-1950

Implementation of this decision will begin immediately. This decision is subject to appeal pursuant to 36 CFR 217.8 and 36 CFR 217.9. Notice of appeal must be in writing and submitted within 45 days of this decision to:

John W. Mumma, Regional Forester
USDA Forest Service
P.O. Box 7669
Missoula, Montana 59807

A copy of the notice of appeal must be sent to:

Tom Kovalicky, Forest Supervisor
Nez Perce National Forest
Rt. 2, Box 475
Grangeville, Idaho 83530

TOM KOVALICKY
Forest Supervisor

January 2, 1990
Date

Nez Perce National Forest
Land and Resource Management Plan

Amendment No. 7
January 1990

Forest Plan, Page II-20

Range, Item 6, Change to read as follows:

Provide forage for elk needs in allotment management plans on all allotments that include elk winter range. The assumption is made that available forage is not a limiting factor on summer habitat.

Forest Plan, Appendix O, Page O-2

Items 1c and 10, Add after the third paragraph:

In the annual monitoring report, the Forest will display for each Timber Sale Decision Notice signed during the reporting fiscal year, the following information: the summer elk objectives; preharvest level of elk habitat effectiveness; and the level of elk habitat effectiveness under the preferred alternative.

The Forest Service shall develop in collaboration with the Tribe, a methodology for randomly selecting half of the Forest Service's land disturbing activities for evaluation of elk habitat effectiveness

The Nez Perce National Forest will invite the Idaho Department of Fish and Game, University of Idaho, and the National Forest Research Station to participate, along with the Nez Perce Tribe, in developing a study plan to validate and, if needed, refine the Nez Perce elk effectiveness model. This study plan will review applicable, ongoing elk research in northern Idaho. Model changes and refinements will be incorporated into the Nez Perce Forest version of the elk effectiveness model, and the amended version of the model will be used in future forest planning. It is intended that this study will be completed before the next Forest Land and Resource Management Plan.

Forest Plan, Appendix O, Page O-3

Items 1d and 10, Add after the second paragraph:

In the annual monitoring report, a general description of how well the other wildlife habitat protection standards have been met will be included. Specific sales where the interdisciplinary process has failed to address or meet any of the other wildlife habitat protection standards in the integrated management planning process will be identified along with the failed standard.

Item 1e. Add the following:

Wildfire acreage will be applied to the estimated 5,000 acres per year of winter range burning when wildfires occur in areas which the Forest had active plans to burn or harvest timber for winter range improvement.

Should the Forest fall more than 8,000 acres behind on planned winter range burn acreage for any reason other than complying with Regional Forester cease burn orders for regionwide fire emergencies, the Forest will initiate Forest Plan amendment proceedings. The process will explore, evaluate and recommend alternate ways to achieve compensatory winter range forage improvement. If concerned parties agree that no achievable alternatives are satisfactory, they will review previous burn accomplishment records and amend the Forest Plan objective of 5,000 acre proportionately downward.

Forest Plan, Page II - 17

Cultural Resources, Item 5, Replace with the following:

The Forest Service and the Tribe will undertake a process of consultation to protect cultural sites of prehistoric or present use. The Forest Service will notify the Tribe of all land disturbing activities. This notification will occur at a stage when the Forest Service's plans are sufficiently definite that the Tribe will be able to judge the possible location and extent of impacts to cultural sites. Notification will also include information of sufficient detail to allow the Tribe to determine if there may be potential adverse impacts to cultural sites. Notification will also be timed early enough in the decisionmaking process so that the Forest Service will be able to alter its plans based on the Tribe's comments and suggestions.

The Forest Service will take into consideration the Tribe's comments in designing and locating land disturbing activities. The Forest Service will not necessarily follow the Tribe's suggestions for protection of cultural sites in every case, but the consultation process will involve an accommodation between the interests of the Forest Service and the Tribe. In cases where the Forest Service is unable to adopt the Tribe's suggestions, the Forest Service will notify the Tribe of its reasons for failing to do so.

The Tribe may also propose that the Forest Service undertake certain rehabilitative measures for cultural sites of prehistoric or present use which are currently suffering degradation. The Forest Service will consider such suggestions in light of the treaty and appropriate laws.

Forest Plan, Page VI - 18

7. Range, Forest Plan Direction, Add the following paragraph:

The Forest Service acknowledges that the Nez Perce have a treaty grazing right on public lands throughout the Nez Perce National Forest based on treaties signed by the Nez Perce in 1855 and 1863 This right encompasses cattle and horses owned by tribal members or by the Nez Perce Indian Tribe The Forest Service will negotiate the terms and conditions of any tribal grazing with the Tribe. The Bureau of Indian Affairs may also have a role in setting terms of tribal grazing.

Forest Plan, Page V - 9

E. Budget, Add the following after the first paragraph:

The plan states that certain mitigation measures and certain monitoring programs will be undertaken by the Forest Service. The environmental impact statement prepared for the Forest's ten year management plan was written based on the assumption that these measures and programs will occur, and the Forest outputs projected in the EIS are based on such assumptions. Changes to the budget in any given year, may require projects scheduled for that year to be rescheduled. If the budget is significantly different from the Plan over a period of several years that objectives and monitoring requirements cannot be met, the Plan itself may have to be amended. Such an amendment would meet NEPA requirements.

Forest Plan, Page II - 4

Roadless Areas, top of page, Replace first paragraph with the following:

The classification of 60,851 acres of tentatively suitable land in East Meadow Creek is deferred. This area is identified as an opportunity. Based on additional information, site specific evaluation, and changes in market conditions or technology, change in classification of this area may be initiated.

In the interim, this area will be managed to emphasize fish, wildlife, and dispersed recreation opportunities. However, there will be no investments that will remove options to manage for a full range of resource uses in the future. The East Meadow Creek Roadless Area is currently not in the suitable timber base. The Forest Plan calls for no capital improvements in this roadless area.

Monitoring and evaluation will precede any consideration or decision to proceed with the development of East Meadow Creek. Any decision concerning suitability or additional timber scheduling will require a Forest Plan amendment with full environmental analysis and public involvement.

Second Decade Allowable Sale Quantity (ASQ)

While not a Forest Plan decision; the following clarifies second decade ASQ statements made in the Nez Perce national Forest Plan Record of Decision.

The Forest did not make any promise to increase the Forest ASQ in the second decade. The National Forest Management Act of 1976 requires the Forest Service to determine the Forest ASQ in each National Forest Plan based on the best available information. Information and analysis developed in the NEPA process for the current Forest plan indicates that an increase in the ASQ may be possible in the second decade while meeting other multiple use goals and standards.

The Forest Service is undertaking a monitoring program over the next ten years to verify or identify changes in that information and analysis. Whether or not the Regional Forester makes a decision to implement any increase in the ASQ in the second decade will depend on further analysis or knowledge gained through monitoring, changed conditions, new issues, etc. No change will be made in the ASQ without following processes prescribed by the National Forest Management Act and the National Environmental Policy Act.

End of Amendment ***

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Research Article

Evaluating Habitat Suitability Models for Nesting White-Headed Woodpeckers in Unburned Forest

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ABSTRACT Habitat suitability models can provide guidelines for species conservation by predicting where species of interest are likely to occur. Presence-only models are widely used but typically provide only relative indices of habitat suitability (HSIs), necessitating rigorous evaluation often using independently collected presence-absence data. We refined and evaluated presence-only habitat suitability models for nesting white-headed woodpeckers (*Picoides albolarvatus*), a narrowly distributed species of conservation concern that occupies dry conifer forests of the Inland Pacific Northwest, USA. We developed 2 models using Mahalanobis D^2 and Maxent techniques from nest location datasets collected on the eastside of the Cascade Mountain Range, Oregon (1 dataset in 1997–2004 and another, sampling a broader spatial extent, in 2010–2011). Consistent with known ecology of white-headed woodpeckers, both HSI models related positively with percent ponderosa pine, moderate levels of canopy cover (approx. 40%), and moderate-to-high levels of heterogeneity in forest structure. Unlike Mahalanobis HSIs, however, Maxent HSIs were consistently and positively related with nest prevalence and positively related with habitat use estimated with independent point count data. Locations with high Maxent HSIs were characterized by canopy openings adjacent to closed canopy forests. The fact that this habitat feature was described by Maxent HSIs but not by Mahalanobis HSIs possibly explains why Maxent HSIs better predicted white-headed woodpecker occurrence. Additionally, we used presence-absence data for model evaluation that sampled a broader spatial extent than nest surveys and therefore allowed us to demonstrate the generality of Maxent HSIs. Additional nest location data collected across a broader portion of the species range would be valuable for further model improvement and evaluation, but until such data are available, we recommend use of Maxent HSIs to guide habitat conservation and restoration efforts in unburned dry forests of Oregon. Published 2014. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS forest restoration, Mahalanobis D^2, Maxent, model validation, *Picoides albolarvatus*, presence-only models, species distributions.

The white-headed woodpecker (*Picoides albolarvatus*) is a species endemic to dry, conifer forests of western North America (Garrett et al. 1996), and habitat for this species has been a focus of forest restoration (Hessburg et al. 2005). Breeding habitat consists of mature forest landscapes containing canopy openings and large-coned pine trees (e.g., *Pinus ponderosa*) that produce seeds, an important food resource (Ligon 1973, Raphael and White 1984, Garrett et al. 1996). Nest placement frequently occurs in open-canopied forest patches often adjacent to relatively closed-canopy forest thought to provide critical food resources (Wightman et al. 2010, Hollenbeck et al. 2011). These complex habitat requirements make identification of suitable breeding habitat challenging.

Habitat suitability index (HSI) models are used to guide land management decisions aimed at species conservation (Maiorano et al. 2006, Barrows et al. 2008, Keenan et al. 2011). Habitat suitability models identify statistical relationships between species and their environments. These models can be used to predict the environments and geographic locations where species are most likely to occur. Models typically provide continuous indices of habitat suitability (HSI; 0–1 range) that indicate likelihood of species occurrence (0 = least likely, 1 = most likely) and can be discretized into classes that discriminate high- from low-suitability habitat (Hirzel et al. 2006, Freeman and Moisen 2008, Liu et al. 2013).

Habitat suitability models use different types of data to derive metrics with different meanings (Lele et al. 2013). Presence-absence models estimate an HSI that portrays the probability of species presence at specific locations within a specified timeframe (e.g., occupancy probabilities; MacKenzie et al. 2002,2006), requiring both habitat use (species presence) and

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non-use (absence) data. Habitat suitability models derived from resource selection theory aim to quantify habitat selection by comparing used locations to a random sample representing locations available to the species (HSI = probability of selecting a location over other available locations; e.g., Phillips et al. 2006, McDonald 2013). Presence-only habitat suitability models quantify the environmental distribution of used locations (habitat-use distribution), requiring only a representative sample of habitat measurements at used locations (e.g., for distance models, HSI = similarity to used habitat; Rotenberry et al. 2006).

Habitat suitability indices generated by different types of models are related (Lele et al. 2013). Outputs from all aforementioned models are largely the realization of habitat selection applied across a particular set of available habitats. Habitat suitability indices typically attempt to infer species distributions from environmental relationships with occurrence data. Thus, if different types of HSIs are fitted to data sampling the same population within the same environmental range, outputs should be correlated. However, occurrence data collected over a limited range of environments and geographic variation in environmental relationships may limit the ability of HSI models to provide generally accurate predictions (Thuiller et al. 2004, Morrison 2012). Additionally, because models quantify environmental relationships differently, their HSIs may diverge when applied in novel environments (Heikkinen et al. 2012, Latif et al. 2013).

Evaluation of HSI models with multiple criteria and independent datasets is invaluable for verifying their utility for guiding management. Evaluation with independent data is standard practice to verify model predictive capacity. Most often, a randomly selected subset of data are withheld from model development for subsequent evaluation (Guisan and Zimmermann 2000). However, to fully evaluate their predictive value, models should also be tested against independently collected data that preferably sample beyond the geographic extent of model development (Heikkinen et al. 2012, Wenger and Olden 2012, Bahn and McGill 2013).

We continued the process of developing and evaluating habitat suitability models for nesting white-headed woodpeckers in unburned forests. Hollenbeck et al. (2011) developed an HSI model that quantified the environmental distribution of white-headed woodpecker nest sites in the East Cascade Mountains using the partitioned Mahalanobis D^2 technique (Rotenberry et al. 2006). When we applied the Hollenbeck et al. (2011) model outside the originally sampled geographic extent, the model assigned relatively low HSI values to new nest locations, suggesting a lack of generality. Therefore, we used the original and new nest locations to develop new habitat suitability models using 2 modeling techniques: Mahalanobis D^2 and Maxent. Mahalanobis HSIs quantify habitat-use distributions, whereas Maxent HSIs quantify habitat selection, but both can be used to infer species geographic distributions (Phillips et al. 2006, Rotenberry et al. 2006). We evaluated the new models using nest locations withheld from model development and independently collected presence-absence data generated from point count surveys. We evaluated both continuous HSIs and suitability classifications derived from HSI thresholds using nest location and point count data.

STUDY AREA

For model development, our study area included forests in the East Cascade and Blue Mountains of eastern Oregon, USA. Nests were located in the Sisters Ranger District on the Deschutes National Forest (44°17′ N, 121°33′ W) and the Chemult and Chiloquin Ranger Districts on the Fremont-Winema National Forest (43°13′ N, 121°47′ W and 42°34′ N, 121°53′ W, respectively), on the eastern slope of the Cascade Mountain Range (Fig. 1). Forests were characterized as dry, mixed conifer and were dominated by ponderosa pine (*Pinus ponderosa*), lodgepole pine (*P. contorta*), or a mix of conifer species typically including Douglas-fir (*Pseudotsuga menziesii*; for additional details, see Hollenbeck et al. 2011). Prior to Euro–American settlement, dry mixed conifer forests of the Inland Northwest were burned by frequent (1–25 years) low- or mixed-severity fires (<20% or 20–70% tree mortality, respectively; Hessburg et al. 2005). Extant dry forest landscapes support primarily mixed and high-severity fires, and these fires are occurring over much larger areas than was formerly the case (Hessburg et al. 2005).

We conducted point count surveys used for model evaluation across a broader geographic extent that included portions of the East Cascade and Blue mountain ranges (Fig. 1). Although the 2 mountain ranges occur in different ecoregions (East Cascade Mountain Range in the East Cascade-Modoc Plateau Ecoregion, and the Blue Mountains in the Middle Rockies and Blue Mountains ecoregions; Baily 1995), both have similar historical disturbance regimes (Hessburg et al. 2005, Franklin and Johnson 2012).

METHODS

Field Surveys

We initially located nests in May–June 1997–2004, in the Deschutes and Fremont-Winema National Forests (Fig. 1). We systematically searched for nest cavities following standard protocol during the nesting season (Dudley and Saab 2003, Hollenbeck et al. 2011). We included cavities only where nesting activity was confirmed. Active nests contained eggs or young, or were identified based on adult behavior indicative of food delivery, frequent visits, or extended time spent in the cavities (Dudley and Saab 2003). We visually inspected cavity contents using a telescoping camera (TreeTop II System, Sandpiper Technologies, Inc., Manteca, CA).

In May–June 2010–2011, we located more nests across a broader geographic extent within each National Forest (Fig. 1). We implemented our nest searching protocol in areas surrounding 37 2.7-km transects randomly located in forests dominated or co-dominated by ponderosa pine in the Sisters and Chemult-Chiloquin Ranger Districts. Ponderosa pine dominance was based on output from gradient nearest neighbor (GNN) analyses (Ohmann and Gregory 2002).

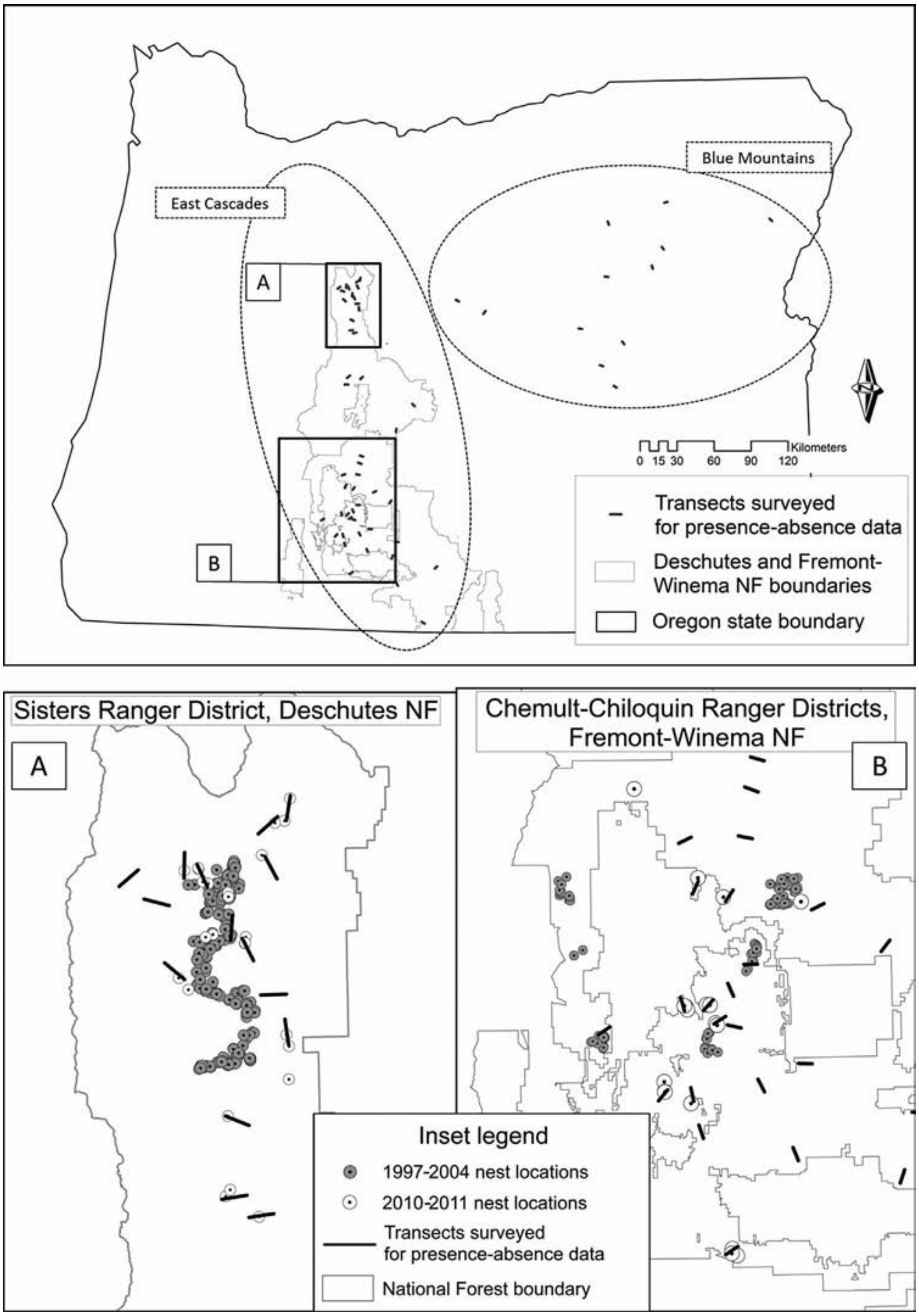

Figure 1. Study area for development and evaluation of white-headed woodpecker habitat suitability models. Nest and transect locations on the A) Sisters, and B) Chemult-Chilouin Ranger Districts, United States Department of Agriculture National Forest system.

When nest searching along transects, we searched within 400 m of the transect centerline, although surveyors sometimes followed birds thought to be nesting ≤2 km away.

We conducted point count surveys in 2010–2012 along 58 2.7-km transects randomly located in forests dominated or co-dominated by ponderosa pine. Transects were spaced ≥1 km apart and we field verified the status of ponderosa pine. We established 10 points spaced roughly 300 m apart along each transect. During each point visit, surveyors broadcast 20 seconds of white-headed woodpecker calls and drumming followed by 30 seconds of silence; we repeated this pattern 3 times in 3 directions (120° separation). At the end of the last broadcast, surveyors would listen for 2 additional minutes (4.5 min total). If the surveyor detected a white-headed woodpecker, they immediately ended the survey. Surveyors estimated that individuals were rarely detected >150 m from survey points. We surveyed 13 transects in the Sisters Ranger District (Deschutes NF) 3–4 times each (mean = 3.77, SD = 0.80) in 2010 (10 May–1 Jul), 46 transects throughout the East Cascade and Blue mountains (including 1 of the 13 Sisters transects) approximately twice each (mean = 2.04 visits, SD = 0.31) in 2011 (26 Apr–5 Jul), and 25 transects (12 Blue Mountain and 13 East Cascade transects) twice each in 2011 (1 May–26 Jun). Thus, we surveyed 33 transects in only 1 year (2010 or 2011), 24 transects in 2 years (2011–2012), and 1 transect in the Sisters Ranger District during all 3 years (2010–2012).

Environmental Data

We compiled environmental variables describing topography and forest structure from remotely sensed data at a 30-m resolution (Table 1). We derived topographic variables from digital elevation model (DEM) layers (United States Geological Survey 2012) and forest structure variables from GNN data (Ohmann and Gregory 2002). We assumed pixels classified as non-forest by GNN to have 0% canopy cover. We summarized variables at 3 scales, the individual pixel containing the nest or point (0.09 ha; slope, cosine aspect), 0.81 ha surrounding the nest or point (local-scale canopy cover), and 314 ha surrounding the nest or point (landscape-scale canopy cover, percent ponderosa pine, edge density; Table 1). We used percent of ponderosa pine forest in a 314-ha area surrounding the nest or point rather than elevation (see Hollenbeck et al. 2011) because ponderosa pine dominance is related to elevation and more directly relevant to white-headed woodpecker ecology. Previous white-headed woodpecker models used interspersion-juxtaposition (IJI) to quantify mosaics of open- and closed-canopy forests (Wightman et al. 2010, Hollenbeck et al. 2011). We instead used edge density because IJI cannot be calculated for neighborhoods with <3 patch types (McGarigal and Ene 2013). We used GNN variables derived from Landsat imagery recorded in 2000 and 2012 for 1997–2004 and 2010–2012 nest locations and point count data, respectively.

Model Development

We developed HSI models using 2 techniques: partitioned Mahalanobis D^2 ($\text{HSI}_{\text{Mahal}}$; Rotenberry et al. 2006) and Maxent (HSI_{Max}; Phillips et al. 2006). Both techniques have proven successful at discriminating used from unused locations for a variety of species when evaluated with independent presence-absence data (Elith et al. 2006, Tsoar et al. 2007). Nevertheless, model outputs can be highly sensitive to changes in spatial extent (Latif et al. 2013). We acknowledge that the original (1997–2004) and new (2010–2012) white-headed woodpecker data represented partially overlapping spatial extents, different sample sizes, and were collected using different sampling designs (Table 2). To reduce potential biases related to sampling design, we accounted for potential biases related to roads, sampling distribution, and sample size during model development and evaluation (Appendices S1–S3, available online at www.onlinelibrary.wiley.com). We used pixels containing >1 nest only once for modeling (404 nests were located within 376 pixels used for modeling). We plotted pixel HSI values (mean ± 1 SD) for each nest or point against environmental variables for 10,000 available pixels (for description, see Appendix S1) to identify habitat relationships (i.e., dose-response plots; Hanser et al. 2011).

Table 1. Variables used for development of Maxent and Mahalanobis D^2 models of habitat suitability for nesting white-headed woodpeckers, eastern Oregon, USA.

Variable name[a]	Description
Slope	Pixel slope as % rise over run
Cosine aspect	Pixel cosine-transformed orientation of slope (unitless)
Local-scale canopy cover	Percent canopy cover for 0.81-ha (3 × 3 cell) neighborhood
Landscape-scale canopy cover[b]	Percent canopy cover for 314-ha (1-km radius) neighborhood
Ponderosa pine[b]	Percent ponderosa-pine-dominated forest for 314 ha (1-km-radius) neighborhood
Edge density[b]	Length of edge between alternate patch types characterized according to canopy cover class (10–40% and 40–80%) within 314-ha (1-km radius) neighborhood.

[a] Variables derived from 30-m resolution land cover data collected in 2002 and 2012.

[b] 314-ha (1-km radius) neighborhoods approximated home range sizes for white-headed woodpeckers reviewed by Garret et al. (1996).

Mahalanobis D^2 model.—Mahalanobis D^2 model HSIs ($\text{HSI}_{\text{Mahal}}$ scores) portray standardized environmental distances (re-scaled $0-1$) from the multivariate mean for species presence locations (Appendix S2; Rotenberry et al. 2006). We constructed $\text{HSI}_{\text{Mahal}}$ models using 2–6 variables consisting of percent ponderosa pine, edge density, and every combination of the remaining 4 variables (Table 1; for their importance to white-headed woodpeckers, see Wightman et al. 2010, Hollenbeck et al. 2011). Variance partitioning can improve model performance and parsimony (Rotenberry et al. 2006, Preston et al. 2008) but not in this study, so we present only unpartitioned $\text{HSI}_{\text{Mahal}}$ models (i.e., those representing 100% of the variation described by each variable combination; Appendix S2). We selected the most parsimonious model (fewest variables) that achieved relatively high median nest $\text{HSI}_{\text{Mahal}}$ for further evaluation. We calculated median nest $\text{HSI}_{\text{Mahal}}$ scores for evaluation data withheld from model development (Appendix S2).

Maxent model.—Maxent models describe environmental distributions of species-use locations in terms of their differences from available locations (Phillips et al. 2006, Elith et al. 2011, Merow et al. 2013). Based on these differences, HSI_{Max} models estimate a relative probability of habitat selection. We fitted models to subsamples of nest location and availability data for which we adjusted sample

Table 2. Number of 30-m pixels (*n*) containing a nest and median nest habitat suitability index (HSI) scores (25th, 75th percentiles) from habitat suitability models for nesting white-headed woodpeckers in the Deschutes and Fremont-Winema National Forests, Oregon. Median scores are for original (1997–2004; Hollenbeck et al. 2011) and newly collected (2010–2011; this study) nest locations.

	1997–2004	2010–2011
n	340	36
Original model		
Mahalanobis	0.58 (0.27, 0.81)	0.36 (0.01, 0.60)
New models		
Mahalanobis	0.59 (0.36, 0.74)	0.61 (0.21, 0.87)
Maxent	0.47 (0.39, 0.55)	0.51 (0.45, 0.56)

sizes to balance fit across data subsets representing different time periods (Kramer-Schadt et al. 2013; Appendix S3). For HSI_{Max}, analysts are advised to favor simple models that perform comparably to more complex models to facilitate understanding of habitat relationships (Merow et al. 2013). We therefore developed HSI_{Max} models for only linear and quadratic relationships with the 6 habitat variables (Table 1). We verified that the simpler HSI_{Max} performed comparably to the most complex (fully parameterized) model.

Model Evaluation

Evaluation with nest location data.—We compared the original Hollenbeck et al. (2011) model to HSI_{Mahal} and HSI_{Max} models by comparing medians and quartiles (25th and 75th percentiles) for the corresponding HSI values assigned to nests from our 2 time periods (Table 2). Because others evaluate HSI_{Mahal} models based on the consistency of HSI_{Mahal} values assigned to used locations (Preston et al. 2008), we looked for greater consistency of nest HSIs across time periods as a sign of improvement over the Hollenbeck et al. (2011) model.

We further evaluated HSI_{Mahal} and HSI_{Max} models and HSI thresholds for classifying suitable habitat using performance metrics calculated with nest location data. We calculated sensitivity (the proportion of nest pixels correctly classified as high-suitability) and specificity (proportion of available pixels classified low-suitability) to evaluate HSI classification thresholds (Jiménez-Valverde et al. 2013). Sensitivity and specificity for alternate thresholds were calculated using nest locations withheld from model development (Appendices S2, S3). We identified thresholds that maximized predictive gain (PG = sensitivity – [1–specificity]; Browning et al. 2005), which also maximizes the sum of sensitivity and specificity (Liu et al. 2013). Using maximum PG thresholds, we categorized moderate-to-high-suitability habitat (HSIs > threshold; hereafter high-suitability habitat) or unsuitable-to-low-suitability habitat (HSIs < threshold; hereafter low-suitability habitat). Additionally, we evaluated several HSI thresholds at intervals of 0.05 above and below maximum PG thresholds to provide additional options for managers with varying goals.

In addition to threshold-based evaluation, we generated calibration plots to examine the extent to which nest prevalence (ratio of nest to available pixels) consistently increased with increasing HSI scores (Phillips and Elith 2010). We generated calibration plots using a dataset of nest and available pixels sampled following the same steps used to develop the HSI_{Max} model (Appendix S3).

Evaluation with point count data.—We used point count data and occupancy models to further evaluate our HSI models. We related the probability of white-headed woodpecker occupancy during the study period, adjusted for detection probability to HSI_{Mahal} and HSI_{Max} scores. We assumed that white-headed woodpeckers during the breeding season were more likely to occur and be detected at survey points within suitable nesting habitat. We used hierarchical occupancy models fitted within a Bayesian framework to estimate probability of occupancy for each survey point ($n = 580$; Royle and Kery 2007). This probability of a point being occupied was modeled as a function of maximum HSI_{Mahal} or HSI_{Max} values within 150 m of the survey point (the maximum distance of most detected birds) as covariates. We used static occupancy models for which repeat surveys of points throughout the study period informed estimation of detection probabilities (MacKenzie et al. 2002).

Probability of occupancy is modeled on a logit scale, so we used alternately scaled versions of HSI_{Mahal} and HSI_{Max} as continuous covariates (Appendix S4). Additionally, we used our HSI classification thresholds to generate categorical covariates to determine if probability of occupancy differed between high-suitability (1) and low-suitability (0) survey points. We used Bayesian *P*-values to assess the statistical support for HSI relationships with probability of occupancy ($P =$ proportion posterior samples of $\beta_{HSI} \leq 0$), whereby low *P*-values indicate statistical support for a positive relationship. All occupancy models included a random effect to account for variation in probability of occupancy among transects ($n = 58$; see also Royle and Kery 2007). All models also included a quadratic fixed effect of survey date and a random year effect as covariates of detection. We fitted occupancy models using JAGS (v. 3.3.0; Plummer 2003) accessed from R (v. 3.0.1; R Core Team 2013) via the R2jags package (Su and Yajima 2014). Additional details and rationale for occupancy models are provided in Appendix S4.

RESULTS

Areas used for nest searching and point count surveys were generally similar with respect to our 6 habitat variables (Table 3). Sites tended to have moderate slopes (9–12%) and comparable levels of canopy cover at the local and landscape scales (43–45%). Sites were consistently dominated by ponderosa pine (70–72%) and contained 64–68 m/ha of edge between open- and closed-canopy patches. Our data also indicated that most sites were on eastern aspects. Nests tended to occur in pixels with less slope, more north-facing aspect, less local-scale canopy cover, more ponderosa pine, and more edge than available sites (Table 3).

Nest Site HSI Comparison

HSI_{Mahal}.—Median nest HSI_{Mahal} values ranged from 0.463 to 0.581 across the 15 candidate models. Median nest HSI_{Mahal} values were highest for 4 models (0.56–0.58), of which we selected the most parsimonious (Table 4). The selected model included landscape-scale canopy cover, percent ponderosa pine, and edge density. The HSI_{Mahal} values were highest for pixels with moderate (25–50%) landscape-scale canopy cover, high percentage of ponderosa pine (>75%), and relatively high amounts of edge (>75 m/ha; Fig. 2).

HSI_{Max}.—The HSI_{Max} model that allowed only linear and quadratic relationships performed comparably to the model that allowed all possible relationships (Appendix S3). The most informative predictors in the simpler HSI_{Max} (selected for further evaluation) were percentage of ponderosa pine,

Table 3. Descriptive statistics (mean [SD]) for habitat variables at white-headed woodpecker nest locations (30-m pixels containing nests), at available locations (pixels sampled from the landscape within which nests were located), and points used for call-broadcast surveys. We drew half ($n = 5{,}000$) of available locations from areas where original nests (1997–2004) were located, and the remaining half from areas where new nests (2010–2011) were located.

Variable	Nest locations (n = 376)	Available locations (n = 10,000)	Survey points (n = 580)
Slope (%)	7.6 (8.0)	8.9 (10.2)	12.3 (11.0)
Cosine aspect	0.07 (0.66)	0.02 (0.66)	−0.14 (0.66)
Local-scale canopy cover (%)	40.1 (13.1)	43.1 (14.1)	44.6 (15)
Landscape-scale canopy cover (%)	43.2 (7.5)	43 (9.5)	44.5 (11.1)
Percent ponderosa pine	79.9 (15.0)	72 (19.4)	70.2 (18.4)
Edge density (m/ha)	73.4 (25.2)	67.5 (28.7)	64.1 (31.7)

and local- and landscape-scale canopy cover (Fig. 3). This model assigned higher HSIs to pixels as the percentage of ponderosa pine increased, at low to moderate levels (<40%) of local-scale canopy cover, and at moderate levels (25–50%) of landscape-scale canopy cover (Fig. 3).

Increasing percent ponderosa pine and moderate levels of canopy cover were consistently identified as high suitability white-headed woodpecker nesting habitat by both $\mathrm{HSI}_{\mathrm{Mahal}}$ and $\mathrm{HSI}_{\mathrm{Max}}$ models (Figs. 2 and 3). Habitat suitability indices were not related to slope or aspect. Both models assigned relatively low HSIs to areas with high local-scale canopy cover and low edge density. The models diverged at high edge densities, with $\mathrm{HSI}_{\mathrm{Max}}$ suggesting that nesting habitat suitability increases, whereas $\mathrm{HSI}_{\mathrm{Mahal}}$ indicated suitability declined. Additionally, at relatively low levels of local-scale canopy cover, $\mathrm{HSI}_{\mathrm{Max}}$ values remained stable, whereas $\mathrm{HSI}_{\mathrm{Mahal}}$ values declined.

Model Comparison and Evaluation

Nest location data.—Median nest $\mathrm{HSI}_{\mathrm{Mahal}}$ and $\mathrm{HSI}_{\mathrm{Max}}$ scores were more similar across datasets than median scores calculated from the original Hollenbeck et al. (2011) model (Table 2), indicating HSIs from our newer models were more general. At optimal (max. PG) thresholds (i.e., $\mathrm{HSI}_{\mathrm{Mahal}} = 0.31$, $\mathrm{HSI}_{\mathrm{Max}} = 0.46$) and some alternative thresholds, both models classified a majority of nest pixels (>60%) as high-suitability (Table 5) while also classifying a substantial portion of the landscape as low-suitability (specificity = 0.28–0.56 for thresholds with sensitivity >0.60; Table 5). The $\mathrm{HSI}_{\mathrm{Max}}$ model was more informative than the $\mathrm{HSI}_{\mathrm{Mahal}}$ model, however (predictive gain = 0.17 and 0.09 for optimal $\mathrm{HSI}_{\mathrm{Max}}$ and $\mathrm{HSI}_{\mathrm{Mahal}}$ thresholds, respectively). Additionally, nest prevalence was more clearly positively related with $\mathrm{HSI}_{\mathrm{Max}}$ compared to $\mathrm{HSI}_{\mathrm{Mahal}}$ scores (Fig. 4).

Point count data.—We detected white-headed woodpeckers during 144 of 1,950 survey visits at 111 of 580 points along 39 of 58 transects. Survey points were associated with a wide range of HSI values (mean [SD, min.–max.] $\mathrm{HSI}_{\mathrm{Mahal}} = 0.55$ [0.12, 0.11–0.84]; $\mathrm{HSI}_{\mathrm{Max}} = 0.44$ [0.32, 0.00–1.00]). The $\mathrm{HSI}_{\mathrm{Mahal}}$ outputs at point count locations were not related to probability of the site being occupied from the occupancy models (Fig. 5A). In contrast, we found a statistically supported positive relationship between $\mathrm{HSI}_{\mathrm{Max}}$ and probability of point count location being occupied (Fig. 5B). Three $\mathrm{HSI}_{\mathrm{Max}}$ thresholds were significantly related to probability of occupancy, whereas relationships were not supported for any $\mathrm{HSI}_{\mathrm{Mahal}}$ thresholds (Table 5). Occupancy models used to estimate these relationships provided a reasonable fit to the data and accounted for inter-annual and intra-seasonal variation in detectability, as well as variation among transects (Appendices S4, S5).

DISCUSSION

Habitat suitability models can serve as useful tools for predicting the distribution of white-headed woodpeckers during the nesting season. In particular, our $\mathrm{HSI}_{\mathrm{Max}}$ model appeared to outperform the $\mathrm{HSI}_{\mathrm{Mahal}}$ model in differentiating nest from available locations and predicting white-headed woodpecker occupancy of point count locations. Both $\mathrm{HSI}_{\mathrm{Mahal}}$ and $\mathrm{HSI}_{\mathrm{Max}}$ models characterized locations used and selected for nesting more generally than did the Hollenbeck et al. (2011) model. Nevertheless, $\mathrm{HSI}_{\mathrm{Max}}$ scores were better able to distinguish nest from available locations. Only $\mathrm{HSI}_{\mathrm{Max}}$ was clearly positively related to nest prevalence as indicated by calibration plots and significantly positively related with probability of white-headed woodpecker occupancy of a site estimated with independent data from point count surveys. Several $\mathrm{HSI}_{\mathrm{Max}}$ thresholds were also

Table 4. Variables and median nest habitat suitability index values ($\mathrm{HSI}_{\mathrm{Mahal}}$) for selected and alternative Mahalanobis D^2 models for nesting white-headed woodpeckers in eastern Oregon, 1997–2004 and 2010–2011. Means and standard deviations for median nest $\mathrm{HSI}_{\mathrm{Mahal}}$ are for 500 evaluation datasets withheld from model development. Variables included in each model are indicated with an x.

Slope	Cosine aspect	Local canopy cover	Landscape canopy cover	Ponderosa pine (%)	Edge density	Median nest $\mathrm{HSI}_{\mathrm{Mahal}}$ (SD)
Selected model						
			x	x	x	0.562 (0.147)
Other highest median nest $\mathrm{HSI}_{\mathrm{Mahal}}$ models						
x			x	x	x	0.581 (0.151)
		x	x	x	x	0.562 (0.16)
x		x	x	x	x	0.559 (0.17)
x	x		x	x	x	0.539 (0.162)
		x		x	x	0.537 (0.14)

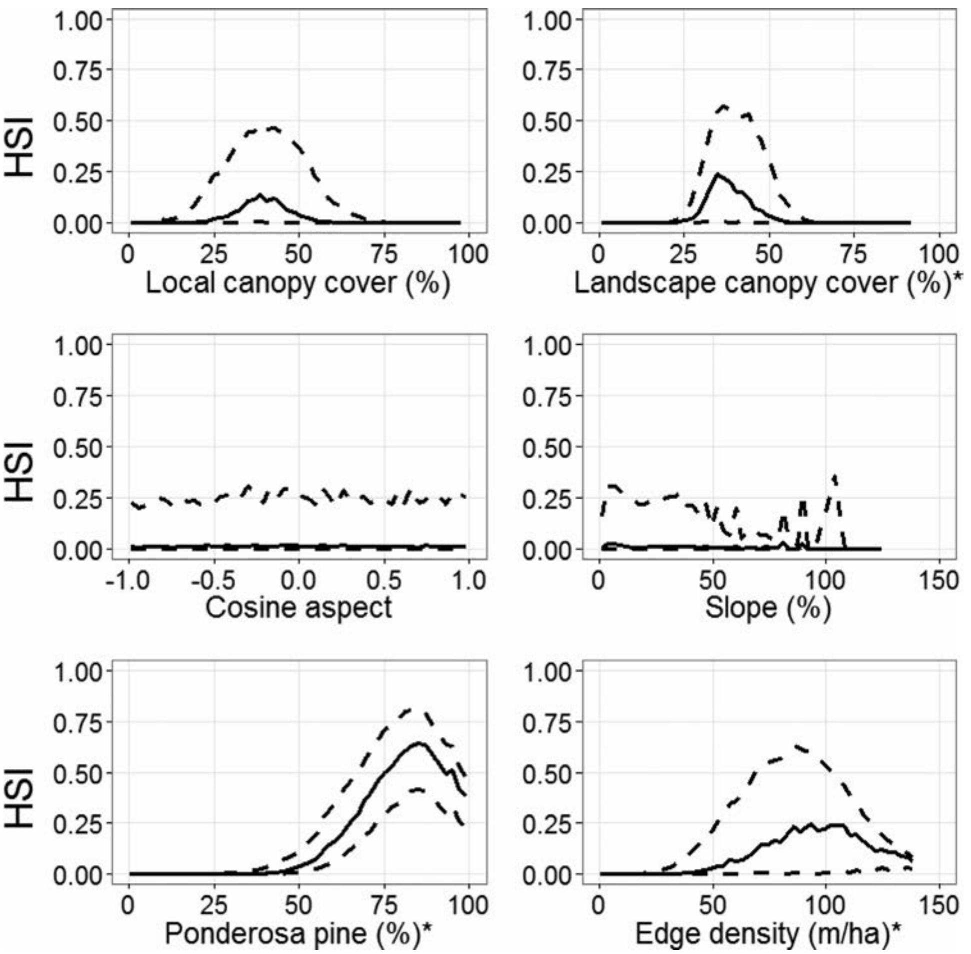

Figure 2. Mahalanobis D^2 model mean (solid line) ± standard deviation (dashed lines) habitat suitability index (HSI) values for nesting white-headed woodpeckers by environmental variables measured in eastern Oregon, 2002 and 2012. Asterisks indicate variables that were included in the final selected model.

significantly related to white-headed woodpecker occupancy of point count locations. Therefore, the $\mathrm{HSI}_{\mathrm{Max}}$ model appears better suited to inform the presence of white-headed woodpecker habitat for management in unburned forests of eastern Oregon.

Differences in model performance and habitat relationships emphasized between $\mathrm{HSI}_{\mathrm{Max}}$ and $\mathrm{HSI}_{\mathrm{Mahal}}$ models were possibly attributable to how the models quantified environmental relationships with nest locations. Heterogeneity in canopy cover is a key element of suitable nesting habitat for white-headed woodpeckers (Wightman et al. 2010, Hollenbeck et al. 2011). We quantified landscape heterogeneity using the edge density metric. Edge density, however, contributed minimally to the $\mathrm{HSI}_{\mathrm{Max}}$ model. Instead, $\mathrm{HSI}_{\mathrm{Max}}$ mainly reflected a negative relationship with local-scale canopy cover combined with a positive relationship with moderate levels of landscape-scale canopy cover. This combination is consistent with white-headed woodpecker nest placement in relatively open-canopied locations adjacent to more closed-canopied forests where nesting individuals presumably forage (Wightman et al. 2010, Hollenbeck et al. 2011). The $\mathrm{HSI}_{\mathrm{Mahal}}$ model quantified the average conditions at nest locations (i.e., habitat use) rather than the direction of habitat selection. Average canopy cover at nest locations did not differ across scales (Table 3), so $\mathrm{HSI}_{\mathrm{Mahal}}$ could not have portrayed the cross-scale trade-off in relationships with canopy cover.

Habitat selection models, such as $\mathrm{HSI}_{\mathrm{Max}}$, may be most effective for predicting species distributions that are mainly determined by habitat selection rather than other population attributes (e.g., dispersal, fitness). High abundance or low availability of desirable habitats may result in substantial use of less desirable habitats, lessening the influence of habitat selection on geographic distribution. Our results suggest use of marginal nesting habitat by white-headed woodpeckers is not substantial enough to negate the predictive value of habitat selection models.

Model Evaluation

Model evaluation criteria provided various insights for interpreting HSI models and extracting useful predictions. Sensitivity (proportion of nests correctly classified high-suitability) and specificity (proportion of the landscape classified low-suitability) provide information on the utility of HSI classification thresholds (Table 5). Lower thresholds designate more nest locations but also more of the landscape as habitat. Thus, lower thresholds are useful if land managers desire liberal estimates of habitat. In contrast, higher

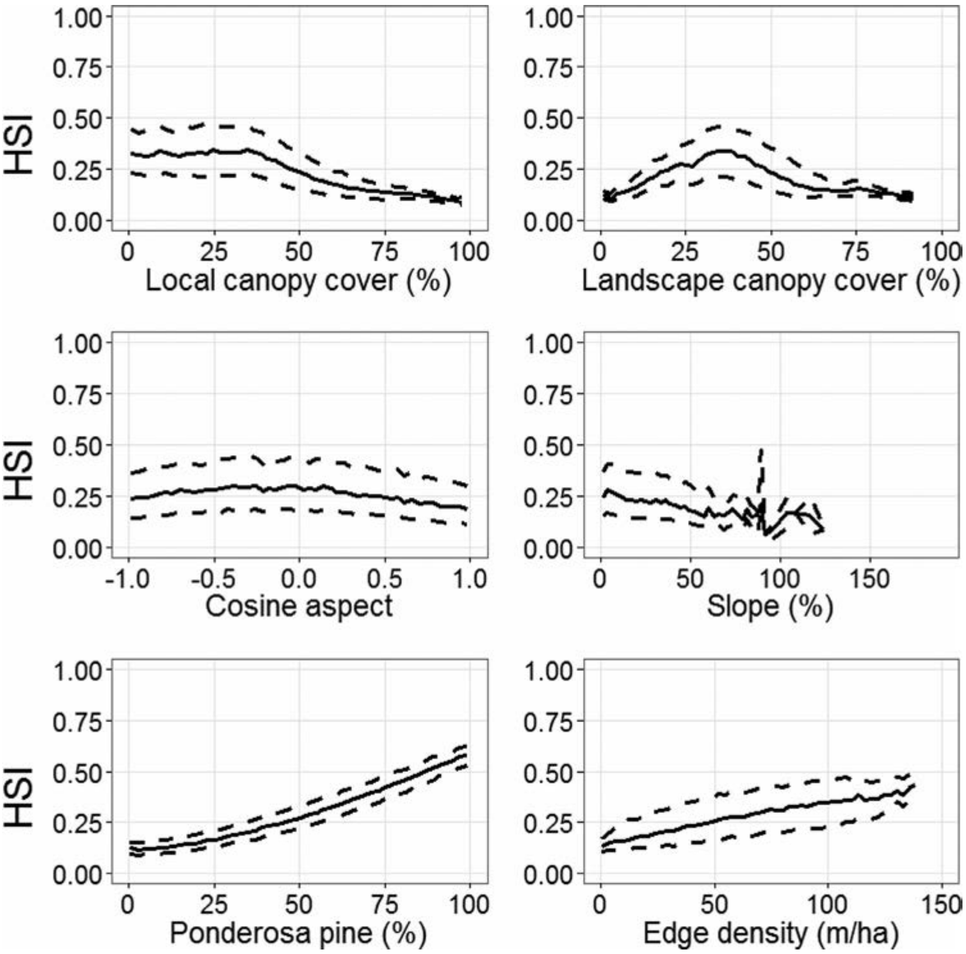

Figure 3. Maxent mean (solid line) and standard deviation (dashed lines) habitat suitability index (HSI) values for nesting white-headed woodpeckers by environmental variables measured in eastern Oregon, 2002 and 2012. We derived means by averaging across 10 replicate models that we used for mapping and evaluating HSIs. The percent contribution of each variable to the model (relative improvement in model fit attributed to the variable) is as follows: local-scale canopy cover = 29.9%, landscape-scale canopy cover = 15.7%, cosine aspect = 10.7%, slope = 0.4%, ponderosa pine = 40.8%, and edge density = 2.5%.

thresholds exclude more of the landscape but also more nest locations from the habitat designation. Thus, higher thresholds correspond to more conservative estimates of habitat. Some HSI_{Max} thresholds that were informative for discriminating nest from available pixels did not perform as well when evaluated with point count data (Table 5). Given that the focus of HSI_{Max} is to characterize habitat selection for nesting, however, we recommend selecting thresholds based upon criteria derived from nest data, that is, the sensitivity and specificity values that correspond with particular management goals. Our confidence in using HSI_{Max} to classify high-suitability versus low-suitability habitat is bolstered by the fact that multiple thresholds performed well when evaluated with independent point count data.

In addition to nest location data, which provided the clearest evidence of breeding habitat use, we also relied on point count data for model evaluation. We assumed that survey points at 300-m spacing were independent based on home range sizes (67–704 ha; Garrett et al. 1996). At this scale, we expected birds to more frequently occupy survey points in areas similar to highly selected or frequently used locations as indicated by the 2 HSI models we present. This expectation was supported by our data for HSI_{Max}.

Our results suggest consistency in habitat relationships between regions (i.e., East Cascades vs. Blue Mountains) and therefore some transferability of HSI models among areas. Although developed with nest location data from the East Cascade Mountains, HSI_{Max} successfully described habitat use at survey points located in both areas. Generality likely also benefited from using data collected during 2 time periods for model development. Our sample sizes, particularly in the Blue Mountains, however, were limited for detecting regional differences in HSI predictive performance. Additional nest locations from the Blue Mountains would be valuable for further evaluation and refinement of habitat suitability models presented here.

Reliance on remotely sensed data facilitated habitat suitability mapping with greater efficiency and coverage by reducing field effort. Remotely sensed data are limited, however, in their ability to capture fine-scale habitat features potentially important to white-headed woodpecker nesting. For example, we did not incorporate large-tree density despite its importance (Garrett et al. 1996, Hollenbeck et al.

Table 5. Habitat suitability index (HSI) thresholds for classifying low- and high-suitability habitat for nesting white-headed woodpeckers in eastern Oregon, 1997–2004 and 2010–2011. We report the proportion of nest pixels correctly classified highly suitable (sensitivity) and the proportion of the sampled landscape classified low-suitability (specificity; mean [SD] values for 500 and 50 evaluation datasets withheld from model development for Mahalanobis and Maxent models, respectively). We estimated occupancy probabilities with models fitted to point count data (median estimates with 90% Bayesian credible intervals in parentheses).

Model	Threshold	Proportion nests high-suitability	Proportion landscape low-suitability	Occupancy probabilities: Low-suitability points with HSIs < threshold	Occupancy probabilities: High-suitability points with HSIs > threshold
Mahalanobis D^2	0.21	0.799 (0.112)	0.275 (0.033)	0.38 (0.11, 0.98)	0.55 (0.28, 0.98)
	0.26	0.771 (0.12)	0.313 (0.033)	0.41 (0.12, 0.96)	0.57 (0.27, 0.98)
	0.31a	0.734 (0.125)	0.351 (0.032)	0.40 (0.09, 0.96)	0.61 (0.29, 0.99)
	0.36	0.693 (0.132)	0.388 (0.032)	0.40 (0.15, 0.95)	0.57 (0.28, 0.98)
	0.41	0.643 (0.141)	0.428 (0.032)	0.46 (0.18, 0.98)	0.57 (0.26, 0.99)
	0.46	0.596 (0.136)	0.47 (0.033)	0.42 (0.13, 0.97)	0.62 (0.28, 0.99)
Maxent	0.36	0.828 (0.098)	0.305 (0.067)	0.00 (0.00, 0.09)	0.07 (0.00, 0.71)**
	0.41	0.728 (0.121)	0.427 (0.061)	0.06 (0.00, 0.51)	0.50 (0.01, 0.95)**
	0.46[a]	0.610 (0.108)	0.562 (0.046)	0.35 (0.02, 0.93)	0.56 (0.24, 0.99)
	0.51	0.434 (0.110)	0.700 (0.026)	0.51 (0.19, 0.99)	0.54 (0.26, 0.99)
	0.56	0.295 (0.088)	0.828 (0.010)	0.33 (0.06, 0.87)	0.66 (0.33, 0.99)*

[a] Thresholds that maximized predictive gain = sensitivity – (1–specificity).

* Bayesian $P < 0.05$, indicating support for a positive β_{HSI} parameter describing the difference in occupancy probability from low- to high-suitability points.

** Bayesian $P < 0.01$. Bayesian $P > 0.15$ for remaining thresholds without any asterisks ($0.05 < P < 0.15$ never occurred).

2011) because of the poor accuracy of GNN-measured tree density (R^2 <0.3, LEMMA 2014), which likely explains its minimal contribution to earlier versions of models presented here (Hollenbeck et al. 2011). Alternative data sources with better resolution (e.g., LiDAR; Lefsky et al. 2002) may provide additional habitat variables useful for improving model predictive performance.

The HSIs we developed have utility for identifying areas to focus habitat conservation and restoration efforts. These HSIs, however, provide limited insight for designing silvicultural prescriptions to improve habitat suitability. Models that describe tree size and characteristics of canopy openings favored for nesting would be better suited for this purpose. Quantification of nesting habitat with sufficient detail to influence management prescriptions will require both remotely sensed and field-collected environmental data. Such models would be less useful for generating habitat suitability maps but could be combined with HSIs we developed here to provide comprehensive guidance for habitat restoration.

Our study provides models for evaluating how forest restoration or environmental changes (e.g., climate warming) could influence availability of suitable habitat for nesting white-headed woodpeckers. We presented HSI relationships with individual variables across the current landscape, but models that explore interactions of climate, vegetation, and fire are needed to predict future changes to the larger environment (Keane et al. 2011). Assuming no adaptation by the population, researchers could then predict changes to habitat suitability using projected environmental values.

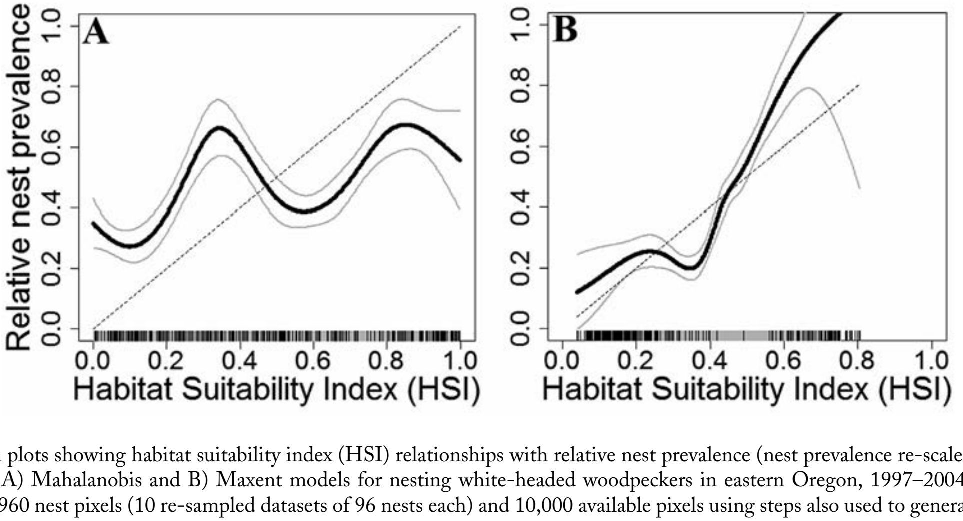

Figure 4. Calibration plots showing habitat suitability index (HSI) relationships with relative nest prevalence (nest prevalence re-scaled to a 0–1 range). We generated HSIs with A) Mahalanobis and B) Maxent models for nesting white-headed woodpeckers in eastern Oregon, 1997–2004 and 2010–2011. We generated plots using 960 nest pixels (10 re-sampled datasets of 96 nests each) and 10,000 available pixels using steps also used to generate data for developing the Maxent model. Calibration curves (black lines) ± 2 standard deviations (gray lines) are from isotonic least squares regression. A curve that lies along the diagonal (dotted line) would indicate an ideally calibrated model. Distributions of nest and available pixels are depicted by gray and black hatches, respectively, along *x*-axes.

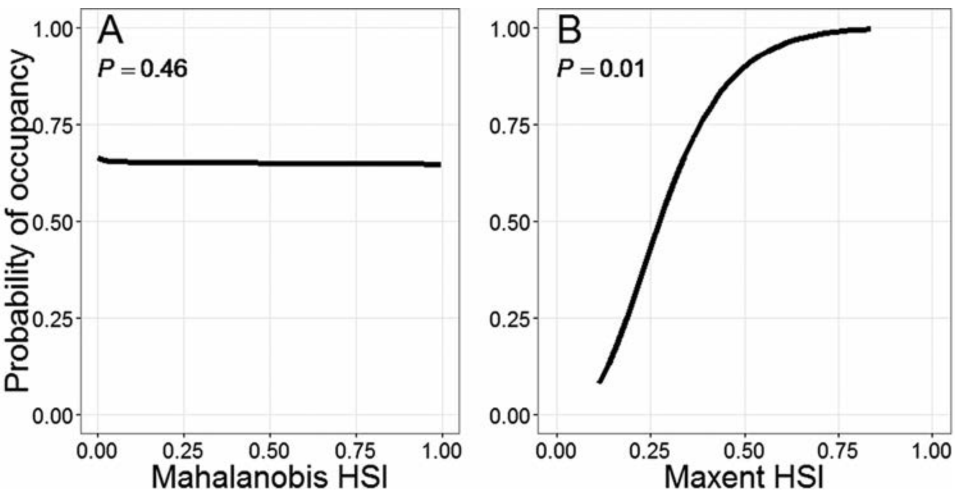

Figure 5. Relationships between probability of occupancy and either A) Mahalanobis D^2 habitat suitability index (HSI) or B) Maxent HSI. We estimated probability of occupancy with models based on point count data for nesting white-headed woodpeckers collected 2010–2012 in eastern Oregon. We report Bayesian *P*-values representing the statistical support for a positive relationship. A low *P*-value indicates most of the posterior mass for the slope parameter, β_{HSI}, corresponds with a positive relationship.

Relating HSIs with specific population attributes, such as occupancy rates, abundance, or population dynamics, would facilitate predictions of likely population responses expected with changes in habitat suitability.

MANAGEMENT IMPLICATIONS

To improve reliability and to effectively inform management, discrete HSI classifications may be more desirable than continuous HSIs. We identified several thresholds from which managers can choose to meet specific objectives. If a management goal is conservation of only the highest suitability habitat, we suggest using higher thresholds. Alternatively, if conservation is focused on providing the most acres of potentially suitable habitat, lower thresholds would be more appropriate. Restoration efforts could target lands with potential for habitat improvement identified by HSI scores below specified thresholds. Areas characterized as low-suitability would need to be field assessed to determine if management prescriptions would be beneficial. Additionally, because HSIs were in part derived from variables describing 1-km neighborhoods, management plans must take into account the area surrounding a location to maintain or improve habitat suitability at that location. Models presented here are based on areas in the Inland Pacific Northwest where white-headed woodpeckers require ponderosa pine forests (i.e., eastern Oregon and Washington, and western Idaho), and should be applied only in areas with at least some ponderosa pine (>10% within 314 ha). Alternative models would be needed in areas where ponderosa pine is not dominant (i.e., in California; Milne and Hejl 1989, Alexander and Burns 2006).

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site.

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File Code: 1920; 1560
Date: February 23, 2023

Honorable Samuel N. Penney
Chairman
Nez Perce Tribal Executive Committee (NPTEC)
P.O. Box 305
Lapwai, ID 83540

Dear Chairman Penney,

Thank you for your response to my message about continuing consultation and coordination on the Nez Perce-Clearwater Revised Forest Plan. As we prepare to enter the final phases of revision of our Land Management Plans, I would like to thank you and the Nez Perce Tribe's leadership, staff, and members for your significant contributions to date. Nearly every section of the plan has been shaped by the tremendous amount of time your staff have spent working through details and concerns with our staff. We could not have gotten to the place we are without the Tribe's input and expertise.

And yet we both acknowledge we have still work to do. As we continue formal government to government consultation with the Nez Perce Tribal Executive Committee, I would like to collectively develop a consultation process to ensure we can exceed our required obligations and truly craft a plan that embodies co-stewardship of the land and resources. In order to manage the Forest using modern science to address climate change and changing social values, we are striving to release our Final Environmental Impact Statement and start the Objection Period by July 2023. Given this timeframe, we are eager to re-engage at both government to government and staff to staff levels.

My staff has been working to develop a schedule for this stage of our consultation process that involves multiple steps to reinitiate conversations. I would like to begin with a NPTEC meeting to highlight to you and your directors the overall intent of the plan, how we have incorporated our tribal trust responsibilities and protection of treaty reserved rights into the plan at a broad level, and outline what work remains. As you requested in your message, I can provide a broad overview to you prior to this meeting. Following this initial meeting, I would ask that we direct our staffs to continue the conversation in focused meetings to discuss how their input has been incorporated and identify any remaining work left to do. We could then reconvene as leadership group to highlight the progress made, identify unresolved issues, and develop next steps and a timeline associated with resolution of those items.

If you are agreeable to this general framework for moving forward, I would further ask that we begin scheduling this series of meetings. It might be most helpful and efficient for us and our staffs if we consolidated this series of meetings and workdays in a solid block of time perhaps in April. If you have a different process you would like to use, I welcome that discussion.

As we prepare for consultation on the final plan, I am transmitting to you and your staff for review the following documents associated with my proposed decision:

- Revised 2023 Land Management Plan (my proposed decision)
- Appendix 1- Land Management Plan maps
- Appendix 2-Glossary
- Appendix 3-Monitoring Plan
- Appendix 4- Management Approaches
- Appendix 5-Nortern Rockies Lynx Management Direction (NRLMD)
- Appendix 6-Washer and Fish Appendix
- Appendix 7- Scenic Character
- Final Biological Assessment transmitted to the Fish and Wildlife Service and National Marine Fisheries Service for Section 7 ESA consultation on November 23, 2022

Thank you for welcoming follow-up with Mike Lopez, Nakia Williamson-Cloud, Aaron Miles Sr., Dave Johnson, and other staff ahead of the initial meeting with NPTEC to continue our work on tasks previously identified by the Nez Perce Tribe and Forest Service including:

- Draft language as a replacement to the Tribal Trust Responsibilities Standard FW-STD-TT-01.
- Drafting text with your Cultural Director conveying the importance of a wide variety of resources to the Nez Perce Tribe to be included as introductions in the revised plan.
- Using the conversations we have had in the All-Forest Meeting, Good Neighbor Authority Workshop, and other discussions to collaboratively develop the verbiage that promulgates co-stewardship as a foundational concept into the revised plan.
- Develop language better reflecting our shared vision for the future of Musselshell Meadows for incorporation in the plan as well as better describe the vision we've heard from Tribal gatherer groups for botanical resources and first foods and will share draft language with you at our first meeting.

We are entering a very exciting time. We will have unprecedented levels of funding and support to meaningfully move towards our desired conditions for both terrestrial and aquatic ecosystems. Development and implementation of co-stewardship as a new way of working together, using our Good Neighbor Authority agreement as a funding mechanism, I am confident we can continue to build a relationship that shows our desire to exceed our statutory and treaty requirements and work with the Tribe as equal partners. A revised Land Management Plan is essential to our future success. The 1987 plans have outlived their useful life and our ability to meet the Administration's and Congress's expectations of us is waning, along with our ability to develop new processes to implement co-stewardship. We look forward to crossing the finish line on forest plan revision with you.

Please reach out to me at cheryl.probert@usda.gov with any ideas, concerns or questions on the process. Technical questions and scheduling on our end will be routed to Forest Planner, Zach Peterson at zachary.peterson@usda.gov.

Sincerely,

CHERYL F. PROBERT
Forest Supervisor

Attachments: USB drive with attachments sent via US Postal Service

cc: Mike Lopez, OLC; Aaron Miles, Sr., Director, DNRM; Dave Johnson, Director, DFRM; Christine Bradbury, Tribal Relations

COHO SALMON MASTER PLAN
CLEARWATER RIVER BASIN

Prepared by

The Nez Perce Tribe

And

FishPro
A Division of HDR Engineering, Inc.

October 2004

Executive Summary

The Nez Perce Tribe has a desire and a goal to reintroduce and restore coho salmon to the Clearwater River Subbasin at levels of abundance and productivity sufficient to support sustainable runs and annual harvest. Consistent with the Clearwater Subbasin Plan (EcoVista 2003), the Nez Perce Tribe envisions developing an annual escapement of 14,000 coho salmon to the Clearwater River Subbasin.

The historical presence of coho salmon in the Clearwater River Subbasin was documented by Schoning (1940, 1947) and Fulton (1968). Nez Perce Tribe elders confirm that coho salmon were present in the mainstem Clearwater River as well as several tributaries, including the North Fork Clearwater River, Lochsa River, Selway River, and South Fork Clearwater River (Paul Kucera, Nez Perce Tribe Department of Fisheries Resources Management, Personal Communication). However, the construction of Harpster Dam in 1910 eliminated coho salmon access to the South Fork Clearwater River. In 1927, the Washington Water Power Diversion Dam was constructed just above the mouth of the Clearwater River. Fish passage facilities were not provided at the time of construction, and retrofitted ladders proved impassable for coho salmon, which were subsequently extirpated from the Clearwater River Subbasin. The Harpster Dam was removed in 1963, and the Washington Water Power Diversion Dam was removed in 1972. However, the North Fork Clearwater River remains inaccessible due to the construction of Dworshak Dam in 1972.

In 1994, the Nez Perce Tribe began coho reintroduction by securing eggs through *U.S. v. Oregon*; by 1998 this agreement provided an annual transfer of 550,000 coho salmon smolts from lower Columbia River hatchery facilities for release in the Clearwater River Subbasin. In 1998, the Northwest Power and Conservation Council authorized the Bonneville Power Administration to fund the development of a Master Plan to guide this reintroduction effort.

This Master Plan describes the results of experimental releases of coho salmon in the Clearwater River Subbasin, which have been ongoing since 1995. These data are combined with results of recent coho reintroduction efforts by the Yakama Nation, general coho life history information, and historical information regarding the distribution and life history of Snake River coho salmon. This information is used to assess a number of alternative strategies aimed at restoring coho salmon to historical habitats in the Clearwater River subbasin. These data suggest that there is a high probability that coho salmon can be restored to the Clearwater River subbasin. In addition, the data also suggest that the re-establishment of coho salmon could be substantially aided by: 1) the construction of low-tech acclimation facilities; 2) the establishment of a “localized” stock of coho salmon; and 3) the construction of hatchery facilities to provide a source of juvenile coho salmon for future supplementation activities.

The Nez Perce Tribe recognizes that there are factors which may limit the success of coho reintroduction. For example, incidental ocean and lower-river commercial harvest

and tribal and non-tribal fisheries, as well as passage at mainstem hydropower facilities will impose mortality on Clearwater River coho salmon. There is also uncertainty regarding the ability of coho salmon from the lower Columbia River to 1) develop and sustain the 500 mile inland migration to the Clearwater subbasin, 2) to spawn in habitat that is dissimilar to the lower Columbia River and 3) to produce viable progeny at a rate that will allow population persistence.

As a result of these uncertainties, the Nez Perce Tribe proposes to utilize a phased approach for coho reintroductions. This Master Plan seeks authorization and funding to move forward to Step 2 in the Northwest Power and Conservation Council 3-Step review process to further evaluate Phase I of the coho reintroduction program, which would focus on the establishment of a localized coho salmon stock capable of enduring the migration to the Clearwater River subbasin. To achieve this goal, the Nez Perce Tribe proposes to utilize space at existing Clearwater River subbasin hatchery facilities in concert with the construction of two low-tech acclimation facilities, to capitalize on the higher survival observed for acclimated versus direct stream released coho. In addition, Phase I would document the natural productivity of localized coho salmon released in two targeted tributaries within the Clearwater River subbasin. If Phase I is successful at establishing a localized coho salmon stock in an abundance capable of filling existing hatchery space, the rates of natural productivity are promising, and the interspecific interactions between coho and sympatric resident and anadromous salmonids are deemed acceptable, then Phase II would be triggered.

Phase II of the coho reintroduction plan would focus on establishing natural production in a number of Clearwater River subbasin tributaries. To accomplish this goal, Phase II would utilize existing Clearwater River subbasin hatchery facilities, and expand facilities at the Nez Perce Tribal Hatchery Site 1705 facility to rear approximately 687,700 smolts annually for use in a rotating supplementation schedule.

The estimated cost of implementing Phase I is $1,672,489, which includes: $100,498 for design, permitting and project administration; $154,284 for capital construction of proposed acclimation facilities; $576,213 for operations and maintenance; and $841,494 for research, monitoring, and evaluation. Component costs for Phase II will be estimated only if the Phase I indicators of success are achieved. The operations and maintenance and research, monitoring and evaluation costs are presently provided to the Nez Perce Tribe by the Pacific Coastal Salmon Recovery Fund through the Columbia River Intertribal Fish Commission. Other agencies, the Idaho Department of Fish and Game, United States Fish and Wildlife Service Lower Snake River Compensation Plan, the Oregon Department of Fish and Wildlife, and the National Oceanic and Atmospheric Administration Department of Fisheries Mitchell Act program provide eggs, fish, and rearing facilities. Costs have been further contained by using existing facilities, and locating juvenile releases to take advantage of existing monitoring programs and infrastructure.

In short, this document identifies a proposed alternative (Phase I), complete with estimates of capital, operations and maintenance, monitoring and evaluation, and permitting that is anticipated to raise average smolt replacement rates from 0.73 (current) to 1.14 using primarily existing facilities, with a limited capital investment for low-tech acclimation facilities. This increase in survival is expected to provide the opportunity for the establishment of a localized broodstock in the near-term, and provide the opportunity to establish natural production over the long-term. Phase II information is presented in this document to clearly articulate the long-term intent and vision of the coho salmon reintroduction program. Phase II would be proposed only if Phase I meets several indicators of success. If Phase I meets all identified indicators of success, authorization for Phase II funding would be pursued via a supplement to this Master Plan.

Finally, it should be noted that preliminary reintroduction efforts have resulted in the return of 3,738 mature coho salmon to Lower Granite Dam in 2004 alone (as of 1 November 2004; http://www.cbr.washington.edu/dart/dart.html).

Contents

Chapter 1: Introduction 1
- 1.1 The Purpose of the Master Plan 1
- 1.2 Relationship to Other Plans, Programs, and Projects in the Region 3
- 1.3 How to Use the Master Plan 9
- 1.4 Where to Find More Information 10
- 1.5 Organization of the Chapters 11

Chapter 2: Need for the Project 12
- 2.1 Need for Action 12
- 2.2 History and Status of Clearwater River Subbasin Coho Salmon – Limiting Factors 13
- 2.3 Ecological Significance of Coho Salmon in the Clearwater River Subbasin 15
- 2.4 The Nez Perce Tribe's Need 15
- 2.5 Lack of Mitigation for the Loss of Coho Salmon 18

Chapter 3: Proposed Alternative and Other Alternatives 20
- 3.1 Goals and Objectives of the Program 20
- 3.2 Description of the Existing Coho Production and Release Program 23
- 3.3 Phase I Alternatives 25
- 3.4 Selection of a Preferred Alternative 27
- 3.5 Description of the Proposed Reintroduction Program (Phase I) 30
- 3.6 Phase I Indicators of Success and Failure 32
- 3.7 Description of the Long-Term Coho Reintroduction Program (Phase II) 35
- 3.8 Harvest Management 39

Chapter 4: Proposed Phase I Facility Modifications and Operations 41
- 4.1 Existing Hatchery Facilities Producing Clearwater Coho Salmon 41
- 4.2 Phase I Proposed Acclimation Facilities 43
- 4.3 Facility Management 48
- 4.4 Proposed Production Program Summary 49
- 4.5 Budgets 51

Chapter 5: Research Monitoring and Evaluation 53
- 5.1 Coho Salmon Restoration Program Management Goals and Objectives 53
- 5.2 Assumption Associated with Management Objectives 53
- 5.3 Monitoring and Evaluation Goals and Objectives 55

Chapter 6: Background Information Used to Guide Coho Salmon Reintroduction 86
- 6.1 Management Context 86
- 6.2 Preliminary Reintroduction Results 86
- 6.3 Yakima Subbasin Coho Reintroduction 90
- 6.4 Guidance from Water Temperature, Habitat Preference, and Life History Data 93
- 6.5 Life History Characteristics of Grande Ronde Coho Salmon 94
- 6.6 Integration of Data Sources 95

Chapter 7: Limiting Factors 96
- 7.1 Harvest 96
- 7.2 Hatcheries 98
- 7.3 Mainstem Snake and Columbia River Hydrosystem 99

7.4 Habitat 100
7.5 Aquatic Species Richness 112

Appendix A. Project Management – Recommendations of the APRE………..……128

Tables

Table 1-1. Relationship of the coho salmon reintroduction program to Fish and Wildlife Program initiatives. 4
Table 1-2. Relationship of the coho salmon reintroduction program to legal and other initiatives. 6
Table 2-1. Counts of adult coho salmon at Lewiston Dam 1965 through 1972. 14
Table 2-2. Coho salmon counts at Lower Granite Dam from 1977 through 1987. 14
Table 3-1. Programmatic factors used to screen alternative coho salmon reintroduction strategies. 22
Table 3-2. Estimated adult return and juvenile production for the currently planned 2005 (Alternative 2; Status Quo) coho salmon releases in the Clearwater River Subbasin. 28
Table 3-3. Estimated adult return and juvenile production following implementation of Alternative 3. 29
Table 3-4. Estimated adult return and juvenile production following implementation of Alternative 4. 29
Table 3-5. Indicators of success for Phase I broodstock acquisition. 33
Table 3-6. Indicators of success for Phase I production, productivity, predation, and competition studies. 34
Table 3-7. Juvenile release and adult return schedule in stream sets included in the rotating supplementation schedule (listed years are arbitrary, and are provided for illustration purposes only). 37
Table 3-8: Alternative streams identified for potential supplementation using the rotating supplementation schedule. 37
Table 4-1. Literature standards and surface water quality measurements for proposed acclimation sites. 46
Table 4-2. Estimated budget for the construction of the proposed coho acclimation pond at the NPTH NLV satellite facility. 48
Table 4-3. Estimated budget for the modification of the existing Musselshell Pond. 48
Table 4-4. Estimated expenditures for the Clearwater River Coho Salmon Project. 51
Table 4-5. O&M and RM&E budget estimates for implementation of Phase I of the Nez Perce Tribe Clearwater River Subbasin coho salmon reintroduction project. 52
Table 5-1. Coho salmon production numbers for release into the Clearwater Subbasin. 57
Table 6-1. Summary of NPT juvenile coho releases in the Clearwater River subbasin. 88
Table 6-2. Summary of observed survival rates of NPT coho release groups. 90
Table 6-3. Number of coho salmon redds enumerated in the Potlatch River and Lolo Creek from 1999 through 2003. 90
Table 6-4. Counts of adult and jack coho salmon passing LGD from preliminary NPT coho salmon reintroduction efforts. 90
Table 7-1. BPA funded Clearwater River Subbasin habitat improvement projects expected to benefit coho salmon. 103
Table 7-2. Additional Clearwater River Subbasin habitat improvement initiatives expected to benefit coho salmon. 104
Table 7–3. Stream habitat conditions within the Clearwater River basin. 105
Table 7-4. Reintroduced native fishes present in the Clearwater River Subbasin. 113

Table 7-5. Native fishes of the Clearwater River Subbasin. 113
Table 7-6. Exotic fishes present in the Clearwater River Subbasin............................... 114

Figures

Figure 1-1. Map of the Clearwater River subbasin showing facilities and tributaries pertinent to the coho salmon reintroduction program. 2
Figure 2-1. Historical Nez Perce Tribe range and reservation sizes under the Treaty of 1855 and Treaty of 1866. 17
Figure 4-1. Preliminary design for the NLV coho acclimation facility at the NPTH. 47
Figure 7-1. Monthly average flow of the Lochsa River at Lowell. 107
Figure 7-2. Monthly average flow of the Selway River at Lowell. 107
Figure 7-3. Monthly average flow of the South Fork at Stites. 108
Figure 7-4. Monthly average flow of the Mainstem at Spalding. 108
Figure 7-5. Average maximum water temperature in the Mainstem Clearwater River at Spaulding, September 1 through November 30 for an 11 year period. 109
Figure 7-6. Average minimum water temperature in the Mainstem Clearwater River at Spaulding, September 1 through November 30 for an 11 year period. 109
Figure 7-7. Average maximum water temperature in the Mainstem Clearwater River at Orofino, September 1 through November 30 for a 4 year period. 110
Figure 7-8. Average minimum water temperature in the Mainstem Clearwater River at Orofino, September 1 through November 30 for a 4 year period. 110
Figure 7-9. Average water temperatures in Newsome Creek during the period 1990 through 1993. 111
Figure 7-10. Average water temperatures in Mill Creek during the period 1990 through 1993. 111
Figure 7-11. Tolerable and preferred temperature ranges for coho salmon. 112

Chapter 1: Introduction

In this chapter:

- The purpose of the Master Plan
- Relationship to other programs
- How to use the master plan
- Where to find more information
- Organization of the chapters

1.1 The Purpose of the Master Plan

The Northwest Power and Conservation Council (NPCC; formerly the Northwest Power Planning Council - NWPPC) requires Master Plans for new artificial production programs and facilities proposed to restore salmon populations throughout the Columbia River Basin. The purpose of a Master Plan is to provide the NPCC, program proponents, and others with the information they need to make sound decisions about whether the proposed program should move forward to design, construction, and operation.

In 1997, the NPCC adopted a 3-Step Review Process for new production initiatives:

- Step 1 – conceptual planning, primarily in the form of a Master Plan;
- Step 2 – preliminary design and cost estimation, National Environmental Policy Act (NEPA), and Endangered Species Act (ESA) review;
- Step 3 – final design review prior to new facility construction.

New production initiatives are generally defined as projects that propose to:

a) construct significant new production facilities;
b) begin planting fish in waters they have not been planted in before;
c) increase significantly the number of fish being introduced;
d) change propagated stocks or the number of propagated stocks;
e) change the location of production facilities; or
f) initiate funding of existing facilities with ratepayer funds that were formerly funded otherwise.

This Master Plan involves elements “c” and “f” listed above and fulfills the first step (Step 1) of the planning and approval process.

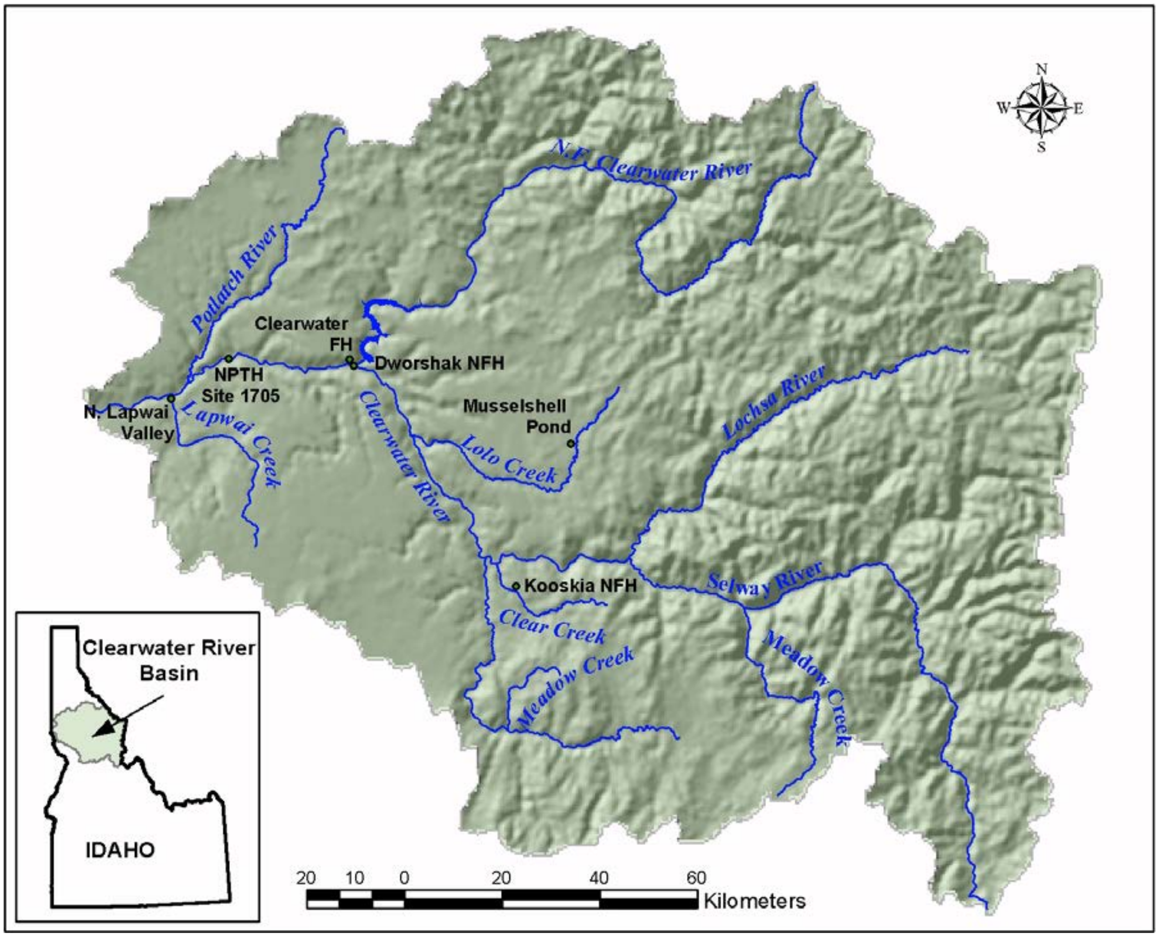

Figure 1-1. Map of the Clearwater River subbasin showing facilities and tributaries pertinent to the coho salmon reintroduction program.

This Master Plan details an integrated recovery program designed to guide the reintroduction of coho salmon (*Oncorhynchus kisutch*) to the Clearwater River Subbasin of Idaho (Figure 1-1), provide the potential for establishment of natural spawning aggregates of coho salmon in targeted watersheds within the Clearwater River Subbasin, and provide for tribal and recreational fishing opportunities.

Coho were declared extirpated from the Snake River Basin in 1986. The opportunity for reintroduction arose when parties to the *U.S. v. Oregon* process reprogrammed production at existing coho salmon hatcheries in the lower Columbia River (LCR). The Nez Perce Tribe (NPT) initiated a reintroduction program in the Clearwater River Subbasin with juvenile coho salmon releases in 1995. Funding for initial releases was obtained from the Bureau of Indian Affairs 638 funds. Monitoring and evaluation funding for initial releases was provided by the Pacific Coastal Salmon Recovery Fund. Since the reintroduction effort is consistent with the Mitchell Act Program, Mitchell Act funding was secured in 1999 and 2000.

In 1998, the (NPT) submitted a proposal for funding a Coho Master Plan to the Columbia Basin Fish and Wildlife Authority (CBFWA) in order to develop a restoration plan for Coho Salmon in the Clearwater River Subbasin. The NPCC authorized funding for the development of a Master Plan in November 1998 (November 13, 1998 letter to Bob Lohn, BPA Fish and Wildlife Division, from John Etchart, Chairman, NPCC). In doing so, the NPCC determined that the coho proposal would initiate the 3-Step Review Process. Once the Master Plan is submitted to the Council, the Step One review will be triggered.

1.2 Relationship to Other Plans, Programs, and Projects in the Region

The Master Plan for the reintroduction of coho salmon in the Clearwater River Subbasin must be consistent and work in concert with other efforts to restore salmon and steelhead in the Clearwater River Subbasin and throughout the Columbia River Basin. The consistency of this Master Plan to the many ongoing efforts is demonstrated in Tables 1-1 and 1-2.

Table 1-1. Relationship of the coho salmon reintroduction program to Fish and Wildlife Program initiatives.

Program/Plan	Manager	Relationship to Master Plan
Nez Perce Tribal Hatchery Operations and Maintenance (BPA 198335000)	NPT	The Nez Perce Tribal Hatchery would provide use of one or more of its satellite facilities for acclimation of coho salmon as well as staff and equipment support. Future expansion of NPTH (should Phase II of the proposed coho program be implemented) would provide coho incubation and rearing.
Nez Perce Tribal Hatchery Monitoring And Evaluation (BPA 198335003)	NPT	This project has been developed to monitor the results of NPTH Chinook salmon supplementation in order to optimize hatchery and natural production, sustain harvest, and minimize ecological impacts. Weirs and screw traps operated by the NPTH RM&E program would be used to monitor juvenile coho emigration and adult returns.
Salmon Supplementation Studies in Idaho Rivers (BPA 198909800, 198909801, 198909802, 198909803)	IDFG NPT USFWS SBT	The goal of this multi-agency effort is to evaluate the utility of supplementation as a recovery/restoration strategy for depressed stocks of spring and summer Chinook. Time series data on spring Chinook salmon condition factor would be used to determine whether competition resulting from the supplementation and subsequent natural production of coho salmon is negatively affecting sympatric spring Chinook salmon.
Idaho Natural Production Monitoring and Evaluation (BPA 199107300)	IDFG	This program monitors the abundance of anadromous salmonid populations using redd counts, carcass recoveries, juvenile emigrant trapping, and snorkel counts.
Protect and Restore Lapwai Creek Watershed (BPA 199901700)	NPT	This project includes several habitat improvement components including channel re-vegetation, riparian fencing, and culvert assessment/replacement. This habitat/watershed project will improve coho salmon spawning and rearing habitat in one of the primary watersheds identified for coho production releases.
Protect and Restore Lolo Creek Watershed (BPA 200002509)	NPT	This project includes several habitat improvement components including road obliteration, channel realignment, channel re-vegetation, riparian fencing, and off sight watering development. This habitat/watershed project will improve coho salmon spawning and rearing habitat in one of the primary tributaries identified for coho restoration.

Table 1-1. Relationship of the coho salmon reintroduction program to Fish and Wildlife Program initiatives.

Program/Plan	Manager	Relationship to Master Plan
Clearwater Focus Program (BPA 199608600, 199706000)	SCC/NPT	Coordination program to implement NWPCC Fish and Wildlife Program; habitat improvement projects ongoing in Idaho, Lewis, Nez Perce SWCD and Clearwater & Nez Perce National Forests; facilitate subbasin-wide Policy Advisory Group; initiated assessment in 1999.
Aquatic Resource Access Restoration	Clearwater NF, NPT	This project will replace culverts in four upper Lolo Creek tributaries (Mox Creek, Chamook Creek, Gold Creek and Musselshell Creek). Increased access to Musselshell Creek would benefit adult coho returning to this watershed from juvenile acclimation in Musselshell pond.

Table 1-2. Relationship of the coho salmon reintroduction program to legal and other initiatives.

Program or Plan	Requirement or Other Connection to Program	Coho Master Plan
Treaty of 1855	The Nez Perce Tribe reserved "The exclusive right of taking fish in all the streams running through or bordering said reservation ...and… taking fish at all usual and accustomed places …".	Restoration of salmon runs resulting from fish production in the proposed facilities would assist in meeting federal obligations to the Nez Perce Tribe.
U.S. v. Oregon	Treaty fishing rights litigation addressing Columbia Basin salmon and steelhead harvest and enhancement goals.	Proposed program would assist in meeting obligations and agreements under the lawsuit.
U. S. v. Oregon Fall Fishery Agreement 2000	Agreement by co-managers that the NPT would develop a coho reintroduction plan for the Clearwater River.	Fulfills agreement.
Scientific Review Team Review of Artificial Production (SRT; Brannon et al. 1999)	Independent scientific review of the Columbia Basin artificial production program, analysis of effectiveness in meeting mitigation responsibilities and enhancing salmonid production, and evaluation of supplementation of natural runs. Describes guidelines that provide the biological basis for NPCC policy on artificial production.	Proposed program is consistent with guidelines and recommendations developed by the SRT for artificial production facilities.
Artificial Production Review (APR; NPCC 1999)	NPCC report to Congress on the use of artificial production in the Columbia Basin that includes recommendations for policy reform and strategies for implementing new policies.	This master plan and the proposed program are consistent with APR recommendations and policies.

Table 1-2. Relationship of the coho salmon reintroduction program to legal and other initiatives (continued).

Program or Plan	Requirement or Other Connection to Program	Coho Master Plan
Pacific Northwest Power Planning and Conservation Act of 1980	This Act established the Northwest Power Planning Council for the purpose of mitigating for the development and operation of hydroelectric projects within the basin. The Council implements the Fish and Wildlife Program to protect, mitigate, and enhance fish and wildlife in the Columbia River basin.	The proposed program would be funded through the Fish and Wildlife Program.
Mitchell Act	The Mitchell Act authorized the Secretary of Commerce to implement salmon hatcheries in Oregon, Washington, and Idaho as a means to mitigate for salmon production lost as a result of the construction of the federal Columbia River hydro-power system.	Lower Columbia River Mitchell Act hatcheries have been reprogrammed to provide coho salmon smolts for release in upriver areas, including the Clearwater River Subbasin. These smolts are the basis for reintroduction efforts discussed in this Master Plan.
Pacific Coastal Salmon Recovery Fund	Established by Congress in FY2000 to provide grants to assist state, local, and tribal salmon recovery efforts, administered by NOAA Fisheries through CRITFC.	Has provided operations and maintenance funding for reintroduction effort. Results from the experimental program are used to quantify the feasibility of reintroduction effort and help determine the future program direction.
Lower Snake River Compensation Plan	The Lower Snake River Compensation Plan was authorized by Congress as part of the Water Resources Development Act of 1976. A major element of this plan provided funding for the design and construction of hatcheries to compensate for the loss of salmon and steelhead resulting from Federal hydropower development.	Although the Lower Snake River Compensation Plan is not legally mandated to compensate for the loss of coho salmon, the program has allowed the use of some existing facilities for coho production.

Table 1-2. Relationship of the coho salmon reintroduction program to legal and other initiatives (continued).

Program or Plan	Requirement or Other Connection to Program	Coho Master Plan
Wy-kan-ush-mi Wa-kish-wit: Spirit of the Salmon Tribal Recovery Plan (NPT *et al*. 1995).	Plan developed by the four Columbia River Treaty Tribes to restore fish runs.	The proposed program is recommended by the Tribal Recovery Plan. The plan sets a return goal of 14,000 adult coho salmon to the Clearwater River Subbasin.

1.3 How to Use the Master Plan

The NPCC has specific requirements including details about program goals and objectives, expected benefits, expected impacts, alternatives, historical information, consistency with other programs, and other information necessary for the NPCC, program proponents, and others to make decisions. In accordance with Section 7.4B of the Fish and Wildlife Program (NPCC 1994) this master plan addresses:

- project goals; (Section 3.1)
- measurable and time-limited objectives; (Section 3.6)
- factors limiting production of the target species; (Chapter 7)
- expected project benefits; (Chapter 2)
- alternatives for resolving the resource problem; (Section 3.3)
- rationale for the proposed project; (Chapter 6)
- how the proposed production project will maintain or sustain increases in production; (Section 3.5)
- the historical and current status of anadromous and resident fish in the subbasin; (Sections 2.2 and 7.5)
- the current (and planned) management of anadromous and resident fish in the subbasin; (Section 3.8)
- consistency of proposed project with Council policies, NOAA Fisheries recovery plans, and other fishery management plans; (Tables 1-1 and 1-2)
- potential impact of other recovery activities on the project outcome; (Section 7.4)
- production objectives, methods and strategies; (Section 3.5)
- broodstock selection and acquisition strategies; (Section 3.5)
- rationale for the number and life-history stage of the fish to be stocked, particularly as they relate to the carrying capacity of the target stream and potential impact on other species; (Section 3.5 and Chapter 6)
- production profiles and release strategies; (Section 3.5)
- production policies and procedures; (Section 4.2)

- production management structure and process; (Section 4.2)
- related harvest plans; (Section 3.8)
- constraints and uncertainties; (Section 3.1 and Chapter 7)
- monitoring and evaluation plans; (Chapter 5)
- conceptual design of the proposed production and monitoring facilities, including an assessment of the availability and utility of existing facilities; (Section 3.1 and Chapter 4)
- cost estimates for various components, such as fish culture, facility design and construction, monitoring and evaluation, and operation and maintenance (Chapter 4).

In addition to the items listed above, this Master Plan also addresses Artificial Production Review (APR) hatchery guidelines (Appendix A).

1.4 Where to Find More Information

The Master Plan contains general and technical information pertinent to the proposed program and alternatives. In addition to the information included in this Master Plan, many supporting documents have been completed during the preparation of the Clearwater River Subbasin Coho Salmon Master Plan:

- Ashe, B. and D.B. Johnson. 1996. Nez Perce Tribe implementation plan for reintroduction of cuhlii (coho salmon) (BY96) in the Clearwater River basin. Nez Perce Tribe Department of Fisheries Resources Management, Lapwai, ID.
- Johnson, D.B. and B. Ashe. 1997. Nez Perce Tribe implementation plan for reintroduction of cuhlii (coho salmon) (BY97) in the Clearwater River basin. Nez Perce Tribe Department of Fisheries Resources Management, Lapwai, ID
- Davenport, C. 2002. Pacific Coastal Salmon Recovery Fund Semi-Annual Report, for the period November 2001-May 2002.
- Davenport, C. 2002. Pacific Coastal Salmon Recovery Fund Annual Report, FY 2001-2002.
- Davenport, C. 2003. Pacific Coastal Salmon Recovery Fund Semi-Annual Report, for the period November 2002-May 2003.

1.5 Organization of the Chapters

- Chapter 2 describes the need for the program;
- Chapter 3 describes the proposed and other alternatives;
- Chapter 4 contains descriptions of proposed facilities and budgets for construction, design, operations and maintenance, research, monitoring, and evaluation, and permitting;
- Chapter 5 describes the research, monitoring, and evaluation plan;
- Chapter 6 provides background information used to formulate and evaluate alternatives; and
- Chapter 7 describes the factors limiting the natural sustainability of coho salmon in the Clearwater River Subbasin;

Chapter 2: Need for the Project

In this chapter:

- The need for action;
- Status of coho salmon in the Clearwater River Subbasin;
- Ecological significance of coho salmon;
- The Nez Perce Tribe; and
- Mitigation

2.1 Need for Action

The Nez Perce Tribe (NPT) motivation for implementing an integrated coho restoration program in the Clearwater River Subbasin arises from the recognition that:

- coho salmon were historically present in the Clearwater River Subbasin and are a natural feature of this complex ecosystem;
- the treaty signed by the United States government with the NPT in 1855 reserved harvest rights for the NPT;
- cuhlii (coho) salmon are of cultural importance to the NPT; and
- the loss of coho salmon from the Snake River Basin remains unmitigated.

Thus, the NPT believes that integrated restoration of coho salmon in the Clearwater River Subbasin is warranted ecologically, legally, and culturally. The factors motivating the NPT to undertake coho reintroduction are not unprecedented. As discussed in section 6.3, the Yakama Nation (YN) recently undertook a similar coho reintroduction in mid-Columbia River subbasins.

In addition, these efforts are consistent with the recently released report of the Artificial Production Review and Evaluation (APRE; NPCC 2003), which states:

> *"Hatcheries could be used to enhance biodiversity by producing a wider variety of salmonid species and life histories. Greater species and life history diversity makes sense ecologically and could provide greater harvest opportunities by enhancing adult returns over a longer time period."*

2.2 History and Status of Clearwater River Subbasin Coho Salmon – Limiting Factors

NPT elders confirm the historical presence of coho salmon in Clearwater River Subbasin tributaries including the Clearwater River, North Fork Clearwater River, Lochsa River, Selway River, and South Fork Clearwater River (Paul Kucera, Nez Perce Tribe Department of Fisheries Resources Management, Personal Communication). Schoning (1940, 1947) and Fulton (1968) also document that residents of the area caught coho salmon in the Clearwater River Subbasin.

Salmon runs in the Clearwater River Subbasin were virtually eliminated by the construction of hydroelectric dams (Mathews and Waples 1991). In 1910, the Harpster Dam, constructed on the lower South Fork Clearwater River, prevented all fishes from returning upstream of Harpster, ID, and eliminated access to over 95% of the watershed and its high quality spawning grounds (Schoning 1940). In 1927, the Washington Water Power Diversion Dam constructed just above the mouth of the Clearwater River eliminated all upriver salmon runs (Parkhurst 1950; USFWS 1962). A crude fish ladder was built on the lower Clearwater River dam, which allowed steelhead passage during higher flow periods, but proved almost impassible during lower flows when salmon arrived (Parkhurst 1950). The ladder was not modified for a period of 12 to 14 years; eliminating all late returning fish, like coho and fall Chinook salmon.

The cumulative loss of anadromous fish to the NPT as a result of these two dams was substantial (Cramer *et al*. 1993). The Harpster Dam was removed in 1963 and the lower Clearwater River dam was removed in 1972, making available most of the salmon production areas in the drainage. However in 1971, Dworshak Dam was built just upstream of the mouth of the North Fork Clearwater River. Dworshak Dam lacks fish passage, resulting in the permanent loss of productive salmonid spawning aggregates and high quality habitat. The lower Clearwater River temperature regime continues to be altered by Dworshak Dam, resulting in warmer water in the winter and cooler water in the summer (Arnsberg *et al*. 1992, Arnsberg and Statler 1995).

From 1962 through 1968, the Idaho Department of Fish and Game (IDFG) attempted to reintroduce coho salmon in the South Fork Clearwater River using hatching channels at Meadow Creek, Red River and Crooked River on the South Fork Clearwater River. A total of 11 million eggs were planted from Eagle Creek National Fish Hatchery (ECFNH), Spring Creek National Fish Hatchery (SCNFH), Abernathy Fish Hatchery (AFH), the Little White Salmon National Fish Hatchery (LWSNFH), and the Washougal National Fish Hatchery (WNFH). These efforts were largely unsuccessful due to ice formation, de-watering, (Richards 1967, Gray 1969), flooding, and siltation (Richards 1966). However, some coho adults were counted at Lewiston Dam from 1965 until 1972, apparently as a result of this program (Table 2-1). Despite the challenges faced by this program, adult coho did return to the Clearwater River Subbasin even with harvest rates of 30-40% in the lower Columbia River and the construction of four mainstem Snake River dams during this period (Ice Harbor, 1961; John Day, 1968; Lower Monumental, 1969; and Little Goose, 1970). Coho salmon were observed spawning in Three Mile Creek, a tributary of the South Fork Clearwater River in November 1968 (Richards

1969). However, systematic monitoring of naturally spawning coho was never undertaken by the IDFG. In 1986, coho were considered extirpated in the Snake River basin (including the Clearwater River Subbasin), as evidenced by subsequent zero counts at Lower Granite Dam (Table 2-2; http://www.cbr.washington.edu/dart/dart.html).

Table 2-1. Counts of adult coho salmon at Lewiston Dam 1965 through 1972.

Year	Adult Coho Salmon
1965	21
1966	115
1967	43
1968	325
1969	31
1970	40
1971	61
1972	9

Table 2-2. Coho salmon counts at Lower Granite Dam from 1977 through 1987.

Year	Adult Coho	Jack Coho
1977	267*	n/a
1978	152*	n/a
1979	158*	n/a
1980	30*	13
1981	1*	16
1982	31*	28
1983	25*	26
1984	0	0
1985	1	0
1986	1	0
1987	0	0

*Coho salmon enumerated in these years may have been returning to the Grande Ronde River Subbasin.

Since the demise of the IDFG coho reintroduction program in 1968, the only coho program operating in the Snake River basin was initiated by the NPT in 1995 (see section 6.2).

Currently, the primary factors expected to limit the success of coho reintroduction include habitat degradation, passage mortality (juvenile and adult), ocean and in-river fisheries, and periods of poor ocean productivity. Numerous habitat restoration initiatives are underway in the Clearwater River Subbasin (see Section 7.4), however it is difficult to quantitatively evaluate the potential direct benefits of these activities for coho salmon. As mentioned previously, the two dams largely responsible for the extirpation of coho salmon have been removed. However, coho salmon returning to the Clearwater River Subbasin must pass eight mainstem hydropower dams; likewise their progeny must successfully navigate these structures during emigration. Although there is considerable debate regarding the quantification of mortality imposed by Snake and Columbia River hydropower facilities, it is generally agreed that these structures limit the sustainability of natural production in upriver areas (NPCC 2001). Finally, in-river and ocean fisheries will impact adult return rates through incidental harvest in selective fisheries and ocean harvest. Given that indicator stocks for Clearwater River Subbasin coho are not available, it is difficult to estimate the potential effects of harvest. However, the RM&E plan (Chapter 5) details a strategy to quantify the effects of harvest by comparing adult returns for double index marked and unmarked release groups.

2.3 Ecological Significance of Coho Salmon in the Clearwater River Subbasin

Salmonids are notable for their diversity of life history strategies, sympatric distribution, contribution to ecological processes, and genetic variation. These factors contribute to salmonid productivity and persistence (Independent Scientific Group 1996). Recently, researchers have recognized that salmon are a key contributor to ecosystem processes in the streams that they inhabit, and the same processes that increase salmonid resiliency likely serve to increase the resiliency of the ecosystems they occupy. A growing number of studies document the importance of marine derived nutrients to the ecosystems that salmon inhabit (*e.g.*, Cederholm *et al*. 1999). Decomposing salmon carcasses are now recognized as a source of marine-derived nitrogen that in large part determines the nature of the food web in a stream, which in turn determines the growth and survival of young salmon (Gresh *et al*. 2000). For example, Bilby *et al.* (1998) found a positive relationship between marine derived nitrogen and smolt production. Similar observations have been made in individual river systems from Alaska to Washington (Piorkowski 1997, Larkin and Slaney 1997, Bilby *et al*. 1996, Kline Jr. *et al*. 1993, and Mathisen 1972).

Given that the abundance of salmonids returning to the Clearwater River Subbasin has decreased dramatically over the last century, the attendant decrease in marine derived nutrients may be negatively affecting the production capacity of streams and those components of forest ecology that rely on in-stream productivity. It follows that successful reintroduction of coho salmon may have ecosystem benefits beyond the simple restoration of a historical ecosystem component.

2.4 The Nez Perce Tribe’s Need

The NPT was one of the largest Plateau tribes in the Northwest (Walker 1978; Figure 2-1). Historically, they occupied a territory of over 13 million acres that included what is today North central Idaho, Southeastern Washington and Northeastern Oregon. The persistence of the NPT can be attributed in large part to the abundance of salmon, which has served as a primary food source, trade item and cultural resource for thousands of years. The economy and culture of the NPT evolved around Northwest salmon runs. Despite recent declines in the abundance of salmon, the culture of the NPT remains strongly tied to salmon.

The degree to which the NPT is culturally coupled to salmon was recognized in treaties signed between the tribe and the United States Government. The same treaties that confined the NPT to a fraction of their former territory also guaranteed their access to salmon resources. Article three of the treaty of 1855 guarantees to the tribe:
"The exclusive right of taking fish in all the streams running through or bordering said reservation … as also the right of taking fish at all usual and accustomed places in common with citizens of the Territory."

No subsequent treaty or agreement between the NPT and the United States altered this treaty-reserved right. These treaty-reserved fishing rights are the legal basis for the tribe's involvement, as co-managers, in salmon restoration efforts throughout their former range.

In 1905, the United States vs. Winans case established what a "right" implied. The case involved a non-tribal member who attempted to prevent tribal members from fishing at a traditional site by buying and then claiming absolute title to the land (American Indian Resource Institute 1988). The Supreme Court ruled against this claim and established two important precedents. First, hunting and fishing rights are not rights granted by the government to tribal signatories, but rather they are rights reserved by the tribes in exchange for lands (American Indian Resource Institute 1988). Second, tribal members cannot be barred from accessing their usual and accustomed fishing sites since their reserved right is essentially an easement over private as well as public lands (Cohen 1982).

In 1974, a case tried in Washington Federal District Court established what was meant by the right of tribes to harvest fish "in common" with the citizens of the territory. Judge Boldt determined that two distinct entities were involved during treaty making, Indian tribes and the United States, not just individual tribal members and individual citizens of the state (American Indian Resource Institute 1988). The separation of two political entities effectively denied the assertion that all citizens have the same rights with respect to harvesting fish.

The understanding that there are only two entities involved was then applied to the allocation of harvestable fish. The court interpreted "harvest in common" as an equal distribution between the two entities (American Indian Resource Institute 1988). Judge Belloni applied the 50/50 principle to Columbia River fisheries in *U.S. v. Oregon* in 1975 (Nez Perce Tribe *et al.* 1995). In their treaties ceding land to the United States, the NPT had reserved the right to harvest fish in a manner that allows them to maintain a way of life. But although the rights to take fish and regulate the fishery resource have been clearly upheld in numerous courts, these rights are meaningless if there are no fish to be taken or resources to be managed (Nez Perce Tribe *et al*. 1995).

The legal, historic, economic, social, cultural, and religious significance of salmon to the NPT continues today. This Master Plan is a product of the tribe's continued dedication to restoring salmon runs throughout their usual and accustomed territories.

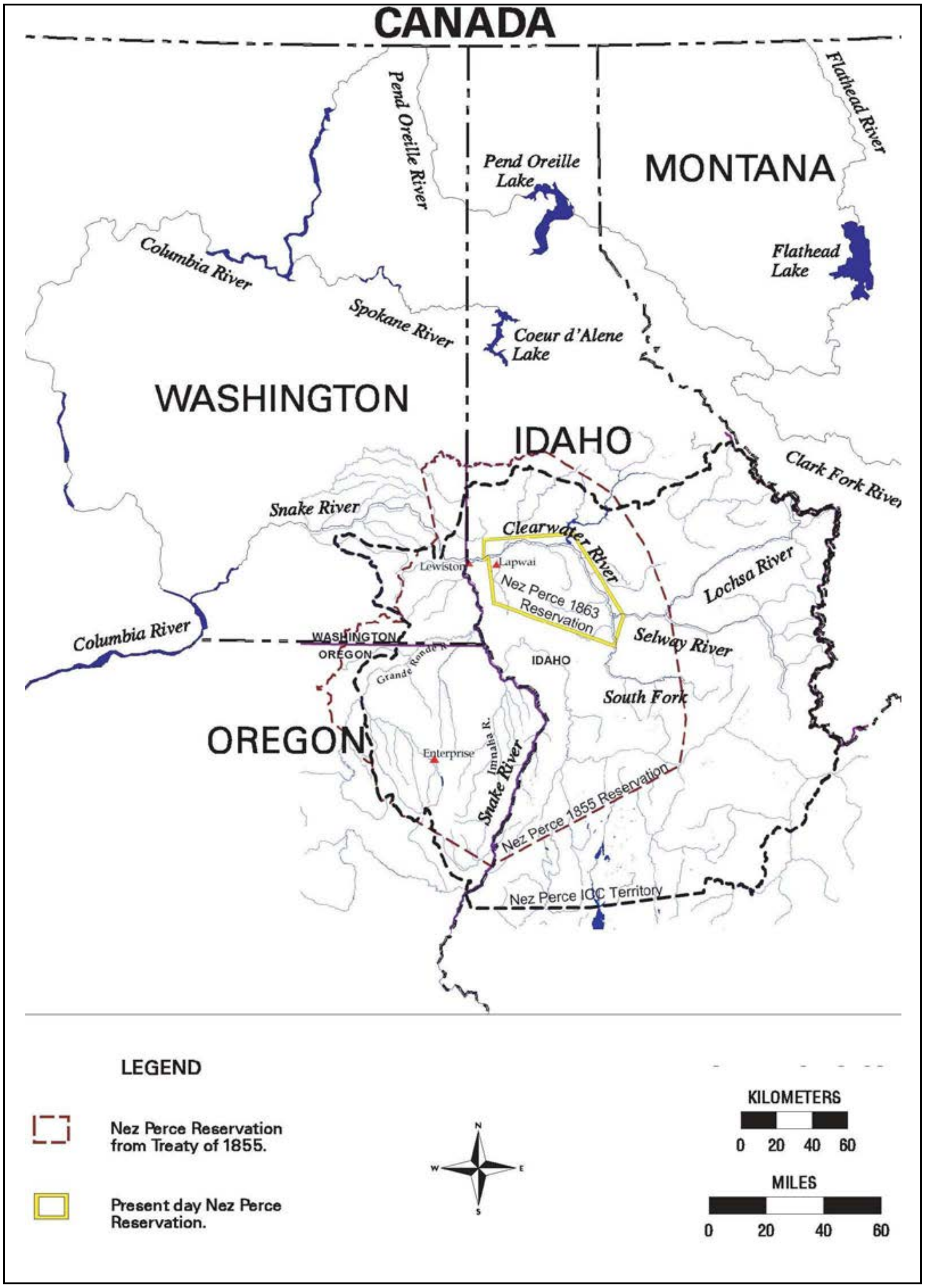

Figure 2-1. Historical Nez Perce Tribe range and reservation sizes under the Treaty of 1855 and Treaty of 1866.

2.5 Lack of Mitigation for the Loss of Coho Salmon

With the exception of a reintroduction attempt by the Idaho Department of Fish and Game from 1962 to 1968 coho salmon have been missing from the Clearwater River Subbasin since their initial extirpation in 1927. The loss of coho salmon has yet to be effectively mitigated. Within the Columbia River Basin, two federal hatchery programs produce salmon to mitigate for the construction and operation of Federal hydropower dams: the Lower Snake River Compensation Plan (LSRCP) and Mitchell Act program. In addition, the Nez Perce Tribal Hatchery, funded by the Bonneville Power Administration Fish and Wildlife Program, was constructed for the purpose of spring and fall Chinook salmon mitigation, and this facility does not currently produce coho salmon.

The LSRCP program was enacted in 1945, when Congress passed Public Law 74, authorizing the construction of four dams on the lower Snake River to provide hydroelectric power generation and navigation (Armacost 1979). These dams (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite) were constructed from 1961-1975. From 1962 to 1975, there was a significant drop in adult migration. It was estimated by federal and state fish and wildlife agencies that the four dams would result in a 48 percent reduction in annual production of Chinook salmon above Lower Granite Dam (U.S. Army Corps of Engineers 1975). To compensate for this loss, Congress authorized the Lower Snake River Compensation Plan (LSRCP) in 1976 (Public Law 94-587) to mitigate for losses of salmon, steelhead and other resources that resulted from construction of the four lower Snake River dams. However, since coho salmon had already been extirpated from the Clearwater River Subbasin they were not included in the plan; and thus not mitigated for.

The Mitchell Act (16 U.S.C. §§ 755-757, May 11, 1938. as amended in 1946) authorized the Secretary of the Interior to carry on activities to conserve fishery resources in the Columbia River Basin. The act authorizes research, surveys, and implementation of methods to improve salmon feeding, spawning, and migration. In practice, the act has funded a number of hatchery programs intended to enhance harvest opportunities within the Columbia River Basin. Unfortunately, most of the facilities constructed under the Mitchell Act are located on the Lower Columbia River, an inequity that is particularly apparent for coho salmon as noted by the APRE (NPCC 2003):

> *“A sizeable majority of Columbia River Basin hatchery production takes place in the lower three provinces. Unfortunately, the communities most affected by the construction of the dams do not share equally in this production.”*

The Nez Perce Tribe coho reintroduction program was made possible as a result of agreements in the *U.S. v. Oregon* forum that reprogrammed Lower Columbia River Mitchell Act hatcheries to produce coho salmon for release in the Clearwater River Subbasin. The LSRCP program has contributed to NPT efforts by providing space at the Clearwater Fish Hatchery per a Memorandum of Understanding valid through 30

September 2008. The Corps of Engineers and the United States Fish and Wildlife Service have contributed to the program by providing the use of Dworshak National Fish Hatchery and Kooskia National Fish Hatchery per a Memorandum of Understanding valid through 30 September 2008.

Chapter 3: Proposed Alternative and Other Alternatives

In this chapter:

- Goals and objectives of the program
- Description of the current program
- Development of Phase I alternatives
- Selection of a preferred alternative
- Description of the proposed alternative (Phase I)
- Phase I indicators of success and failure
- Description of the long-term program (Phase II)
- Harvest management

This chapter describes goals and objectives developed for the Clearwater River Subbasin coho program as well as a phased strategy for implementing the reintroduction and restoration program. These goals and objectives are consistent with the Nez Perce Tribes' vision of restoring all fish species native to the Nez Perce Indian Claims Commission (ICC) Treaty territory (Figure 2-1).

3.1 Goals and Objectives of the Program

The Nez Perce Tribe's overall goal is to reintroduce and restore coho salmon to the Clearwater River Subbasin at levels of abundance and productivity sufficient to support sustainable runs and annual harvest. Consistent with the Clearwater Subbasin Plan (EcoVista 2003), the Nez Perce Tribe (NPT) envisions an annual escapement of 14,000 coho to the Clearwater River Subbasin. Based on results from the existing Clearwater River Subbasin coho reintroduction program and experience in managing anadromous fish populations in the Snake River Basin, the Nez Perce Tribe believes this program will require a substantial hatchery production component (at least in the near-term) and the establishment of highly productive naturally spawning coho salmon aggregates.

The Nez Perce Tribe developed measurable and time limited management objectives aimed at achieving the overall goal of the program. These include:

- Establish a localized Clearwater River coho salmon broodstock.

- Establish natural spawning populations of coho salmon in the Clearwater River Subbasin.

- Utilize hatchery production to achieve optimal production effectiveness while meeting priority management objectives for natural production enhancement, diversity, harvest, and minimizing impacts to non-target populations.

- Restore and maintain treaty-reserved tribal and recreational fisheries.

- Monitor and evaluate program activities and communicate program findings to resource managers.

Because the Clearwater River Subbasin coho salmon reintroduction/restoration program is experimental and uncertainties exist about whether an extirpated salmon species can be reintroduced and restored to healthy abundances 500 miles from the ocean above eight mainstem hydroelectric dams using donor stock from the Lower Columbia River, the Nez Perce Tribe decided to develop the reintroduction program in two distinct Phases.

Phase I: Focus on establishing a localized Clearwater River coho salmon broodstock and meeting broodstock needs.

Phase II: Focus on establishing naturally spawning populations of coho salmon in the Clearwater River Subbasin.

The Nez Perce Tribe considered several alternative strategies to achieve its management objectives. The development of these alternative strategies was guided by information from:

- Preliminary Nez Perce Tribe coho reintroduction efforts to date (Section 6.2)

- Results from coho reintroduction in mid-Columbia River tributaries (Section 6.3),

- Coho salmon life history characteristics (Section 6.4), and

- Historical data and life history information for coho salmon in the Grande Ronde River Subbasin (Section 6.5).

From these data sources, the NPT has developed a number of guiding principles that were used to screen alternative strategies and identify a preferred strategy for implementing Phase I. Guiding principles are listed below, and are accompanied by a reference to the section(s) in this Master Plan with background information:

- Acclimation and volitional release provide a survival advantage over direct stream releases of juvenile coho salmon (Sections 6.2 and 6.3) and may provide the added benefit of decreasing in-river densities by extending the period of emigration relative to direct releases.

- Establishing a localized stock of coho salmon (Clearwater Localized Stock - CLS) will increase smolt to adult return rates (Section 6.3).

- Release of juvenile coho salmon at the smolt life history stage increases survival and decreases the potential for competition and predation compared to releases at earlier life history stages (Section 6.2).

- In the short-term, selecting juvenile acclimation and release points closer to the mouth of the Clearwater River will increase adult capture probabilities, compared to more upstream release points (Section 6.2).

In addition to the biologically based guiding principles, a number of programmatic factors were used to screen alternative strategies (Table 3-1).

Table 3-1. Programmatic factors used to screen alternative coho salmon reintroduction strategies.

A maximum of 550,000 smolts are available annually from LCR hatcheries for transfer and subsequent release within the CRS.	
Existing hatchery facilities in the Clearwater River Subbasin that can be utilized to rear coho are currently limited to:	
Clearwater Anadromous Fish Hatchery (CAFH)	CAFH has space available to rear up to 270,000 progeny to the presmolt stage. Juvenile coho salmon must be removed from CAFH no later than September 15th to avoid conflicts with steelhead production.
Dworshak National Fish Hatchery (DNFH)	DNFH has space available to hold at least 502 adults, spawn them, and rear up to 280,000 smolts.
Nez Perce Tribal Hatchery (NPTH) Site 1705	The NPTH Site 1705 facility has S-shaped NATUREs channels that can be used from October 1 through March 15. These channels could be used to grow presmolts from CAFH to the smolt life history stage prior to either on-station release into the mainstem Clearwater River or off-station releases.
Existing hatchery facilities in the Clearwater River Subbasin that can be utilized for coho acclimation are currently limited to:	
Kooskia National Fish Hatchery (KNFH)	KNFH has space to acclimate smolts transported from DNFH prior to release in Clear Creek. Due to fish health management policies, only progeny reared at DNFH can be acclimated at this facility.

Based on the results of reintroduction efforts to date (section 6.2), it appears that coho salmon reared at LCR hatchery facilities are capable of successfully returning to tributaries of the Clearwater River Subbasin. Approximately half of the juvenile coho released in the Clearwater River Subbasin are the progeny of adults that returned to DNFH or temporary weirs. Given the positive results of hatchery efforts to date, it appears likely that a more intensive reintroduction program could successfully establish natural production in the Clearwater River Subbasin.

Currently, the program is constrained by a lack of acclimation facilities. Based on results obtained thus far, securing acclimation facilities will increase SAR's, compared to the use of direct stream release strategies, and would likely increase the probability of successful restoration. However, the NPT recognizes that even with improved acclimation facilities, there is a risk that out-of-basin mortality could limit survival to a degree that restoration is impossible in the near-term. Therefore, Phase I alternatives discussed in the following section range from halting reintroduction efforts to construction of facilities capable of providing rearing and acclimation space within the Clearwater River Subbasin to meet all juvenile production needs (*i.e.,* capable of meeting the Phase II objective). The proposed alternative (Section 3.5) strikes a balance between status quo coho production and facility development, such that rearing utilizes existing space at Clearwater River Subbasin and LCR hatchery facilities, yet provides for the construction of small-scale, low tech acclimation facilities in order to capitalize on survival advantages observed for juveniles acclimated at KNFH (Section 6.2).

In order to facilitate comparison between the alternatives, a description of the current and long-term programs precedes the discussion of alternatives.

3.2 Description of the Existing Coho Production and Release Program

The Clearwater River Subbasin coho reintroduction program currently has three elements:

- Transfer and release of coho salmon **smolts** from the Eagle Creek National Fish Hatchery (ECNFH), located on the lower Columbia River;
- Release of Clearwater Localized Stock (CLS) coho salmon **smolts** derived from adults collected and spawned in the Clearwater River Subbasin; and
- Release of Clearwater Localized Stock (CLS) coho salmon **presmolts** derived from adults collected and spawned in the Clearwater River Subbasin.

The production and release program has varied substantially in total release number, size at release, and release type (acclimated versus direct stream release) since the program began in 1995 (see the supporting documents listed in Section 1.4 and Table 6-1). Although other hatchery origin coho salmon stocks have been utilized in this effort, the Nez Perce Tribe has elected to utilize production from the ECNFH over the long term.

This stock was selected over the other widely available hatchery origin stock (reared at the Willard National Fish Hatchery) because of its earlier relative run-timing, a characteristic thought to more closely match historical run-timing of Clearwater River Subbasin coho salmon. The following description refers to releases planned for 2005 under the status quo program.

3.2.1 Eagle Creek National Fish Hatchery Smolt Transfers

In 2005, approximately 550,000 LCR coho smolts will be transported to the Clearwater River Subbasin from ECNFH, divided into equal groups, and released without acclimation into the Potlatch River and Lapwai Creek. Upon returning to the Potlatch River and Lapwai Creek (in 2006), adults will be collected at temporary picket weirs, and adults will be transported to DNFH and spawned.

3.2.2 Clearwater Localized Stock Smolt Releases

In 2005, approximately 280,000 CLS stock smolts will be available from DNFH. These smolts will be the progeny of adult coho collected at the DNFH and KNFH from previous NPT coho releases, backfilled as necessary using adults returning to the Potlatch River and Lapwai Creek. DNFH smolts will be transported to KNFH for acclimation and released into Clear Creek. Similar to Lapwai Creek releases, DNFH/KNFH releases will primarily serve a broodstock development purpose at this time. Upon returning as adults, coho will be collected at the KNFH and DNFH hatchery ladders and spawned at DNFH.

3.2.3 Clearwater Localized Stock Presmolt Releases

In 2005, approximately 270,000 coho salmon presmolts will be available from CAFH. These presmolts will be the progeny of adults returning to temporary weirs from previous NPT juvenile coho releases, with broodstock backfilled as necessary using adults returning to the Potlatch River and Lapwai Creek. CAFH presmolts will be transported to Lolo Creek for direct release. Upon collection at the weir in Lolo Creek, returning adults will be transported to DNFH for spawning.

3.2.4 Goals and Constraints of the Current Program

The establishment of natural spawning in the Potlatch River and Lapwai Creek is not a goal of this project. These locations were selected to minimize migration distance and maximize capture opportunity for returning adults. Aside from the primary purpose of collecting adult returns for use as CLS broodstock, these locations provide a “filter” for LCR production. That is, as adults are collected in the Potlatch River and Lapwai Creek, the proportion of total juvenile production of LCR origin will decrease as a higher proportion of CLS stock adults are transported to DNFH and potentially back to

ECNFH[1]. This strategy would play an important role in obtaining broodstock for Phase II of the program (Section 3.7).

To date the NPT coho program has relied solely on existing adult collection, rearing, and acclimation facilities. By doing so, the NPT program has substantially minimized the costs associated with collecting, spawning, rearing, and acclimating coho salmon. However, the use of existing facilities has imposed some constraints on the program. For example, the ability to transfer adults or juveniles between facilities is limited in order to minimize the potential for disease transfer between hatchery complexes. For example, this concern limits smolt acclimation at KNFH to smolts reared at DNFH.

Despite the constraints imposed by limited rearing and acclimation facilities, up to half of the current juvenile releases are progeny of adults that have successfully returned to the Clearwater River Subbasin. Based on data from coho releases to date, a substantial survival advantage could be realized by acclimating all juvenile releases. By doing so, the probability of achieving the Phase I goal (securing a localized broodstock) can be increased.

3.3 Phase I Alternatives

Based on the programmatic constraints listed in Table 3-1, four alternatives were considered. A brief description of the alternatives is presented in the following paragraphs.

Alternative 1: Halt all Coho Salmon Releases
Alternative 1 would effectively halt all coho salmon reintroduction activities within the Clearwater River Subbasin. It is likely that ceasing reintroduction efforts would result in near-term extirpation of coho salmon within the Clearwater River Subbasin. At the very least, ceasing reintroduction activities would be unlikely to achieve the NPT coho salmon integrated restoration goal.

Alternative 2: Status Quo
Alternative 2 would maintain operations at the level proposed for 2005. This includes the release of:

- 280,000 CLS stock smolts from DNFH (acclimated at KNFH on Clear Creek),
- 270,000 un-acclimated CLS stock presmolts in Lolo Creek,
- 275,000 un-acclimated LCR stock smolts in Lapwai Creek, and
- 275,000 un-acclimated LCR stock smolts in the Potlatch River.

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[1] Should the option to ship gametes to ECNFH be exercised, facilities for isolated incubation would be required.

Alternative 3: Construction of Low-Tech Acclimation Facilities

Alternative 3 proposes the construction of low-tech acclimation facilities in Lapwai and Lolo Creeks to capitalize on the higher observed survival of acclimated releases. Specifically, Alternative 3 requests funding to construct an additional pond at the existing NPTH North Lapwai Valley (NLV) site on Lapwai Creek and provide nets for fish containment at an existing millpond owned by the United States Forest Service (USFS) at the Musselshell work center on Lolo Creek. Under this alternative, LCR smolt releases would cease in the Potlatch River, and:

- 280,000 CLS stock smolts from DNFH would be acclimated and released from KNFH on Clear Creek,

- 270,000 CLS presmolts would be transferred from CAFH to the NPTH Site 1705 facility, reared over winter to the smolt stage in existing S-shaped NATUREs channels, transported to the Musselshell acclimation site, and volitionally released into Musselshell Creek in the spring, and

- 550,000 LCR smolts would be acclimated at the proposed NLV facility and volitionally released into Lapwai Creek.

Alternative 4: Construction of Clearwater River Subbasin Rearing and Acclimation Facilities

Alternative 4 seeks to increase rearing and acclimation facilities available for coho salmon in the Clearwater River Subbasin. In order to scale the size of necessary facilities, alternative 4 must necessarily integrate Phase I and II goals such that production and acclimation facilities developed to meet Phase I goals incorporate the flexibility to meet Phase II needs if the program proves successful.

Alternative 4 would expand hatchery facilities at NPTH to spawn 1,404 adults and rear approximately 687,700 coho salmon smolts for use in the Phase II rotating supplementation schedule discussed in Section 3.7. Initially, broodstock for the expanded NPTH facility would be obtained from adults returning from the release of 550,000 LCR smolts in Lapwai Creek. In the mid-term, this plan will allow the NPTH facility to act as a “filter” such that adults returning from the release of LCR smolts are intercepted, transported to the expanded NPTH facility, and spawned. The resulting CLS progeny would be reared to the smolt stage and released in natural production areas. This strategy was selected to maximize the potential for natural selection to act on first generation LCR smolts and adults prior to their introduction to natural spawning areas. Additionally, this strategy slowly severs reliance on LCR coho salmon transfers such that genetic drift should be minimized, and the full compliment of useful genetic variation present in LCR hatchery broodstocks should be present in the CLS broodstock and Clearwater River Subbasin natural spawning aggregates.

The following releases would be pursued under this alternative:

- 280,000 CLS smolts would be acclimated at KNFH for release into Clear Creek,

- 270,000 CLS presmolts would be transferred from CAFH to the NPTH Site 1705 facility, reared over winter to smolt stage in existing S-shaped NATUREs channels, transported to the Musselshell acclimation site, and volitionally released into Musselshell Creek in the spring,

- 550,000 LCR smolts would be acclimated at the proposed NLV facility, and volitionally released into Lapwai Creek, and

- 729,000 CLS smolts would be divided into three release groups (243,000 per group) for release into the American River, Red River, and Crooked River, for a duration of three years, at which time these releases would cease, and releases would occur in O'Hara Creek, Newsome Creek, and Mill Creek for a period of three years.

3.4 Selection of a Preferred Alternative

In the short-term the coho salmon reintroduction program is necessarily focused on stimulating adequate adult returns to provide broodstock at existing Clearwater River Subbasin hatchery facilities. As discussed in the development of screening criteria, juvenile acclimation, releases at the smolt life history stage, and locating juvenile release points lower in the Clearwater River Subbasin are expected to increase adult return rates. In addition, replacement of LCR coho stocks with CLS coho stocks at the CAFH and DNFH facilities is expected to result in a survival benefit as natural selection acts to increase the prevalence of phenotypes that are beneficial within the environmental context of the Clearwater River Subbasin.

Since broodstock acquisition must be emphasized at this time, it follows that any alternative considered must yield an average replacement rate greater than one. In order to quantitatively predict the potential to achieve the Phase I objective under a range of alternatives, we used a stochastic model to simulate expected adult returns based on the production associated with each alternative. Survival values used in the simulation include juvenile survival to Lower Granite Dam (LGD), Smolt to Adult Return rate (SAR) from LGD to LGD, and adult dropout rate from LGD to collection facilities. Arrays of potential survival and dropout values were populated using observed data collected from preliminary NPT coho reintroduction efforts (Section 6.2). Adult return estimates for given alternatives were calculated by randomly drawing a value from the appropriate arrays for juvenile survival to LGD, SAR from LGD to LGD, and dropout rate, and multiplying the total juvenile release by the randomly selected values. For each release group within each alternative, 32,000 estimates were constructed. Mean adult return estimates and 95% confidence intervals were extracted from each set of estimates and reported for each alternative. Since presmolts have not been previously released, data were not available to directly estimate an expected return for this group. Therefore, we used the upper 95% confidence limit of parr to smolt survival for coho parr released in Lolo Creek (21%) as an assumed value for presmolt to smolt survival. The estimated presmolt to smolt survival, while based on limited data, is similar to the 18.1% mean parr to smolt survival values reported by Kiefer and Lockhart (1997) for spring Chinook salmon in the upper Salmon River measured from 1988 to 1995. After accounting for presmolt to smolt mortality, presmolt survival to LGD was assumed to be equivalent to acclimated CLS smolt survival to LGD. Presmolt SAR from LGD to LGD was assumed to approximate SAR's of acclimated CLS stock smolts, and adult dropout rates were assumed to approximate values observed for CLS smolts.

Production estimates for localized coho salmon in the hatchery environment were calculated assuming 2,100 eggs per female and 70% survival from egg to smolt in the hatchery environment (observed at DNFH). Egg to presmolt survival was assumed to be 75%. Prespawning mortality was assumed to be 10%. Based on recent coho escapement within the Clearwater River Subbasin, we assumed that females constitute an average of 37% of the adult return (including jacks).

Utilizing the stochastic model described above, total adult return, potential presmolt and smolt hatchery production from the estimated adult return, and the juvenile to juvenile replacement rate for each release type (calculated as potential juvenile production in generation two divided by the number of juveniles released in generation one) were estimated (Tables 3-2 to 3-4). Estimates are not provided for alternative one (halting all coho releases), since few data exist to evaluate the natural production potential of adults returning from preliminary juvenile releases.

Table 3-2. Estimated adult return and juvenile production for the currently planned 2005 (Alternative 2; Status Quo) coho salmon releases in the Clearwater River Subbasin.

Stream	Stock	Number Released	Adult Return (95% CI)	Potential Production[1]	Replacement Rate
Clear Creek	CC	280,000 Smolt	578 (464, 593)	282,817	1.01
Lolo Creek	CC	270,000 Presmolt	115 (90, 140)	60,260	0.22
Lapwai Creek[2]	LCR	275,000 Smolt	323 (6, 882)	157,950	0.57
Potlatch River[2]	LCR	275,000 Smolt	323 (6, 882)	157,950	0.57
				Mean Replacement	**0.73**

[1] Potential production refers to the number of smolts (presmolts in Lolo Creek) that could be produced by spawning all returning adults in hatchery facilities.

[2] Return rates based on direct stream release.

Table 3-3. Estimated adult return and juvenile production following implementation of Alternative 3.

Stream	Stock	Number Released	Adult Return (95% CI)	Potential Production	Replacement Rate
Clear Creek	CC	280,000 Smolt	578 (464, 693)	282,817	1.01
Lolo Creek	CC	270,000 Smolt	557 (447, 668)	272,716	1.01
Lapwai Creek[1]	LCR	550,000 Smolt	1,404 (88, 3,186)	687,653	1.25
				Mean Replacement	**1.14**
[1]Return rate based on acclimated release.					

Table 3-4. Estimated adult return and juvenile production following implementation of Alternative 4.

Stream	Stock	Number Released	Adult Return (95% CI)	Potential Production	Replacement Rate
Clear Creek	CC	280,000 Smolt	578 (464, 693)	282,817	1.01
Lolo Creek	CC	270,000 Smolt	557 (447, 668)	272,716	1.01
Lapwai Creek	LCR/CC	550,000 Smolt	1,404 (88, 3,186)	687,653	1.25
American River[1]	CC	243,000 Smolt	500 (402, 601)	Unknown	Unknown
Red River[1]	CC	243,000 Smolt	500 (402, 601)	Unknown	Unknown
Crooked River[1]	CC	243,000 Smolt	500 (402, 601)	Unknown	Unknown
Ohara Creek[2]	CC	243,000 Smolt	500 (402, 601)	Unknown	Unknown
Newsome Creek[2]	CC	243,000 Smolt	500 (402, 601)	Unknown	Unknown
Mill Creek[2]	CC	243,000 Smolt	500 (402, 601)	Unknown	Unknown
				Mean Replacement[3]	**1.14**
[1]Streams in group one of the three year rotating supplementation schedule.					
[2]Streams in group two of the three year rotating supplementation schedule.					
[3]Replacement rate calculated only for Clear, Lolo, and Lapwai Creeks.					

Alternatives 1 and 2 are unlikely, on average, to yield positive replacement rates, and are therefore considered inappropriate. Alternatives 3 and 4 both yield average smolt to smolt replacement rates of 1.14, suggesting that implementation of either alternative would be appropriate. In fact, implementation of Alternative 3 could act as a precursor to implementation of Alternative 4. This would allow the program to proceed as a phased approach wherein immediate implementation of Alternative 3 (as Phase I) would allow the NPT to determine whether adequate broodstock could be collected for activities under Alternative 4 (Phase II), while simultaneously testing whether the establishment of natural production can be accomplished in a subset of natural production areas. Implementing such a phased approach would enable the NPT to conduct these tests with a limited initial capital investment (construction of two low-tech acclimation facilities). Should Phase I goals and objectives be achieved, Phase II (Alternative 4 - construction of an expansion to the NPTH facility) would be pursued via a supplement to this Master Plan.

The following sections detail a proposal to implement Alternative 3 as Phase I of the reintroduction program, and provide a roadmap for potential transition to Alternative 4 as

Phase II of the program. The transition to Phase II would occur only if the Phase I indicators of program success (Section 3.6) are achieved.

3.5 Description of the Proposed Reintroduction Program (Phase I)

The proposed coho reintroduction program would implement Alternative 3 (hereafter "Phase I"). The primary goal of Phase I is the establishment of:

- A sustainable return of 954 Clearwater Localized Stock (CLS) adult coho salmon to capture facilities to fulfill broodstock needs for existing Clearwater River Subbasin facilities (452 for CAFH and 502 for DNFH)
- A sustainable return of an additional 1,404 adults to capture facilities to ensure that broodstock will be available for an expansion of the NPTH facility if Phase II is implemented.

The completion of four tasks will aid in achieving the Phase I goal:

- Task One: Continue to optimize production at existing spawning and rearing facilities in the Clearwater River Subbasin and maintain the transfer of 550,000 LCR stock coho smolts for release in Lapwai Creek.
- Task Two: Construct low-tech facilities to acclimate all coho juveniles prior to release in areas with existing adult collection facilities to enable broodstock collection.
- Task Three: Conduct tests of supplementation aimed at determining whether returning adult coho can spawn under natural conditions and produce viable progeny.
- Task Four: Implement a Research Monitoring and Evaluation (RM&E) program capable of providing information necessary to inform management, quantitatively track progress toward meeting Phase I goals, Phase II triggers, and determining the optimal size of release groups for establishing natural production.

3.5.1 Phase I Tasks One and Two

For the duration of Phase I, 550,000 coho salmon smolts would be transported to Lapwai Creek from ECNFH (LCR stock) for acclimation in the newly constructed pond at the NPTH NLV satellite site (Section 4.1). These coho would be volitionally released, and upon return adults would be collected in Lapwai Creek using a temporary picket weir. Adults would be held at DNFH for use as CLS broodstock.

Fertilized eggs from up to 452 adults collected on Lapwai Creek (held and spawned at DNFH) would be transported to CAFH. These eggs would give rise to an average of 270,000 presmolt coho salmon that would either be released in Lolo Creek or transferred to the NPTH Site 1705 facility where they would be reared until the smolt stage. At the smolt stage, juveniles from NPTH Site 1705 would be transported to the Musselshell Pond (proposed for modification; Section 4.1) on Lolo Creek. Juveniles would be acclimated and volitionally released from Musselshell Pond, and upon return adults would be collected for broodstock using a temporary picket weir on Lolo Creek that is currently operated for spring Chinook salmon as part of ongoing NPTH operations. These adults would be used as CLS broodstock at DNFH.

DNFH would hold and spawn up to 502 adults, collected at KNFH on Clear Creek, to produce an average of 280,000 coho salmon smolts. Smolts would be transported to KNFH for acclimation, and volitionally released into Clear Creek. Upon return, adults would be collected at an existing weir on Clear Creek operated by the USFWS, and transported to DNFH for spawning and use as CLS broodstock.

3.5.2 Phase I Task Three

The ultimate goal of the coho reintroduction program is the establishment of coho natural production within the Clearwater River Subbasin that in concert with hatchery production can sustain tribal and recreational fisheries. While the primary goal of Phase I is acquisition of a CLS broodstock, a comprehensive evaluation of natural production is planned in order to determine whether CLS coho salmon are capable of spawning under natural conditions and producing viable progeny. If natural production is documented in a limited set of streams, managers could more confidently implement Phase II, wherein the reestablishment of natural production is the primary goal.

Locations for testing natural production were screened using the following criteria:

- Natural production tests should be conducted in tributaries with established RM&E programs to allow cost sharing;
- Tests should be conducted in areas with existing infrastructure (*e.g.*, weirs and screw traps) to enumerate adult escapement and estimate juvenile production; and
- Sites should be selected to minimize logistical challenges, such that operations and maintenance costs can be minimized.

Then following goals were established for testing natural production:

- A target of 250 adults should be released in test locations, such that natural production can be readily evaluated;
- Where possible, adult escapement should be enumerated, such that subsequent redd counts can be used to estimate the number of adults per redd; and
- Juvenile production should be estimated, to determine whether reintroduced coho salmon can produce viable progeny.

Using these screening criteria, Lolo and Clear Creeks are proposed for testing natural production in Phase I. Natural production tests would be pursued by releasing a target of 250 adults above the adult collection weirs on Lolo and Clear Creeks. Since broodstock collection is the first priority during Phase I, adults would be released for natural production only in years when adult returns to Lapwai, Clear, and Lolo Creeks are surplus to broodstock needs at CAFH and DNFH. A limited fishery may be opened on a case-by-case basis to harvest excess adults.

3.5.3 Phase I Task Four

In years when escapement allows the release of surplus adults into natural production areas, redd counts would be performed in Lolo and/or Clear Creeks (if adults are released in both locations), such that an estimate of the number of adults per redd can be evaluated. In addition, the existing screw traps would enumerate juvenile coho salmon emigrants the subsequent year, such that natural production can be documented. Additional detail is provided in the RM&E plan (Chapter 5).

3.6 Phase I Indicators of Success and Failure

A number of time-limited indicators of success and failure have been compiled that are amenable to evaluation using the RM&E program (Chapter 5). The primary objective of Phase I is securing a localized Clearwater River Subbasin coho salmon broodstock (CLS stock). To achieve this goal, the NPT would use existing spawning and rearing facilities in the Clearwater River Subbasin in concert with rearing space at LCR hatcheries to meet juvenile release goals capable of returning an average of 2,358 adult coho salmon to adult capture facilities in the Clearwater River Subbasin for use as broodstock. Aside from hatchery production, Phase I of the reintroduction project has an experimental supplementation component. While the bulk of supplementation would occur during Phase II of the program, RM&E of limited supplementation in Phase I (in Clear and Lolo Creeks) is expected to guide Phase II activities. Therefore, indicators of program success and failure for Phase I have a broodstock component and a natural production component. RM&E components are summarized below for the purposes of establishing indicators of success and failure. More detailed RM&E plan information is available in Chapter 5.

3.6.1 Phase I Broodstock Indicators of Success and Failure

Broodstock goals for Phase I have two associated indicators of success (Table 3-5):

- A return of 954 Clearwater Localized Stock (CLS) adult coho salmon, in three years out of the nine year evaluation period, to fulfill broodstock needs for existing Clearwater River Subbasin facilities (452 for CAFH and 502 for DNFH)

- A return of an additional 1,404 adults, in three years out of the nine year evaluation period, to ensure that broodstock would be available for an expansion of the NPTH facility if Phase II is implemented.

Escapement would be measured at capture facilities on Lolo Creek, Clear Creek, Lapwai Creek, and at DNFH under RM&E Objective 1 (Chapter 5). Enumeration of an average of 2,358 adult coho at capture facilities over one three-year period within nine years (three generations) after implementation of Phase I would be an indicator of success. Failure to achieve a three-year average of 2,358 adult coho at capture facilities within this period would indicate failure. The second component of broodstock acquisition is the replacement of LCR origin coho with CLS stock coho. Establishment of 100% CLS broodstocks at CAFH and DNFH within nine years of the implementation of Phase I would indicate success, failure to achieve this goal within this period would indicate failure. In short, activities in Phase I must demonstrate that a sustainable broodstock source is available for DNFH, CAFH, and an expansion of NPTH, prior to construction of the NPTH expansion.

Table 3-5. Indicators of success for Phase I broodstock acquisition.

Phase I: Broodstock Acquisition		
Location	**Escapement**	**Origin**
CAFH	452	Naturalized CC Stock
DNFH	502	Naturalized CC Stock
Lapwai/Potlatch	1,404	LCR and CC Stock
Total	2,358	Total Escapement Past LGR

3.6.2 Phase I Natural Production Indicators of Success and Failure

There are two components to natural production monitoring that must be completed during Phase I:

- Establishment of baseline production and productivity estimates for naturally spawning coho in Clear and Lolo Creeks

- Establishment of measures of competition between coho and spring Chinook salmon and steelhead in Clear and Lolo Creeks.

The long-term success of coho salmon reintroduction requires that adult coho return to a targeted tributary, spawn, and produce viable progeny. During Phase I, RM&E Objective 2 (Chapter 5) would establish a baseline that yields natural production estimates in Clear and Lolo Creeks. At a minimum these measures would require a means to capture representative juvenile samples in both Clear and Lolo Creeks (preferably using a rotary screw trap) sufficient to allow estimation of total juvenile coho salmon abundance. A means for estimating adult escapement (preferably a weir) must be available in both Clear and Lolo Creeks to allow estimation of adult coho salmon escapement. Together, these two measures would allow an estimate of productivity (number of smolts divided by the number of adults). Finally, multiple pass redd counts should be performed in both Clear and Lolo Creeks in order to estimate the number of adults per redd. Indicators of success (Table 3-6) would be the establishment and operation of adult and juvenile capture facilities within a statistically valid experimental design. Indicators of failure would be an inability to capture juveniles and adults in an abundance allowing estimation of juvenile production and adult escapement and redd production.

In addition to the establishment of production and productivity estimates for coho, RM&E Objective 5 (Chapter 5) would implement a competition study in both Clear and Lolo Creeks. At a minimum this study would enable a comparison of condition factors of juvenile spring Chinook salmon and steelhead prior to substantial coho salmon supplementation, and in the presence of coho salmon. Indicators of success (Table 3-6) would be the establishment of a statistically valid comparison of condition factors of spring Chinook salmon and steelhead in Clear and Lolo Creeks prior to and following coho supplementation. Failure would be indicated by the inability to implement a statistically valid competition study.

Table 3-6. Indicators of success for Phase I production, productivity, predation, and competition studies.

Phase I: Natural Production Survival/Interactions Indicators of Success	
Clear and Lolo Creeks	**Baseline Coho Production and Productivity**
	Juvenile Abundance
	Adult Escapament (Hatchery and Natural)
	Redd Counts
Clear and Lolo Creeks	**Competition**
	Juvenile Chinook and Steelhead Condition Factor

3.6.3 Triggers for the Implementation of Phase II

Phase II would expand facilities at the NPTH to hold and spawn 1,404 adult coho and rear up to 687,700 coho salmon smolts. Coho salmon smolts produced at the expanded NPTH facility would be used in the rotating supplementation schedule discussed in Section 3.7.2. Three triggers have been identified after which the program would progress to Phase II:

- Achieving all Phase I indicators of success;
- Establishing that competition has not surpassed acceptable limits due to the reintroduction of coho salmon; and
- Confirming the availability of LCR coho salmon smolts for a minimum of six years (two generations) following completion of the NPTH expansion.

Measuring the achievement of indicators of success is relatively straightforward, and ensuring the availability of LCR smolts is a planning exercise. Defining acceptable limits of competition is more challenging. For the purposes of this project, a statistically significant decrease in the condition factors of juvenile steelhead or Chinook salmon following the introduction of coho salmon would be considered unacceptable. If unacceptable levels of competition are observed, coho salmon reintroduction would be reevaluated.

3.7 Description of the Long-Term Coho Reintroduction Program (Phase II)

If all indicators of Phase I success (Section 3.6) are achieved, the long-term coho reintroduction program would implement Alternative Four (hereafter "Phase II") via a supplement to this Master Plan. The primary goal of Phase II would be the initiation of a rotating supplementation program designed to reintroduce coho salmon to several tributaries within the Clearwater River Subbasin. Achieving this goal would require the construction of additional Clearwater River Subbasin rearing facilities for coho salmon. Four tasks are associated with the Phase II goal:

- Task One: Continue development of a Clearwater River Subbasin localized coho salmon stock (CLS stock).
- Task Two: Construct facilities at the Nez Perce Tribal Hatchery (NPTH) to accommodate holding and spawning 1,404 adults and rearing 687,700 smolts.
- Task Three: Increase supplementation using a rotating release schedule.
- Task Four: Provide harvest opportunities for tribal and recreational anglers.

3.7.1 Phase II Tasks One and Two

Implementation of Phase II would require the establishment of a CLS broodstock to populate an expansion of the existing NPTH facility. Since CAFH and DNFH should have a sustainable broodstock source prior to implementation of Phase II (Section 3.6), adult returns to Lapwai Creek would be reprogrammed to serve as broodstock for the expanded NPTH facility. On average, the annual release of 550,000 LCR smolts from the NPTH NLV acclimation facility would return 1,404 adult coho salmon to Lapwai Creek. These adults would be spawned at the expanded NPTH facility yielding an average of 687,700 smolts for use in supplementation activities.

3.7.2 Phase II Task Three

Since data regarding the historical abundance and distribution of coho salmon is limited, the NPT would approach Phase II using a rotating supplementation schedule aimed at quickly determining which Clearwater River Subbasin tributaries have the potential to support natural production. Initially, juvenile coho salmon from the Phase II expansion of the NPTH would be released in Newsome Creek, Red River, and Crooked River for a period of three years (one generation). Supplementation would then cease in these locations and begin in Lolo Creek, O'Hara Creek and Clear Creek for a period of three years (one generation). This rotating supplementation schedule was designed to:

- Aid in monitoring and evaluation;
- Quickly determine which streams are most likely to support natural production; and
- Limit the size of rearing facilities necessary to support supplementation objectives.

Staggering supplementation activities between stream groups for a period of three years allows the program to take advantage of the three-year generation length of coho salmon, such that in each set of streams one generation of adult returns is dominated by hatchery origin adults, and the next generation is dominated by natural origin adults (Table 3-7). This structure allows M&E activities to more easily estimate adult return rates and productivity of hatchery and natural origin individuals. In addition, one set of streams can act as a reference for the other set of streams, enabling researchers to statistically control for the effects of environmental fluctuation on survival of juveniles and adults of natural and hatchery origin. Finally, after one generation of supplementation, adult returns and juvenile productivity in the following generation should indicate which streams within a set of targeted streams provide the greatest potential for the establishment natural production (*i.e.*, those streams exhibiting the highest natural production and productivity). Those streams exhibiting relatively high rates of natural production would be eligible for another three year treatment period, while those streams that fail to support natural production, or in which negative side effects of supplementation (*e.g.,* high rates of competition) are observed would be abandoned. Several candidate streams (Table 3-8) have been identified as alternates should supplementation fail to establish natural production in the streams identified in the rotating supplementation schedule. The candidate streams would also be eligible for supplementation if it is determined that continued supplementation is unnecessary in the first two sets of streams.

Finally, the rotating supplementation schedule allows the project to move forward in a more cost effective manner by building a rearing facility approximately half of the size that would be required if all streams were supplemented simultaneously. Simply stated, since half of the targeted streams would be supplemented in a given year, the program requires only half of the total number of juveniles than would be necessary if all streams were supplemented simultaneously.

Table 3-7. Juvenile release and adult return schedule in stream sets included in the rotating supplementation schedule (listed years are arbitrary, and are provided for illustration purposes only).

Year	Juvenile Releases	Adult Returns		
2005	**HSR**			
2006	**HSR**	**HR**		
2007	**HSR**	**HR**		
2008	*HSR*	**HR**		
2009	*HSR*	*HR*	**NR**	
2010	*HSR*	*HR*	**NR**	
2011	**HSR**	*HR*	**NR**	
2012	**HSR**	**HR**	*NR*	**HR + NR**
2013	**HSR**	**HR**	*NR*	**HR + NR**
2014	*HSR*	**HR**	*NR*	**HR + NR**
2015	*HSR*	*HR*	**NR**	*HR + NR*
2016	*HSR*	*HR*	**NR**	*HR + NR*
2017		*HR*	**NR**	*HR + NR*

Bold text indicates release and return schedule in the first set of streams, italicized text represents release and return schedule in the second set of streams.
HSR = hatchery smolt release.
HR = hatchery adult return.
NR = natural adult return.

Table 3-8: Alternative streams identified for potential supplementation using the rotating supplementation schedule.

Stream	Location
Pete King Creek	Lochsa River
Fish Creek	Lochsa River
Asotin Creek	Snake River
Potlatch River	Lower Clearwater River
Tucannon River	Lower Snake River

3.7.2.1 Deriving the Size of Release Groups

Determining the optimal number of juveniles to release per year in a given stream was based on two considerations: 1) release size should be large enough to generate an ecological impact (positive or negative) such that the efficacy of coho reintroduction can be statistically evaluated and 2) juvenile release groups should be large enough to reasonably ensure that enough adults return to initiate a healthy natural spawning aggregate. Minimum release sizes were estimated using genetic principles and a cohort-based approach.

The Clearwater River Subbasin constitutes a somewhat novel environment for LCR coho salmon. There are several obvious environmental differences between Clearwater River Subbasin and LCR tributaries (*e.g.*, distance from the ocean), suggesting that LCR origin coho may not be optimally adapted for the Clearwater River Subbasin environment. Therefore, it is likely that natural selection will serve to increase the prevalence of traits that are beneficial within the environmental context of the Clearwater River Subbasin. Such selection is expected to be beneficial for the program, however it may be useful to balance selection for phenotypes of immediate value (*e.g.,* ability to sustain a prolonged migration) against the potential for a management induced “genetic bottleneck” that might result from prematurely isolating Clearwater River Subbasin broodstock from LCR production. To avoid such a bottleneck, the NPT program proposes to slowly phase out the use of LCR transfers by releasing first generation LCR juvenile transfers only in Lapwai Creek. Upon return, these adults would be spawned to create first generation CLS stock coho salmon smolts for use in supplementation activities. In this manner, Lapwai Creek acts as a “filter” allowing some immediate selection on LCR phenotypes, while simultaneously maintaining gene flow between the original broodstock source and supplemented tributaries.

The number of smolts released for supplementation purposes can likewise be guided by genetic considerations. Release groups should be large enough that subsequent adult escapement to the targeted tributaries maintains abundance capable of minimizing the random loss of genetic variation (genetic drift) typical of small populations. Directly measuring the maintenance of quantitative genetic variation among coho aggregates in targeted streams is beyond the scope of this program, however genetic principles can still be employed to minimize genetic drift. The following calculations assume that there are a number of alleles within the source population at a given locus, and that these alleles are of equal phenotypic value (*i.e.,* they are selectively neutral). Therefore, the probability of an allele being perpetuated into the next generation is related to the proportion of individuals possessing that allele in the current generation. This probability can be calculated using binomial probability as follows (adapted from Kincaid 1997):

$PR = 1-(1-p)^{2Ne}$
PR = probability of maintaining an allele
p = frequency of the allele
N_e = effective population size

Using this equation, one can determine how large a parental population must be to avoid the random loss of an allele. To do so, one first defines how large the effective population size must be to maintain genetic variation at a specified level. For example, to maintain a 95% probability of maintaining an allele that occurs at a frequency of 5% or greater (for one generation) requires an effective population size equal to 30 in the parental generation. Second, one must have an estimate of the ratio of effective spawners to total spawners (N_e/N) in the parental generation. Since the coho salmon used for NPT reintroductions originated from LCR hatcheries, an N_e /N estimate (0.065) was obtained for an LCR hatchery from Simon *et al.* (1986). Third, the N_e /N ratio can be used to estimate a minimum adult escapement necessary to achieve an N_e of 30, approximately

470 adults in this case. Therefore, a minimum escapement of 470 adults per treatment stream is necessary to probabilistically meet the criterion of maintaining a 95% probability that alleles occurring at a frequency of 5% or greater are not lost as a result of genetic drift for a period of one generation.

In order to determine how many juveniles must be released in a particular stream in order to return 470 adults in the next generation, data from NPT reintroduction activities (Section 6.2) were employed. On average, releasing 229,000 acclimated CLS stock smolts would return 470 adults in the next generation.

3.7.3 Phase II Task Four

Hatchery production would serve to supply juveniles for supplementation and to provide harvest opportunities for tribal and recreational anglers. Production from DNFH/KNFH would continue in order to provide supplementation opportunities in Clear Creek. Production from CAFH would continue as a means to provide presmolts for final rearing at the NPTH 1705 facility for supplementation in Lolo Creek. LCR coho releases in Lapwai Creek would proceed into the foreseeable future to provide first generation CLS stock adult returns for use as broodstock to provide smolts for the rotating supplementation schedule.

Harvest of Clearwater River Subbasin coho in ocean and mainstem Columbia River fisheries is expected to occur. Targeted Clearwater River Subbasin harvest opportunities are expected to arise under two circumstances:

- The abundance of natural origin adults allows for ample escapement for natural spawning while simultaneously providing for some of the broodstock needs. Using a fraction of natural origin adults for broodstock should result in a surplus of hatchery origin adults that could be targeted in a fishery.

- If supplementation activities successfully establish highly productive naturally spawning coho salmon aggregates, the number of locations and the size of supplementation release groups could be scaled down. If this occurs, production from the expanded NPTH facility could provide a targeted fishery.

3.8 Harvest Management

Given that the success of coho salmon reintroduction is unpredictable, it is premature to speculate on the number of coho salmon that may eventually be available for harvest. In addition, it is impossible to speculate whether fisheries would take the form of targeted terminal tributaries or selective/non-selective mainstem harvest. However, some assumptions regarding Tribal, State, and Federal management of coho fisheries are possible.

Management of Tribal fisheries for coho salmon would provide for the release of all protected species. Bag limits, gear restrictions, seasons, and areas restrictions would be employed to regulate harvest of coho salmon and protect other fish. Tribal harvest would be adjusted annually to provide for adequate escapement of broodstock and natural spawners. The impacts of coho salmon fisheries would be monitored under Objective 4 of the RM&E program (Chapter 5). Harvest management in the Clearwater River Subbasin would be coordinated with regional co-managers under RM&E Objective 6 (Chapter 5).

Fisheries co-managers would likely open a season for coho salmon in the Clearwater River Subbasin once it has been determined that a surplus is available. Since coho salmon return to the Clearwater River Subbasin during fall months, harvest is expected to be concurrent with steelhead harvest; primarily during the mid-September and October fishery. The State steelhead sport fishery occurs in the mainstem Clearwater River upstream to the mouth of the South Fork Clearwater River (RM 74.7) and in the South Fork to Castle Guard Station (RM 30.7).

Management of State sport fisheries by IDFG provides for the release of all protected species. Bag limits, gear restrictions, seasons, and area restrictions would be employed to regulate harvest of coho and protect other fish. Sport harvest would be adjusted annually to provide for adequate escapement of coho for broodstock and natural spawners. Sport harvest would be coordinated with the Nez Perce Tribe.

Chapter 4: Proposed Phase I Facility Modifications and Operations

In this chapter:

- Description of existing hatchery facilities involved in producing Clearwater coho salmon
- Description of proposed hatchery facilities and construction costs for Phase I
- Facility management
- Description of Clearwater coho production proposed in this master plan
- Summary of Operations and Maintenance; Research, Monitoring, and Evaluation; Permitting; Design; and Construction costs

This chapter contains a description of the production program at existing and proposed facilities that would occur if this master plan is approved and funded. It also contains a description of the agreements that exist between co-managers for production of Clearwater coho at existing hatchery facilities and conceptual design and cost estimates for proposed acclimation facilities. Annual operation and maintenance and monitoring and evaluation costs for the proposed production program are also detailed. The Clearwater River Subbasin coho reintroduction program currently has three elements:

- Transfer of 550,000 coho salmon smolts from the Eagle Creek National Fish Hatchery (ECNFH), located on the lower Columbia River;
- Release of 280,000 Clearwater Localized Stock (CLS) coho salmon smolts derived from adults collected and spawned in the Clearwater River Subbasin; and
- Release of 270,000 Clearwater Localized Stock (CLS) coho salmon presmolts derived from adults collected and spawned in the Clearwater River Subbasin.

4.1 Existing Hatchery Facilities Producing Clearwater Coho Salmon

Dworshak and Kooskia National Fish Hatcheries

Dworshak National Fish Hatchery (DNFH) is located on the south bank of the North Fork of the Clearwater River, 1.5 miles downstream from Dworshak Dam and 72.5 river miles upstream from Lower Granite Dam. Dworshak NFH is operated by the U.S. Fish and

Wildlife Service (USFWS) and produces spring chinook salmon for the Lower Snake River Compensation Plan and steelhead for Dworshak Dam mitigation.

Kooskia National Fish Hatchery (KNFH) is located 1.5 miles southeast of Kooskia, Idaho near the confluence of Clear Creek and the Middle Fork Clearwater River. The facility is operated by the USFWS as a satellite facility to DNFH. Kooskia NFH is used for adult collection and rearing only (spawning and incubation occur at DNFH). Kooskia NFH produces spring chinook salmon to help restore depleted upriver salmon stocks.

The NPT and the USFWS have a Memorandum of Understanding (MOU) in place that details the coho salmon production operations at both DNFH and KNFH. The USFWS operates the adult fish ladder at DNFH and the weir on Clear Creek at KNFH during October - November to assist with capturing coho salmon for broodstock. The USFWS provides holding for up to 500 adult coho salmon at DNFH. Coho salmon are spawned at DNFH and eggs are incubated for production at DNFH and Clearwater Anadromous Fish Hatchery (CAFH). Eggs for production at CAFH are incubated to the eyed stage at DNFH and then transported to CAFH for incubation and rearing. The USFWS provides egg incubation and juvenile rearing space for up to 320,000 coho salmon at DNFH and final rearing and acclimation for 280,000 coho salmon smolts at KNFH. Coho smolts are released from KNFH in May. The Nez Perce Tribe is responsible for all phases of fish culture. This includes cleaning, feeding, sampling, treating, hauling and releasing. In addition, the Tribe is responsible purchasing fish tags and coordinating all fish marking. Finally, the Tribe contracts with the State or a Federal entity for fish health certifications.

Clearwater Anadromous Fish Hatchery

Clearwater Anadromous Fish Hatchery (CAFH) is located on the North bank of the North Fork of the Clearwater River, 1.5 miles downstream from Dworshak Dam and 72.5 river miles upstream from Lower Granite Dam. CAFH is a Lower Snake River Compensation Plan facility, operated by the Idaho Department of Fish that produces spring chinook salmon and steelhead for release in the Clearwater River. The NPT and the IDFG have a MOU in place that details the coho production operations at CAFH. Adult coho salmon are not held or spawned at CAFH. Eggs for production at CAFH are imported at the eyed stage from DNFH or Eagle Creek National Fish Hatchery if there is a shortage in Clearwater stock. The IDFG provides egg incubation and juvenile rearing space for up to 270,000 coho salmon. Similar to the DNFH/KNFH MOU, the Nez Perce Tribe is responsible for all phases of fish culture. This includes cleaning, feeding, sampling, treating, hauling and releasing. In addition, the Tribe is responsible purchasing fish tags and coordinating all fish marking. Finally, the Tribe contracts with the State or a Federal entity for fish health certifications.

Coho salmon are reared to presmolt stage (50 fpp), transported to Lolo Creek, and direct stream released in late September or early October. With the construction of facilities proposed in this master plan, these fish would be transferred from CAFH to Nez Perce Tribal Hatchery for final rearing to smolt stage. Smolts would then be transferred to

Musselshell Pond for acclimation from late March to early April, and released into Musselshell Creek, a tributary to Lolo Creek.

Nez Perce Tribal Hatchery

Nez Perce Tribal Hatchery (NPTH) is located at river mile 32 on the Clearwater River, and is operated by the Nez Perce Tribe Department of Fisheries Resources Management. NPTH is authorized through the Columbia Basin Fish and Wildlife Program to produce spring chinook and fall chinook salmon for release in the Clearwater River. Currently, no coho salmon are reared at NPTH. With the construction of facilities proposed in this master plan, presmolts (50 fpp) from CAFH would be transferred to NPTH for final rearing to smolt stage. Smolts would then be transferred to Musselshell Pond for acclimation from late March to early April, and released into Musselshell Creek.

Eagle Creek National Hatchery

Eagle Creek National Fish Hatchery (ECNFH) is located at river mile 25 on Eagle Creek in the Willamette River Basin. Eagle Creek NFH was authorized under the Mitchell Act and currently operates as part of the Columbia River Fisheries Development Program. ECNFH is operated by the USFWS to help compensate for fish losses in the Columbia River Basin caused by mainstem dams. The USFWS produces coho salmon for the NPT through the *US v Oregon* Fall Season Agreement and Court Order. The USFWS spawns coho salmon at ECNFH to produce 550,000 coho smolts. These smolts are transported and released into the Clearwater River basin in March (275,000 to Lapwai Creek and 275,000 to the Potlatch River). Additional eggs may be taken at ECNFH, incubated to eye-up and transported to CAFH to backfill production if there is a shortage of Clearwater broodstock.

4.2 Phase I Proposed Acclimation Facilities

The construction of two low-tech acclimation facilities is included in the proposed alternative. The facility proposed at the existing NPTH NLV satellite on Lapwai Creek would be used to acclimate up to 550,000 coho smolts. An existing millpond in the Lolo Creek watershed at the United States Forest Service (USFS) Musselshell Work Center would be modified to provide acclimation for 270,000 CLS stock coho smolts. Completion of these facilities would provide acclimation for coho salmon that are currently direct stream released, resulting in 100% acclimation for all coho salmon production in the Clearwater River Subbasin.

4.2.1 North Lapwai Valley Acclimation Site

This Master Plan proposes to modify an existing Nez Perce Tribal Hatchery facility known as the North Lapwai Valley (NLV) acclimation site. NLV is operated by the NPT with funding from the Columbia Basin Fish and Wildlife Program, and is located approximately 0.75 miles upstream of the confluence of Lapwai Creek and the Clearwater River in Nez Perce County, Idaho. The NLV is currently used to acclimate fall Chinook salmon subyearling smolts, which precludes the use of existing facilities for the acclimation of coho salmon. The NLV satellite currently has two ponds, with approximately 13,150 cf of rearing space each, with both a surface and groundwater supply system that can be mixed to control water temperature. An assessment of water quality suggests that this site meets established standards from peer-reviewed literature (Table 4-1). The ponds are located in the higher elevation area of the site with discharge entering Lapwai Creek near the State Highway Route 95 bridge crossing. The site was designed for additional pond construction and has adequate living quarters for personnel to occupy during acclimation. The following modifications are proposed at this site:

- Excavate a pond to acclimate up to 550,000 coho salmon down slope from the existing ponds (Figure 4-1). The proposed pond would be 23,000 cubic feet, allowing the acclimation of 550,000 coho smolts at a density index (Piper et al. 1982) of 0.3.
- Tap into the existing pond overflow, well, and surface water head tank.
- Construct a first pass water supply through the overflow of the existing head tank, and allow for diversion of second pass water through the overflow from existing ponds.
- Construct small check dams to impound a series of small pools along the existing overflow ditch leading to Lapwai Creek.

Preliminary cost estimates are presented in Table 4-2.

4.2.2 Musselshell Pond

This master plan also proposes to modify an existing mill pond in the Lolo Creek drainage known as Musselshell Pond. This modification would allow acclimation of 270,000 smolts. The current production at CAFH is 270,000 presmolt coho salmon. These presmolts will be transported to NPTH where they will be reared until the smolt stage. At the smolt stage, juveniles will be transported to the Musselshell Pond, acclimated and volitionally released.

Nets would be placed into Musselshell Pond to prevent juveniles from leaving the pond until they are acclimated. The nets would be doubled across the outfall area of the pond allowing for a net to be removed for cleaning while still retaining the fish within the pond. At smolting the nets would be removed, thus allowing volitional release. Analysis of water samples from this site suggest that water quality is acceptable for acclimation (Table 4-1). A preliminary cost estimate for modifications to Musselshell Pond is presented in Table 4-4.

Upon return, adults could be captured at an existing NPTH adult collection facility on Lolo Creek. The proposed trap site is located approximately 13 miles upstream of the confluence of Lolo Creek with the Clearwater River. Currently a portable weir and trap at this site is fished from July to September for spring Chinook salmon. The trap could be operated through November to collect coho salmon. Returning fish would swim into a trap box, be netted out and placed into a 500-gallon transport tank on a one-ton vehicle, and transported to holding ponds at DNFH, or allowed to pass the weir and spawn in the Lolo Creek watershed.

It should be noted that the Musselshell facility, though intended solely for use as a coho acclimation facility at this time, could provide an acclimation opportunity for steelhead or Chinook salmon. Development of this facility would therefore provide additional flexibility for fisheries comanagers.

Table 4-1. Literature standards and surface water quality measurements for proposed acclimation sites.

Parameter	Daily and Economon 1983	ADFG 1983	Wedemeyer and Wood 1974	Piper *et al.* 1982	Musselshell Creek	Lapwai Creek
Alkalinity - ppm	20.0	NR	20.0 - 200.0	10.0 - 400.0	11.0	365.0
Aluminum - ppm	0.01	0.01	NR	NR	0.06	0.04
Un-ionized Ammonia - ppm	0.02	0.0125	0.012 - 5.0	0.01	NR	NR
Arsenic - ppm	0.05	0.05	NR	NR	NR	NR
Barium - ppm	5.0	5.0	NR	NR	0.013	0.048
Calcium - ppm	52.0	NR	52.0	4.0 - 160.0	2.5	30.5
Copper - ppm	0.03	0.03	0.03	NR	NR	0.001
Fluoride - ppm	0.5	0.5	NR	NR	NR	0.2
Iron - ppm	0.1	0.1	1	0.5	0.12	0.05
Lead	0.02	0.02	NR	0.03	NR	NR
Magnesium - ppm	15.0	15.0	NR	NR	0.5	11.2
Managanese - ppm	0.01	0.01	NR	0 - 0.01	0.006	0.007
Mercury - ppm	0.2	0.0002	NR	0.002	NR	NR
Nitrate - ppm	1.0	1.0	NR	0.0 - 3.0	NR	0.7
Nitrite - ppm	1.0	0.1	0.55	0.1 - 0.2	NR	NR
Nickel	0.01	0.01	NR	NR	NR	NR
pH	6.7 - 8.6	6.5 - 8.0	6.7 - 9.0	6.5 - 8.0	6.76	8.34
Potassium - ppm	5.0	5.0	NR	NR	0.6	3.4
Sodium - ppm	75.0	75.0	NR	NR	2.6	16.6
Sulfate - ppm	50.0	50.0	NR	NR	0.7	7.1
Total Dissolved Solids - ppm	400.0	400.0	400.0	NR	62.0	201.0
Zinc	0.005	0.005	0.04	0.03	NR	NR

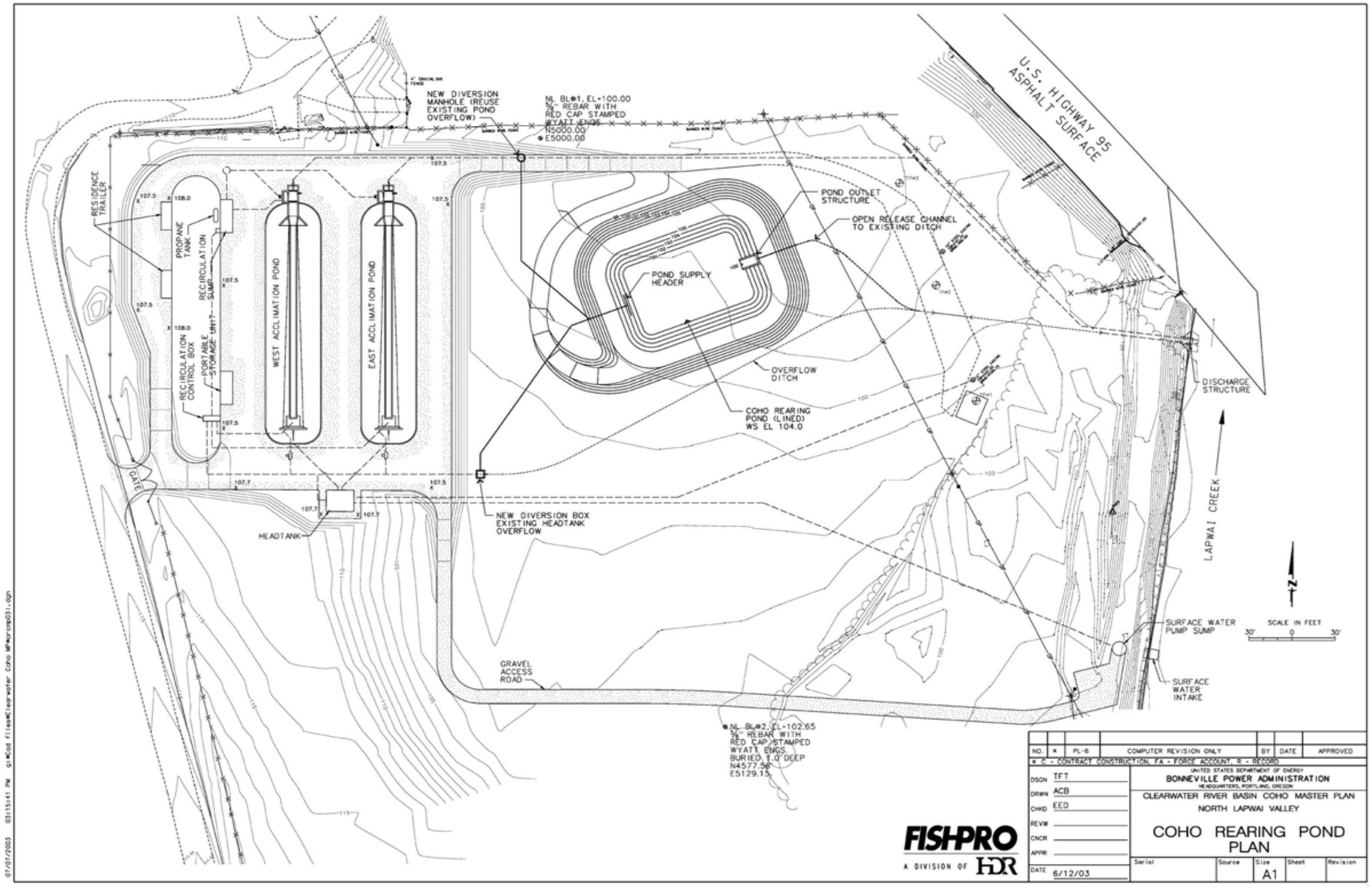

Figure 4-1. Preliminary design for the NLV coho acclimation facility at the NPTH.

Table 4-2. Estimated budget for the construction of the proposed coho acclimation pond at the NPTH NLV satellite facility.

Item	Activity	Quantity	Unit	Cost	Amount	Total
Pond						$60,708
	Excavation	356	CY	$15.00	$5,340	
	Fill	1,500	CY	$15.00	$22,500	
	Grading	19,200	SF	$0.25	$4,800	
	Sand Liner Bedding	150	CY	$0.45	$68	
	Lining	12,000	SF	$1.50	$18,000	
	Supply Header	1	LS	$3,000.00	$3,000	
	Outlet Structure	1	LS	$7,000.00	$7,000	
Piping						$41,825
	Reuse Diversion Manhole	1	EA	$10,000.00	$10,000	
	Overflow Diversion Manhole	1	EA	$10,000.00	$10,000	
	24" Schedule 40 PVC	150	LF	$75.00	$11,250	
	18" Schedule 40 PVC	120	LF	$60.00	$7,200	
	24" Schedule 40 PVC Drainpipe	45	LF	$75.00	$3,375	
Pond Access						$11,445
	Excavation	67	CY	$15.00	$1,005	
	Fill	312	CY	$15.00	$4,680	
	Grading	3,600	SF	$0.25	$900	
	Base Grael 8"	72	CY	$45.00	$3,240	
	Top Gravel 3"	27	CY	$60.00	$1,620	
New Open Channel to Existing Ditch						
	Excavation	100	LF	$45.00	$4,500	$4,500
Subtotal Material Cost						$118,478
Contingency (25%)						$29,619
Total Site Cost						**$148,097**

Table 4-3. Estimated budget for the modification of the existing Musselshell Pond.

Item	Quantity	Unit	Cost	Amount	Total
8' x 200' Nets	2	EA	$2,250	$4,500	
End Anchors	2	EA	$500	$1,000	
Total Material Cost					$5,500
Contingency (25%)					$1,375
Total Site Cost					**$6,187**

4.3 Facility Management

Facilities utilized for incubation, early rearing, final rearing, and acclimation of coho salmon will continue to be operated by the current facility agency and co-manager. The acclimation facilities proposed in this document will be operated by the NPT. The Tribe will development agreements with the USFS for Musselshell Pond.

The Nez Perce Tribe would function as the lead agency for the coho reintroduction program and therefore, would be primarily responsible for planning, operation and maintenance, and monitoring and evaluation of the reintroduction program as it is described in the Master Plan. Continued optimization of hatchery production will be pursued under RM&E Objective 3 (Chapter 5), which is aimed at determining optimal release rearing, release, and marking strategies. RM&E Objective 2 (Chapter 5) will evaluate whether hatchery practices ensure the maintenance of genetic diversity and life history traits.

The NPT will continue to participate in the development of the Clearwater Annual Operating Plans (AOPs) to coordinate coho project operations with its co-managers. The AOPs include:

- Details of day-to-day project operation;
- A fish production plan that identifies stocks and number of fish produced by the project during the fiscal year, release locations, life stages, numbers, and dates;
- Tasks required to complete general project objectives; and
- An identification of personnel required to complete the tasks and duties outlined in the AOP

4.4 Proposed Production Program Summary

This section contains an overview of the production program at existing and proposed facilities that would occur if this master plan is approved and funded.

Adult Collection and Spawning

The Nez Perce Tribe currently operates temporary weirs consisting of tripods, picket panels, and trap boxes in Lapwai Creek and Lolo Creek from early October to mid-December to collect adult coho salmon. This trapping would continue under the proposed program. Protocols for operation follow basic adult trapping and handling procedures consistent with IHOT guidelines (IHOT 1995). The weir/traps are monitored 24 hours a day and routinely checked for accumulation of debris and proper operation. Design of the weir allows for unimpeded upstream and downstream movement of juvenile fish, as well as controlled movement of adult sized fish. Captured adults are sampled daily. Adults taken for broodstock are transferred to a vehicle and transported to DNFH. These fish are placed in an adult holding pond for spawning. Adults released for natural spawning are returned to the stream upstream of the weir.

A semi-permanent weir on Clear Creek is currently operated by the USFWS at KNFH. This trapping would continue under the proposed production program. The weir operates from early October to mid December each year. Adults taken for broodstock are transferred to a transportation vehicle and transported to DNFH. These fish are placed in an adult holding pond until spawned. Currently, no adults are released above the weir for natural spawning. However, as part of the reintroduction effort, adults may be passed at Clear Creek. The number of adults passed is determined by broodstock needs and harvest and natural production goals.

A fish ladder and trap on the North Fork of the Clearwater River is currently operated by the USFWS at DNFH. This trapping would continue under the proposed program. The ladder operates from early October to mid December. The ladder is open 24 hours a day until the USFWS collects approximately 500 steelhead. Once the steelhead goal is met, the ladder is opened a few days a week to allow for additional coho salmon collection. Fish in the ladder are sorted weekly, and coho salmon are placed in the adult holding pond until spawned.

Spawning typically begins in mid October and is completed by mid December. Once a week, ripe females are spawned with at least one male. In most cases, a 1:1 male to female ratio is maintained.

Egg Incubation and Juvenile Rearing

Eggs from adults captured in Lapwai Creek, Lolo Creek, Clear Creek and North Fork Clearwater River are incubated at DNFH and CAFH. Additional eggs from these adults may be incubated to eye-up and transported to CAFH. At hatch, fish are transferred to indoor vats and reared until steelhead rearing space is needed. Fish (typically 600-800 fish per pound (fpp)) are then moved to the outdoor concrete raceways and reared to the smolt stage (20 fpp).

Eggs from both ECNFH and DNFH are incubated at CAFH. At hatch, fish are transferred to indoor vats and reared to approximately 500 fpp. These fry are then transferred to outdoor raceways and reared to presmolt stage (50 fpp). Due to water limitations at CAFH, these fish are transported off station by late September or early October.

Smolt Release

Under the proposed production program, during the second week of March, 550,000 coho salmon smolts would be transported from ECNFH to the Clearwater River basin for release into the North Lapwai Valley Acclimation Pond. Smolt size at release is 20 fpp. Under the current program (Section 3.2) these smolts are direct stream released into Lapwai Creek (275,000) and the Potlatch River (275,000).

Coho salmon reared at DNFH are transferred to fish transportation trucks and taken to KNFH during the first week of April. These fish are acclimated for six weeks and volitionally released into Clear Creek. There would be no change to this production under the proposed production program.

Under the proposed production program, during the last week of September or first week of October, presmolts (50 fpp) from CAFH would be transported to NPTH. Fish would be reared to the smolt stage (20 fpp) and transferred to the Musselshell Pond in late March for acclimation. Smolts would be volitionally released into Musselshell Creek. This would constitute a change from a direct-stream presmolt release to an acclimated smolt release.

Fish Health Monitoring

A systematic fish health monitoring and disease control program is currently in place and referenced in the Memoranda of Understanding (MOU) with both DNFH and CAFH. Fish health monitoring and disease control will follow the respective hatcheries' guidelines. It is the goal of these control measures to:

- Document occurrence of disease(s) in wild/natural population.
- Monitor adult mortalities and spawned adults for presence of viral, bacterial, fungal and parasitic agents.
- Conduct examinations at all life stages when unusual loss occurs to determine cause of loss and recommend preventative and therapeutic treatment.

Disease control and monitoring practices conform to standards developed by the Nez Perce Tribe Fish Health Policy, the Integrated Hatchery Operations Team (IHOT 1995), and other standard fish culture disease monitoring protocols. The Nez Perce Tribe Fish Health Policy defines policies, goals, and performance standards for fish health management, including measures to minimize impacts to wild fish.

4.5 Budgets

Cost estimates for the new facilities are shown in Table 4-4. Cost estimates for construction of facilities were prepared by HDR Inc.

Table 4-4. Estimated expenditures for the Clearwater River Coho Salmon Project.

Expenditure	Estimated Cost
Planning: • Design @ 10 percent of construction costs ($15,498), • NEPA/ESA costs ($50,000), • and 0.5 FTE for project administration ($35,000)	$100,498
Construction (includes capital, engineering, and construction administration)	$154,284
Project-wide O&M (FY 2006)	$576,213
Project-wide M&E (FY 2006)	$841,494
Total	**1,672,489**
Note: Estimates are in 2004 dollars	

Both the Operations and Maintenance (O&M) and Research, Monitoring, and Evaluation (RM&E) budgets have start-up capital costs including one-time purchases of a rotary screw trap and data loggers ($22,000 in RM&E), and trailers and tanks ($50,000 in O&M). The outyear costs are reduced by these one-time purchase amounts and increased by the standard 3% annually (Table 4-5).

Table 4-5. O&M and RM&E budget estimates for implementation of Phase I of the Nez Perce Tribe Clearwater River Subbasin coho salmon reintroduction project.

Fiscal Year	O&M	RM&E
2006*	$576,213	$841,494
2007	$541,999	$844,079
2008	$558,259	$869,401
2009	$575,007	$895,483
2010	$592,257	$922,348

*2006 budget estimates include one-time purchases of a rotary screw trap and data loggers ($22,000 in RM&E), and trailers and tanks ($50,000 in O&M).

Chapter 5: Research Monitoring and Evaluation

In this chapter:

- Management goals and objectives
- Assumptions associated with management objectives
- Monitoring and evaluation goals and objectives
- Annual monitoring and evaluation budget estimates

5.1 Coho Salmon Restoration Program Management Goals and Objectives

The Nez Perce Tribe's overall goal for coho salmon in the Clearwater River Subbasin is to reintroduce and restore coho salmon to levels of abundance and productivity sufficient to support sustainable runs and annual harvest. Accompanying that goal are related objectives that detail a level of annual escapement and state the need to maintain genetic attributes and life history characteristics of naturally spawning coho salmon that support:

- Protection, mitigation, and enhancement of Columbia River Basin anadromous fish resources;
- Long-term harvest opportunities for tribal and non-tribal anglers; and
- Maintaining ecological and genetic impacts to non-target populations within acceptable limits.

5.2 Assumption Associated with Management Objectives

The following objectives were formulated to meet the goals stated above and to address management needs. Assumptions were developed for each objective. To achieve success, the following assumptions must be met for each management objective.

Management Objective 1: Develop a localized Clearwater River coho salmon broodstock to support components of the restoration program.

- Localized broodstock will be more effective in establishing natural production.
- Hatchery escapement meets identified broodstock goals.

Management Objective 2: Establish natural production of coho salmon in the Clearwater River subbasin.

- Hatchery escapement meets identified natural production goals.

- Adult returns from natural production are detected.

- Stream fidelity among returning hatchery and natural origin spawners is high.

Management Objective 3: Operate the hatchery program so that life history characteristics and genetic diversity support natural production of coho salmon.

- Genetic structure of the founding population is diverse and robust enough to support local adaptation over time.

Management Objective 4: Keep impacts of the hatchery program on non-target species within acceptable limits.

- Natural production of steelhead and Chinook salmon is not adversely effected.

Management Objective 5: Restore and maintain treaty-reserved tribal and recreational fisheries.

- Hatchery and natural-origin adult returns can be adequately forecasted to guide harvest opportunities.

- Hatchery adult returns are produced at a level of abundance adequate to support fisheries in most years with an acceptable level of impact to natural-spawner and broodstock collection.

- Ocean and Lower Columbia River fisheries do not constrain broodstock and natural escapement.

- In-basin fisheries do not constrain broodstock and natural production escapement.

Management Objective 6: Operate the hatchery programs to achieve optimal production effectiveness while meeting priority management objectives for natural production enhancement, diversity, harvest, and impacts to non-target populations.

- We can identify the most effective rearing and release strategies.

- Management methods (weirs, juvenile traps, harvest, adult out-plants, juvenile production releases and marking strategies) can be effectively implemented as described in management agreements and monitoring and evaluation plans.

Management Objective 7: Coordinate monitoring and evaluation activities and communicate program findings to resource managers.

- Coordination of needed and existing activities within agencies and between all co-managers occurs in an efficient manner.
- Accurate data summary is continual and timely.
- Results are communicated in a timely fashion locally and regionally.
- The RM&E program facilitates scientifically sound adaptive management of the coho salmon restoration program.

5.3 Monitoring and Evaluation Goals and Objectives

Based on the above management objectives and assumptions, underlying Research, Monitoring, and Evaluation (RM&E) objectives were developed to assess the results of the supplementation efforts so that operations can be adaptively managed. We organized the methodology section of the RM&E plan according to RM&E objectives relevant to the management objectives. These RM&E objectives required quantifiable measures that describe structural and functional attributes of interest as well as progress toward meeting the objective.

The goal of the Nez Perce Tribe coho salmon reintroduction RM&E program is to monitor and evaluate the results of the coho restoration program so that operations can be adaptively managed to optimize hatchery and natural production, and minimize deleterious ecological impacts. Pursuant to this goal, research data collection and analysis for the coho restoration RM&E program endeavors to:

1) provide science-based recommendations for management and policy consideration;

2) demonstrate when the reintroduction program meets its restoration goals; and

3) assist in the re-establishment of tribal and recreational fisheries.

This document should be viewed as an adaptable tool that describes the scope of research, the approach towards monitoring and evaluation efforts, and the existence of ongoing research, monitoring and evaluation projects and their relationship to the coho salmon restoration program. As such, the associated methods to accomplish the objectives are subject to modification as critical uncertainties are addressed, new technology is developed and new questions arise. We also desire to be consistent and coordinated with other regional monitoring and evaluation plans and subbasin planning recommendations.

5.3.1 RM&E Objective 1. Determine If Program Targets for Contribution Rate of Hatchery Fish Are Being Achieved and if They Can Be Improved.

Information gathered under this M&E objective is intended to evaluate how well hatchery production techniques are working and whether certain practices can be modified to improve benefits. The program objectives include both developing a localized coho salmon broodstock and optimizing hatchery product performance. Sampling under this objective is designed to address the following management assumptions:

1. Localized broodstock will be more effective in establishing natural production.

2. Hatchery escapement can meet identified broodstock goals.

3. We can identify the most effective rearing and release strategies.

Management methods (weirs, juvenile traps, harvest, adult out-plants, juvenile production releases and marking strategies) can be effectively implemented as described in management agreements and monitoring and evaluation plans.

5.3.1.1 Task 1.A. Monitor fish culture and hatchery operational practices at each of the facilities utilized for the Nez Perce Tribe coho restoration program.

In-hatchery guidelines have been established by the Integrated Hatchery Operations Team (IHOT 1995). Each of the hatcheries involved with the reintroduction effort are required to follow the IHOT guidelines. Documentation of fish performance and rearing conditions will follow IHOT (1995) protocols and include: egg-take, egg-to-fry, and egg-to release survival rates; daily mortality; rearing densities and loading factors; calculation of growth rate; monthly fish health examinations of dead and live fish; and the size, condition, number, date, and location of release.

- Activity 1.A.1. Develop NPT coho salmon annual operation plan. This includes documenting the juvenile rearing and release activities at all Nez Perce Tribe coho restoration program facilities. This activity will be a cooperative effort between the Monitoring and Evaluation project and the Production Division within the tribe.

    - ☐ Subactivity 1.A.1.1. Determine egg-to-fry, fry-to-parr, parr-to-presmolt, and presmolt-smolt survival rates for each release group of coho.

    - ☐ Subactivity 1.A.1.2. Document numbers, size, time of release, and release location for all NPT coho reintroduction/supplementation fish.

    - ☐ Subactivity 1.A.1.3. Conduct periodic monitoring for size during rearing.

    - ☐ Subactivity 1.A.1.4. Participate in planning processes for ponding and rearing.

    - ☐ Subactivity 1.A.1.5. Prepare and submit tag, mark, and release reports.

- ❑ Subactivity 1.A.1.6. Summarize and evaluate the results of subactivities 1.A.1.1 - 1.A.1.4.

5.3.1.2 Task 1.B. Estimate the number of smolts and adults produced from each hatchery by treatment and rearing strategy.

The Nez Perce Tribe coho restoration program strategies are intended to produce a sufficient number of smolts to support a localized Clearwater River broodstock, to be utilized for rebuilding natural production and supporting harvest. The numbers of fish to be released was based on assumptions about the number of smolts and adults that would result, on average, from each reintroduction strategy. Accordingly, these numbers need to be evaluated to determine whether adjustment is needed to meet program objectives. This evaluation will be completed through three activities described below.

- o Activity 1.B.1. Mark a portion of the hatchery-reared coho salmon with a unique mark so they can be detected as smolts and as adults.

Coded Wire Tags (CWT), Passive Integrated Transponder (PIT) tags, and other marks will be used on some fish for specialized purposes, as described in the following three subactivities. New marking techniques will be evaluated to obtain a mark that has the least impact to the fish.

- ❑ Subactivity 1.B.1.1. CWT tag a portion of the hatchery release groups differentially to indicate release strategy and location.

A total of 825,000 coho will be marked (Table 5-1). CWT's are used so a wand detector can be used to distinguish them from naturally produced fish. Such opportunities will be available whenever juveniles are captured by seining or at traps, and whenever adults are recovered in harvest, passing weirs, entering hatcheries, or as carcasses. This will require the personnel conducting the various field sampling tasks carry the hand-held wands that detect CWT's, and that all fish captured be checked with the wand.

Table 5-1. Coho salmon production numbers for release into the Clearwater Subbasin.

Location	Life Stage	Number Released	PIT Tags	CWT	Adult Collection	Adipose Fin Clip	Juvenile Trap
Mussellshell-Lolo Creeks	Smolt	270,000	1,500	270,000	Yes		Yes
Lapwai Creek	Smolt	550,000	2,000	275,000	Yes	50,000	No
Clear Creek	Smolt	280,000	1,500	280,000	Yes		Yes
Dworshak	-	-	-	-	Yes		-

- Product: Representative CWT groups released in reintroduction streams.

  - ❑ Subactivity 1.B.1.2 . PIT tag fish from each of the release groups so that survival to Lower Granite Dam can be estimated.

A group of PIT-tagged fish will be included with each release group that represents a particular strategy in a particular stream. Detections of these PIT-tagged fish as they pass screw traps and dams in the Snake and Columbia rivers will enable estimation of emigration timing, travel time, and survival for that strategy. Detection probability for PIT- tagged spring Chinook salmon yearlings passing Lower Granite Dam (LGR) often ranges from 20% to 45% (Smith *et al*. 1994). Further, survival of smolts migrating from Snake River tributaries to LGR is typically 75-85% for yearling spring Chinook salmon (Smith *et al*. 1998). Thus, for PIT-tagged coho salmon leaving NPT reintroduction streams, we might expect 15-40% of yearling smolts to be detected as they pass LGR. If a particular release strategy includes dispersal of hatchery fish to multiple release points within a stream, then the PIT-tagged fish will be evenly divided in proportion to all fish released at each point.

- Products:

  1. Representative PIT tag group released with each treatment in each stream.
  2. Estimated mean difference in survival to LGR between release groups.
  3. Estimated egg-to-smolt and release-to-smolt survival for each release group.
  4. Differentiation of individuals of localized versus lower Columbia River stock origin.

  - ❑ Subactivity 1B.1.3. Estimate harvest rates of Clearwater coho salmon in the ocean and Columbia River.

A group of smolts to be released into Lapwai Creek will be double index marked with adipose fin clips (50,000) and CWT’s (100,000). This marking will occur in conjunction with marking subactivity 1.B.1.1. This subactivity deals only with the estimation of harvest rate (percentage of population harvested) in the ocean, Columbia River, and Clearwater River. Because CWT recoveries of NPT coho salmon from ocean and river catches are likely to be low for the next decade or more, we will use the differences in survival rates between the adipose-clipped and CWT marked adult returns vs. the CWT only adult returns.

  - ❑ Subactivity 1.B.1.4. Conduct tests for each type of marking to estimate rates of tag loss, tag detection efficiency, and post-tagging mortality.

Rates of long-term CWT loss will be determined from the number of readable CWT's recovered from hatchery fish that are adipose fin clipped. Rates of PIT tag shedding will be determined from experiments coordinated with other entities using PIT tags in the Snake River basin each year, such that results can be pooled. Efficiencies for detecting either PIT tags or CWT's when fish are captured as juveniles at traps or by seining will be evaluated. Efficiencies for detecting CWT's in unmarked adults will be performed at the hatcheries where fish can be thoroughly examined to see if CWT's are being missed, and which detection strategies are most effective. Initially, a hand wand will be used in the same way applied to spawning surveys, and then all fish be subjected to a more thorough second examination with another CWT detector. Results from the first and second checks will be compared to estimate the percentage of CWT's missed during the first examination.

- Products:

    1. Estimate of delayed mortality after either PIT or CWT tagging.

    2. Estimated percentage of sampled fish with PIT tags or CWT's that are correctly identified as having a tag.

    3. Tag retention estimates

- o Activity 1.B.2. Estimate abundance of hatchery fish departing as smolts from selected treatment streams.

Emigration from the stream is expected to proceed directly following release. The number of fish released will be interpreted as equivalent to the number of fish that emigrated. The dates that smolts pass any of the mainstem dams will be detected from PIT-tagged fish, and can be used to verify that immediate migration occurred.

- Product: Number of coho salmon smolts stocked in each treatment stream.

    - ❑ Subactivity 1.B.2.2. Assemble PIT tag detections throughout the Columbia basin for fish tagged in NPT coho reintroduction streams, and estimate abundance passing Lower Granite Dam (LGR).

Numbers of PIT-tagged fish reaching LGR from each treatment stream will be estimated by the SURPH.1 model (Lady *et al*. 2001). Due to sample size constraints, the SURPH.1 model will be used to calculate a point estimate of total fish arriving at LGR. Therefore, the survival of PIT-tagged hatchery fish reaching LGR from NPT releases can be estimated. PIT tag detections at mainstem dams will be downloaded from the PTAGIS database.

- Products:

    1. Estimate and 95% confidence interval for the number of smolts from each stream that reach LGR or other mainstem dams.

    2. Time frequency distribution of passage at LGR or other mainstem dams for each release group.

- Activity 1.B.3. Estimate total hatchery adults produced from each release in each stream.

A portion of hatchery-reared adults will bear CWT's, so the number returning can be estimated from recoveries in fisheries, at hatcheries or on the spawning grounds. Sampling to estimate the abundance of adults will include operation of weirs, returns to hatcheries, and carcass surveys.

- ☐ Subactivity 1.B.3.1. Operate weirs and ladders or conduct spawning surveys to estimate escapement of hatchery-produced coho salmon into reintroduction streams.

Spawner abundance will be estimated in all reintroduction streams. Adult coho salmon entering Lapwai Creek, Lolo Creek, Clear Creek (Kooskia National Fish Hatchery), and Dworshak National Fish Hatchery will be counted at temporary weirs constructed across those streams or permanent ladders at existing hatcheries. Each weir will have a fish trap so that all fish passing the weir can be counted, measured, sampled for scales and tissue, examined for marks or tags, given a secondary mark, and released above the weir or transferred to a holding pond for broodstock.

Temporary weirs are excellent tools for monitoring adult escapement into streams where flows are typically less than 1,000 cfs during the passage season. We must plan for the likelihood that some fish will pass upstream during high flows in each stream when the weirs are not operating. Accordingly, a mark will be applied to each fish trapped at each weir so that marked to unmarked ratios during spawning ground surveys (Subactivity 1.D.3.2) can be used to estimate the total number of adults entering that stream.

In Lolo Creek, the abundance of spawners will be estimated from spawning ground surveys. Surveys will be conducted as described under Subactivities 1.D.3.1 and 1.D.3.2. Carcasses will be marked returned to the river, and redds will be marked during each of the three ground surveys per season in Lolo Creek. To estimate total escapement, the redd count will be multiplied by 2.07 redds per female (Berghe and Gross 1983) and multiplied by male to female ratios that are recovered from other NPT adult collection sites (Activity 1.B.3). This estimated total escapement for a particular return year will be separated into brood year returns based on age composition determined from scale samples. Total return for each brood year will be calculated by summing the estimated escapement of each age group in different run years.

Spawner abundance in the mainstem Clearwater River will be conducted by the NPTH RM&E project through their weekly fall Chinook salmon spawning ground surveys. Low numbers of spawners in the large river channels make ground surveys ineffective. To estimate total escapement in this area, the redd count will be multiplied by 2.07 redds per female (Berghe and Gross 1983) and multiplied by male to female ratios that are observed at other adult collection facilities (Activity 1.B.3) Aerial surveys are described further under Subactivity 1.C.1.1.

- Products:

    1. Estimate of hatchery and natural escapement by age at weirs or ladders on Lapwai Creek, Lolo Creek, Clear Creek (Kooskia National Fish Hatchery), and Dworshak National Fish Hatchery.

    2. Estimated number of spawners in the mainstem Clearwater River.

- Activity 1.B.4. Estimate smolt-to-adult survival for each treatment based on smolt abundance from Activity 1.B.2 and adult abundance in Activity 1.B.3.

Smolt-to-adult survival is strongly influenced by factors that are independent of supplementation practices, so estimates of this parameter are needed to understand how out of subbasin effects, such as variation in ocean survival or variation in mainstem passage survival, may have influenced the number of surviving adults. The most reliable estimator of smolt-to-adult survival will be the number of adults arriving at Lower Granite Dam divided by the estimated number of smolts passing LGR (subactivity 1.B.2.2).

The number of surviving adults can be expressed in a variety of forms including the number of adults returning to Lower Granite Dam or total catch plus spawner escapement. Each of these abundance estimates requires that the age of adult fish be determined wherever they are recovered, so that fish of each age can be assigned to their broodyear of origin. For a portion of the hatchery fish, the CWT's will reveal their brood year. Scale sample analysis and CWT recoveries will be used for age determination. The most reliable estimate of smolt abundance will be for numbers arriving at Lower Granite Dam in the case of coho salmon (released as parr and smolts). Smolt-to-adult return rates will be estimated for the coho with the greatest degree of resolution; release location, release timing, and pre-release rearing.

- Product: Estimated mean difference in smolt-to-adult survival between released groups.

- Activity 1.B.5 Document adult returns to each weir/broodstock collection site.

    - ☐ Subactivity 1.B.5.1. Determine size, age, sex, and origin of adult coho returning to each weir/broodstock collection site.

- ☐ Subactivity 1.B.5.2. Document run-timing, spawning-timing, pass/keep scenarios, and spawning matrices for each weir/broodstock collection site.

- ☐ Subactivity 1.B.5.3. Prepare and submit tag and mark recovery reports.

- ☐ Subactivity 1.B.5.4. Summarize results of Subactivities 1.B.5.1 and 1.B.5.2.

5.3.1.3 Task 1.C. Determine the effects of rearing and release treatments on the dispersal of juveniles and adults returning to occupy available habitat in the target streams.

It is assumed that juveniles will disperse after release to evenly fill the available high quality coho salmon habitat in a treated stream. However, the available habitat is spread over hundreds of miles of stream, and the methods for stocking fish so that they disperse to all of this habitat is uncertain. Dispersal rates are likely to differ between point release and scattered releases. Fish released as smolts are expected to migrate following release. Additionally, movements of juveniles will be detected at screw traps, and dispersal of adults upon return will be assessed through spawning surveys.

- o Activity 1.C.1. Determine the effects of treatments on spawning distribution by conducting spawner surveys.

In order for supplementation to achieve the intent of filling available habitat for natural production, spawning of hatchery fish should be dispersed throughout the available habitat. This desired result may be difficult to achieve, because access points for stocking the treatment streams are limited. Recoveries of CWT’s from spawning surveys will be used to characterize the density distribution of spawners from each treatment in each stream. Differences between treatments, streams and years in the dispersal of spawners, relative to the release locations, will be examined for possible correlations to factors of the treatment or the environment.

Redd surveys will be conducted throughout the extent of probable spawning habitat and will be repeated at least three times (about 1 week apart) during the typical spawning period. Reaches where fish choose to spawn may be related to time of spawning, temperature, substrate size, etc. with later maturing fish tending to spawn further downstream. If spawning is not well dispersed, possible causes will be investigated. These will include location and method of stocking, weir impedance, stream temperatures at time of spawning, and gravel quality. If spawners are keying on areas where temperatures are desirable at the time of their spawning, we may find that the inherited time of spawning from the founding population determines the stream reach that will have suitable temperatures at the time of spawning. In order to detect these effects survey areas will be subdivided to look at redds/km within survey sections over time.

- ☐ Subactivity1.C.1.1. Conduct helicopter surveys weekly over larger river reaches and remote stream reaches during the coho salmon spawning season (October through early December).

Spawner abundance in the mainstem Clearwater River will be conducted by the NPTH M&E project through their weekly fall Chinook aerial spawning ground surveys. Portions of the reintroduction streams are only accessible by aerial flights. Flights will be conducted at an elevation of 200 feet above the water surface, and the observers will count the number of new redds, live fish and carcasses. Each redd will be marked on a map. Aerial redd count surveys will be conducted in cooperation with state and federal agencies so that duplication of effort is eliminated.

Carcass examinations will be necessary to estimate the proportions of hatchery and natural fish constructing redds. Locations of carcasses sighted from the air are recorded and the carcasses are retrieved later if possible with the use of jet or drift boats. Retrieved carcasses will be measured (hypural length), examined for marks and tags, sampled for scales and tissues, examined for percentage spawned, and cut in half to avoid re-counting. Measurements and samples taken here will provide data on hatchery/natural composition, brood year composition, percent spawned, age and size at ocean entry, disease incidence and gene frequencies.

- Products:

    1. Total redds and estimated number of spawners in each reach surveyed.

    2. Time frequency distribution of redd construction in each reach surveyed.

- ☐ Subactivity 1.C.1.2 Conduct weekly spawning ground surveys.

Redds and carcasses will be counted during foot surveys in spawning areas from early October through November. Stream reaches to be surveyed include all reintroduction streams and selected large river reaches where spawning is expected. Ground surveys in the large river systems or remote stream reaches will only be opportunistic to recover carcasses observed during aerial counts, as described in the previous subactivity. New redds will be marked and counted, live fish counted, and carcasses will be recovered and processed. Redds will be marked with flagging that records date, identification number, and will be color-coded for each survey period. Marking redd locations with flags (colored washers or rocks in large streams) and recording notes on each redd has been beneficial in areas where multiple redds occur. Processing of carcasses will include measurement of hypural length, examination for marks and tags, scale sampling, examination for percentage spawned, jaw tagging, and return to the flowing river. Recovery of jaw-tagged carcasses on subsequent surveys will be used for mark-recapture estimates of spawner abundance.

- Products:

    1. Percentage of total redds contained in discrete stream sections.

    2. Time-frequency distribution of redds within each stream section.

- ❑ Subactivity 1.C.1.3. Monitor an index of prespawning mortality by recording gamete retention in carcasses during spawning surveys.

Prespawning mortality is an important life history parameter, but is difficult to monitor until adult returns increase. The only index of prespawning mortality that can be obtained with at low fish densities is the percentage of fish recovered on spawning surveys that have retained a majority of their gonads. The focus will be on the percentage spawned in females, as determination of percentage spawned in males is difficult to assess. This will be measured by cutting open each carcass and recording the approximate percentage of gonad that has been retained. The percentage of fish with retained gonads should be nominal when prespawning survival is high, but can increase to a high percentage in years and locations where prespawning mortality is high.

- Product: Annual estimates of the percentage of carcasses that are less than 80% spawned in each stream.

- ❑ Subactivity 1.C.1.4. Count fish collected for hatchery brood stock.

All fish collected for hatchery broodstock by any method will be measured (hypural length), examined for marks and tags, and scale sampled. Numbers of fish entering hatchery ladders will be counted at least weekly and tagged so that time of entry can be compared quantitatively between years and possible treatments so that time of return can be evaluated.

- Products:

    1. Time-frequency distribution of arrival at brood collection points.

    2. Counts of hatchery coho salmon, by age, taken for brood stock.

5.3.2 RM&E Objective 2. Determine the Increases in Natural Production That Results from Supplementation of Coho Salmon in the Clearwater River Subbasin, and Relate Them to Limiting Factors.

One of the primary benefits to be derived from the Nez Perce Tribe coho reintroduction program is the restoration of full natural production of coho salmon to the Clearwater River subbasin. This objective is intended to measure those benefits and refine our understanding of carrying capacity and other factors that affect program success. Sampling under this objective is designed to address the following management assumptions:

1. Hatchery escapement meets natural production goals.

2. Adult returns from natural production are detected.

3. Stream fidelity among returning hatchery and natural origin spawners is high.

5.3.2.1 Task 2.A. Determine the extent of natural production in Lolo Creek and Clear Creek.

A major premise for the Nez Perce Tribe coho restoration program is that habitat for coho salmon is abundant, but nearly vacant in the Clearwater River Subbasin. Further, it is assumed that stocked hatchery fish of Columbia River ancestry will seek find and utilize this habitat, and reproduce naturally. However, the available habitat is distributed over hundreds of miles of stream, and the methods for stocking fish so that they disperse and utilize this habitat are uncertain. There may also be environmental factors that will result in more fish being produced from one portion of a stream than another. Studies of anadromous salmonid rearing in well seeded streams indicate that habitat use by fish is patchy (Hankin and Reeves 1986), and that juveniles use different habitats as they grow and as stream temperatures change. This sampling will monitor the changes in natural production of parr, smolts and adults across years.

- Activity 2.A.1 Estimate adults produced naturally from in Lolo Creek and Clear Creek.

    - ☐ Subactivity 2.A.1.1. Mark hatchery fish released into Lolo Creek and Clear Creek so that hatchery and natural fish can be distinguished.

Marking of hatchery fish was also listed under Activity 1.B.1, and is listed here again to emphasize that marking of hatchery fish is to estimate abundance of natural fish as well as hatchery fish. Hatchery fish are likely to be numerically dominant within the reintroduction streams for the near future, so a small proportion of unmarked hatchery fish could greatly confound the estimation of contributions to catch and spawner escapement by natural fish. All methods for estimating abundance of naturally produced fish also depend on the ability to distinguish natural and hatchery fish. Accordingly, all hatchery fish released in Lolo Creek and Clear Creek will be marked with coded-wire tags (CWT’s), but not adipose fin-clipped, so a wand detector can be used to distinguish them from natural fish. The focus of this phase (phase I) of the restoration program is to establish a localized broodstock. It is assumed that Natural production will be extremely low or nonexistent for the next few years for two reasons: 1) prior releases of coho salmon utilized parr, which are expected to survive at a low rate based on similar experiments performed with spring Chinook salmon and 2) most returning adults will be retained for broodstock, hence limiting natural production. Once a localized broodstock has been established for the entire Clearwater River Subbasin, the natural production phase (phase II) will be expanded with extensive monitoring of natural production.

- ☐ Subactivity 2.A.1.2. Operate weirs or conduct spawning surveys to estimate escapement of naturally-produced coho salmon into treatment streams. (Same as Subactivity 1.B.3.1).

- Activity 2.A.2. Survey the spatial and temporal distribution of natural origin coho salmon spawning in the reintroduction streams.

We need to determine how well the spawners are dispersing throughout the available spawning habitat. Spawning surveys to detect dispersal of hatchery fish were described under Activity 1.D.1, and the sampling under that activity is the same as that required to detect dispersal of natural spawners under this activity. A full description of the sampling is not repeated here, but a summary of each subactivity is given as a reminder of the sampling that is planned.

- ❑ Subactivity 2.A.2.1. Conduct helicopter surveys weekly over the larger river reaches and remote stream reaches during the coho salmon spawning season (October through early December).

Spawner abundance in the mainstem Clearwater River will be conducted by the NPTH M&E project through their weekly fall Chinook aerial spawning ground surveys. Portions of the reintroduction streams are only accessible by air.

- Products:

    1. Total redds and estimated number of spawners in each reach surveyed.

    2. Time frequency distribution of redd construction in each reach surveyed.

- ❑ Subactivity 2.A.2.2. Conduct weekly ground surveys of spawning.

Redds and carcasses will be counted from foot or boat surveys in spawning areas from early October through November. Stream reaches to be surveyed include all reintroduction streams and selected large river reaches where spawning is expected. Ground surveys in the large river systems or remote stream reaches will only be opportunistic to recover carcasses observed during aerial counts, as described in the previous subactivity.

Products:

1. Percentage of total redds enumerated in discrete stream sections.

2. Time-frequency distribution of redds within each stream section.

- ❑ Subactivity 2.A.2.3. Count fish collected for hatchery broodstock.

Hatchery adults collected at weirs or hatcheries for hatchery broodstock must also be accounted for. Accordingly, all fish collected for hatchery broodstock by any method will be measured (hypural length), examined for marks and tags, and scale sampled. Numbers of fish entering hatchery ladders will be counted at least weekly and tagged so that time of entry can be compared quantitatively between years, and possible treatments for time of return can be evaluated.

- Products:

    1. Time-frequency distribution of arrival at brood collection points.

    2. Counts of hatchery coho salmon, by age, taken for broodstock.

- Activity 2.A.3. Survey the spatial and temporal distribution of juvenile coho salmon rearing in target streams.

    - ☐ Subactivity 2.A.3.1. Perform snorkel surveys in reintroduction streams to estimate parr densities in systematic reaches.

Snorkeling counts will be the main sampling tool used to determine densities (an index of abundance) of natural salmonids by habitat type (*i.e.*, pool, riffle, pocket water and run). Marks on hatchery fish will not be visible underwater, so the percentage of juveniles that are hatchery fish in Lolo Creek and Clear Creek will be determined from fish that are captured during seining. Densities of other fish species will also be determined during snorkel surveys. The purpose of these surveys is not to estimate total juvenile abundance, but rather to evaluate how juveniles are dispersed throughout the habitat that supplementation treatments are intended to fill. Streams in the Clearwater River Subbasin generally have high transparency allowing effective snorkeling. Snorkeling will be performed at least once in each stream during July through mid-September of each year.

Surveys will cover stream reaches that are systematically spread over the length of the stream. The cumulative length of these reaches will compose at least 20% of the total stream length expected to be utilized by juvenile coho salmon. Each survey reach will be composed of contiguous stream segments that include a minimum of 10 pools, and 10 riffles. Each diver will count all salmonids, by species, in 2-inch length increments (usually starting at 2-4 inches) within the lane of his visibility range, which usually will extend 1.5- 3.0 m (5-10ft) on each of his sides [3 to 6 m (10 to 20 ft) total width per lane]. Coho salmon will be identified as sub-yearlings or yearlings. Visibility width of each lane will be recorded, so that fish densities are calculated per area of actual observation. Water clarity at the time of each survey will be recorded as the distance (in feet) over which a fellow diver is clearly visible. Visibility must be 5 feet or greater for divers to confidently distinguish fish species underwater.

Survey teams will consist of 3 to 5 members. One member will carry equipment and record data while the other 2-4 members snorkel in an upstream direction to minimize disturbance of fish prior to enumeration. Fish counts and physical characteristics will be recorded separately for each habitat unit (*i.e.*, pool, riffle, pocket water, or run). Snorkelers will move slowly but steadily upstream in an assigned lane, with one lane along each shoreline. The number of snorkelers is dependent upon visibility and width of the stream. Water temperature must be at least 13^{o} C before snorkeling, because the proportion of fish taking refuge in the substrate begins to increase at lower temperatures.

- Products:
    1. Annual estimates of parr/m2 in pool, riffle, pocket water and run habitats, by reach, of each reintroduction stream.

    2. Multiple regression or multi-variate model relating parr density to spawner abundance and habitat features in each stream.

- Activity 2.A.4. Monitor the timing, size and abundance of juvenile coho salmon emigrating from each target stream.

Rotary screw traps will be fished to monitor emigration of juvenile coho salmon from Lolo Creek and Clear Creek, as described in subactivity 1.B.2.1. Coho salmon captured in the traps will be anesthetized, scanned for tags, and natural fish over 60 mm may be PIT tagged as described by Prentice *et al*. (1990). Length, weight and fish condition will be recorded for all PIT tagged fish. Scales (subsample) will be collected and used to determine the age of emigrating fish. PIT tagged fish will be placed in a recovery bucket for a short time (30 - 60 minutes) and released back into the river. Where possible, PIT tagged fish may be held for longer periods (24 to 48 hours) to better estimate tagging mortality. Where extended holding opportunities are not available, mortality rates from hatchery PIT tagging may be applied.

- Products:

    1. Population estimates and 95% confidence intervals for juvenile coho salmon passing the trap as parr (June 1 through August 31), presmolts (September 1 through December 31), and smolts and fry (January 1 to July 31 – weather permitting).

    2. Time-frequency distribution of passage for each life stage.

    3. Mean and 95% confidence interval of mean length for each life stage or date.

5.3.2.2 Task 2.B. Measure life history traits that may reflect limitations to natural production.

We will sample to detect two types of mechanisms that limit natural production: density dependence and quantitative genetic variation. As coho salmon fill the habitat to capacity, density-dependent mechanisms should begin functioning and reveal that capacity limits are being approached. Life history traits that are known to be influenced by fish density include growth, migration timing, and survival. Accordingly, we will conduct sampling to detect changes in these parameters within Lolo Creek and Clear Creek. The key, however, will not be simply to detect change, but to detect when the density-dependent changes are sufficient that no more adults are produced per spawner.

Evidence of limitations of quantitative genetic variation should be expressed by differential survival of inherited life history strategies, such as egg-to-fry survival for different spawning times, parr-to-adult survival for fish that smolt as either subyearlings or yearlings, and survival to ocean entry for fish that move downstream from natal areas in the first summer-fall compared to those that hold until they are yearling smolts. Because the stocks used to initiate the Nez Perce Tribe coho restoration program are not specifically native to the target streams, there is likely to be some change in life-history traits that will gradually result over time from natural selection. The unique balance of habitat quantity and quality for summer rearing and over-winter refuge is likely to vary between streams, so natural selection may gradually alter the proportion of fish that drift downstream for rearing, and the proportion that smolt as either subyearlings or yearlings.

- Activity 2.B.1. Estimate growth, migration timing, and survival of coho salmon.

Under this activity, natural coho salmon will be: captured in rearing areas to measure their growth and tag them for survival estimates; captured in screw traps to determine size and time at emigration; have scale samples taken to establish circuli patterns reflecting growth rate; and interrogated for PIT tags as they pass mainstem dams.

  - ☐ Subactivity 2.B.1.1. Seine for coho salmon parr periodically through the summer to monitor increase in length and to tag parr for survival estimates.

Expression of density-dependent growth is most likely to occur during summer low flow, so we will capture rearing parr to track changes in average length. Density-dependent limitations on growth are generally observed by comparing growth rates between years, and this effect is a measurable indicator that carrying capacity for rearing is being reached (Cramer *et al*. 1985).

Age 0+ coho salmon will be captured by beach seines (100' x 6' x 3/16" mesh and 50' x 4' x 3/16" mesh) and electrofishing once a month from May through September in selected reintroduction streams. Snorkelers will be used to locate concentrations of fish that can be captured by seine. Length measurements (50 fish per sample date) and scale samples (20 fish per sample date) will be dispersed among several sites, to ensure that a representative sample of the population is obtained. All captured fish will be scanned for PIT tags and CWT’s. Previously PIT-tagged fish will be recorded and measured.

The timing and survival of out-migrants can be estimated for PIT-tagged fish as they are detected passing Snake River dams (1.B.2.3). Survival to LGR can all be estimated fairly accurately with as few as 200 PIT-tag detections at LGR per stream. This small number of fish is useful, because detection probabilities at LGR can be estimated from PIT-tagged fish released throughout the Snake River Basin, as was demonstrated by Cramer (1996a and 1996b).

This subactivity deals with tagging of natural parr, so enough parr must be tagged to have 200 or more survive to the smolt stage. Walters *et al.* (1999) reported that detection rates of spring Chinook parr and pre-smolts (fall migrants) from the Clearwater River Subbasin were about one fourth and one half, respectively, of that for Chinook salmon PIT-tagged as smolts. Based on these expected recovery rates, we set PIT deployment goals of 1000 parr, 500 pre-smolts or 250 smolts per selected reintroduction stream each season. If double or triple this base number can be tagged, then survival could be estimated separately for different periods of tagging. In order to achieve these tagging minimums, up to 150 fish per sample date (8-10 sample dates) will be PIT tagged. Each fish >60 mm will be tagged as described by Prentice *et al.* (1990), and will be measured and weighed. PIT tagged fish will be placed in net pens or aerated buckets and allowed to recover 30-60 minutes before release.

- Products:

    1. Regression of mean length on Julian Day for each stream each year.

    2. Multiple regression accounting for variation between years in mean length by July 1(parr) or September 1 (presmolt) as a function of parr density, stream temperature, and flow.

    3. PIT tagged parr to be used for estimating timing of passage and survival to passage to the screw trap and mainstem dams.

- ❑ Subactivity 2.B.1.2 Fish screw traps to determine size and time at emigration and to estimate passage of tagged fish.

Operation of screw traps to estimate size, timing and abundance of emigrants was described under subactivity 1.B.2.1. Here, we add the element of recapturing the fish that were PIT tagged as parr from the previous subactivity. There is no change in sampling with the traps for this subactivity, only the identified need to scan all fish captured for the presence of PIT tags.

Recoveries of PIT tagged parr will enable estimation of survival to smolting, and abundance of parr. Survival to smolting will be determined by estimating total passage of PIT tagged fish at the screw trap (PIT tag catch/trap efficiency). Then, survival can be estimated by expanding PIT tag recoveries. If tagging and recapture rates are sufficient, it may be possible to estimate survival from different periods of the summer in which parr were tagged. Captures of all coho salmon in the traps will also be used to establish the proportion of fish that were PIT-tagged, and that in turn can be used to estimate the abundance of parr, based on the known number of fish that were PIT tagged.

- Products:

    1. Estimate of parr abundance, based on marked-to-unmarked ratio of fish arriving at the screw trap.

    2. Estimate of survival from parr to smolt in each treatment stream.

3. Multiple regression accounting for variation between years in mean length of fall presmolts or spring smolts as a function of parr density, stream temperature, and flow.

4. Multiple regression accounting for variation between years in ratio of presmolt to smolt migrants as a function of parr density, stream temperature, and flow.

- ☐ Subactivity 2.B.1.3. Assemble PIT tag detections throughout the Columbia Basin for fish tagged in reintroduction streams, and estimate abundance and survival to Lower Granite Dam (LGR).

Numbers of PIT-tagged fish reaching LGR will be estimated by the SURPH.2 model (Lady *et al.* 2001). PIT tag detections at mainstem dams will be downloaded from the PTAGIS database. Methods are described under Subactivity 1.B.2.3.

PIT tag recoveries at mainstem dams will enable estimation of smolt migration rates, survival rates from the natal stream to LGR, and total smolts reaching LGR from those streams with rotary screw traps. Migration rates will be calculated as days of travel from release to detection at LGR. Arrival timing at each dam will be summarized by each release group where a minimum of 30 observations are obtained. Survival rate to LGR will be calculated as the number reaching LGR divided by the number leaving each rotary screw trap. Those leaving the screw trap will be the sum of fish tagged at the screw trap, and the estimated number of previously tagged fish pass the screw trap. In study streams without screw traps, the survival rate will be estimated for parr to LGR based on the number of parr that were PIT tagged. In the case of streams with a screw trap, the estimated fraction of the population tagged at the screw trap can be used along with the estimate of PIT tags reaching LGR to estimate total smolts from the study stream reaching LGR.

- Products:

1. Estimate and 95% confidence interval for the number of smolts from each stream that reach LGR or other mainstem dams.

2. Estimate and 95% confidence interval of survival from parr or tributary mouth to LGR or other mainstem dams.

3. Median, 20th percentile, and 80th percentile travel times (days) and arrival times from the screw traps to LGR.

- ☐ Subactivity 2.B.1.4. Sample scales from parr and smolts in selected reintroduction streams to characterize circuli number and spacing that will later be measured on adult scales to determine successful time and size at smolting.

Because new scale circuli are deposited at a consistent rate of about one every 2 weeks, a regression of circuli number on Julian day can be used to estimate dates of life history events that cause a distinct change in growth rate. For example, date of ocean entry and age at ocean entry can be determined from scales. Further, scale radius is highly correlated to fish length at a distinct event, such as ocean entry or annulus formation, and can be used to estimate the size of the fish at that event.

In addition to scales collected during seining, scales will be randomly collected from 25 coho salmon of each age, and 25 steelhead juveniles of each 5 cm size interval for each trap and each month. These scales will be used to establish the relationship of fish length to scale radius, and of date to circuli number. They will also distinguish yearling and subyearling coho salmon during June or July when there may be some overlap in size.

- Products:

    1. Regressions of circuli number on Julian Day for each stream each year. This will enable estimation of dates corresponding to a distinct change in scale patterns, like spring growth or ocean entry.

    2. Regression of length on scale radius, so that size at ocean entry can be estimated on adult scales.

- Activity 2.B.2 Estimate age at maturity, time of river entry and spawning, and prespawning survival of natural and hatchery adults.

    - ☐ Subactivity 2.B.2.1. Determine age at maturity from scales of returning adults handled at weirs, in hatcheries, or on spawning surveys.

Coho salmon collected at weirs, hatcheries, or carcass surveys examined for any marks/tags and measured to the nearest 0.5 cm for fork and hypural lengths. Scales will be read to determine freshwater, ocean, and total age, so each fish can be assigned to a brood year of origin. Age composition within size strata (primarily jack versus adult) will be applied to population estimates for those strata to determine total escapement from each brood in each run year.

- Product: Percentage that each age composes of the returns, by sex, to each stream.

    - ☐ Subactivity 2.B.2.2. Monitor an index of prespawning mortality by recording gonad retention in carcasses during spawning surveys. Methods are described under Subactivity 1.C.1.3.

- Product: Annual estimates of the percentage of carcasses that are less than 80% spawned in each stream.

5.3.2.3 Task 2.C. Determine the influence of environmental variation on natural production.

Growth, survival and carrying capacity for coho salmon in streams are likely to vary between years due to environmental fluctuation. Accordingly, the influence of environmental variables on the previously estimated parameters of rearing densities, juvenile growth rates, migration timing, and survival rates need to be determined, so that any observed changes in those parameters can be assigned to the proper cause.

- o Activity 2.C.1. Monitor environmental variables affecting fish in the treatment and reference streams.

Temperature and flow are each environmental variables that have been demonstrated to influence coho salmon, and which may vary substantially between years. Each of these parameters will be monitored in each reintroduction stream, so they can be used in analyses of cause-effect relationships.

- Product: Data set of daily flow and temperature in each reintroduction stream.

- o Activity 2.C.2. Calculate the correlation of environmental variation to variation in coho salmon population parameters.

Because environmental factors vary, their effects on life-history parameters of salmonids are generally only detectable after a long time series (10-15 years) of data have been assembled. Each of these variables has distinct mechanisms by which they can influence coho populations, but there is a high degree of covariance in these factors that may confound attempts to distinguish their separate effects in a natural stream. These two environmental variables will be examined as independent variables in multiple regression analysis of most population parameters estimated in this M&E plan, but information from studies elsewhere will be needed to deduce the separate effects of these variables.

- Product: Multiple regressions or analyses of covariance for various life history parameters, with environmental variables included as independent variables.

5.3.2.4 Task 2.D. Determine the spatial and temporal distribution of returning adult coho salmon in the Clearwater River Subbasin.

Previous monitoring of adult coho salmon returns has observed a high drop-out rate from Lower Granite Dam to Clearwater River tributaries. This task is designed to better quantify this loss by active and passive tracking of returning adults. In addition, straying, harvest and other potential sources of drop-out may be identified.

- o Activity 2.D.1. Provide sampling protocol for use in the separation system at the Lower Granite Dam Adult Fish Facility.

The origin of fish is determined using visible marks (adipose fin clip) or tags (either coded wire or passive integrate transponder). Female and male fish (adults and jacks) are tagged to obtain information on the movements of all age groups and both sexes.

- Activity 2.D.2. Provide radio tags and data sheets for NOAA Fisheries personnel at Lower Granite Dam.

A total of 50 radio tags will be purchased for this study. Additional tags may be available from an ongoing study conducted by the University of Idaho. These additional tags depend upon angler return rate, and the battery life of returned tags.

- Activity 2.D.3. Capture and radio tag at least 50 adult coho salmon at Lower Granite Dam.

Fish are captured and radio tagged at the Lower Granite Dam Adult Fish Facility. Fish are anesthetized before tagging. Radio tags are coated with glycerin and inserted into the esophagus of study fish. The radio tag used for this study weighs 16 grams (Lotek MCFT-3).

- Activity 2.D.4. Establish fixed monitoring stations.

Fixed-telemetry receivers are maintained and operated by the USFWS and the University of Idaho. In the Clearwater River, fixed telemetry stations are located near the Potlatch Mill (river mile 5) and above Orofino at the NPT Fisheries Office (river mile 47). Tracking data are downloaded from these receivers periodically. Receivers indicate when an individual radio tag (fish) arrived and departed, and in some cases, which direction (upriver or downriver) the fish was traveling.

- Activity 2.D.5. Monitor tagged fish movement via vehicle, boat and aircraft.

Mobile tracking is conducted by the NPT. Tracking effort may be augmented by the University of Idaho and the USFWS. Portions of the Snake River reservoirs are surveyed weekly using fixed-wing aircraft. The roaded sections of the Snake and Clearwater rivers are surveyed weekly via automobile. Portions of the un-roaded section of the Snake River are surveyed weekly by boat and helicopter (while conducting redd searches).

- Activity 2.D.5. Coordinate with NOAA Fisheries, the US Army Corps of Engineers, the US Fish and Wildlife Service, the University of Idaho and other existing telemetry studies for additional radio tracking assistance and data sharing from fixed monitoring sites.

The potential exists for a great deal of cost sharing through coordination of effort with existing research in the Snake and Clearwater rivers. Personnel from other studies may be available to assist with fish handling and tagging at the Lower Granite Adult Facility.

5.3.3 RM&E Objective 3. Utilize genetic data and analyses to adaptively manage broodstock and supplementation activities.

The geographic structure of genetic variation within salmon species has to a large extent dictated the manner in which salmon have been listed under the Endangered Species Act (ESA; Waples *et al*. 1991, Waples 1995, Marshall *et al.* 1995), and to a lesser degree to inform broodstock management and supplementation activities. Since the Clearwater River Subbasin coho salmon reintroduction project utilizes surplus hatchery origin juveniles from lower Columbia River hatchery facilities, the emphasis of genetic monitoring is aimed at adaptive management.

It is generally accepted that genetically diverse populations exhibit greater resiliency to environmental change than less diverse populations. Therefore, it follows that reintroduction programs utilizing a stock(s) with greater genetic variation may be more successful than programs utilizing stocks with less genetic variation. In the case of the Clearwater River Subbasin coho reintroduction program, the ECNFH has been selected as the primary source population. Clearly, the introduction of this stock to the Clearwater River Subbasin will test the adaptability of this stock. Successful colonization of the Clearwater River Subbasin will require a prolonged migration and the ability to spawn in habitat that differs substantially from the lower Columbia River. The success of the reintroduction program rests, in part, of the following assumptions:

1. The ECNFH stock maintains ample phenotypic plasticity and diversity to allow successful colonization of a novel environment.

2. Broodstock and program management activities can successfully maintain genetic and phenotypic variation.

In the strictest sense, natural selection acts on phenotypes (behavioral and physical outcomes of genetic diversity under a given environment context) to determine the fitness of individuals. The expression of genetic diversity as a physical or behavioral trait (phenotype) results from a complex interaction with environmental factors, hence it is not typically possible to select individuals that are expected to exhibit the highest fitness *a priori* using genetic profiles. Therefore, broodstock management typically focuses on implementing practices aimed at maintaining all genetic variation regardless of its value. Presumably, those phenotypes exhibiting the highest survival and fitness will be better represented over time at the expense of less valuable phenotypes. The benefit of such a strategy is that managers do not attempt to directly impose selection, they merely take advantage of natural selection to "fine tune" the stock.

In the case of the Clearwater River Subbasin coho salmon reintroduction, managers will attempt to ensure that all genetic variation present in the founder stock (ECNFH) is initially represented in transfers to the Clearwater River Subbasin. Further, the size of the juvenile release groups has been structured to probabilistically ensure that genetic variation will not be lost as a result of random processes (genetic drift; see section 3.7.2.1), typical of small populations. This strategy is intended to ensure that the reintroduced stock will exhibit the largest possible range of phenotypes on which natural selection can act.

It is difficult to determine *a priori* how large the Clearwater River coho salmon broodstock will need to be in order to maintain genetic diversity. Likewise the optimal size of juvenile release groups is difficult to predict. Therefore, a number of genetic comparisons are recommended to ensure that the coho program is adequately maintaining genetic diversity. These comparisons will require the following minimum sampling:

1. Tissue samples from a minimum of 60 juvenile coho salmon should be collected from ECNFH and each Clearwater River Subbasin hatchery facility rearing CLS stock coho salmon.

2. Tissue samples from at least 60 tissue samples should be collected from adult broodstock at ECNFH and each Clearwater River Subbasin facility with coho broodstock.

Tissue samples should be assayed for variation at several microsatellite markers, and the resulting data should be analyzed to estimate allelic diversity and effective population size (N_e). Allele frequencies and allelic diversity should be compared between all the sample groups recommended above for a minimum period of six years (two generations), and periodically thereafter. Significant differences between sample groups would indicate that genetic drift (the random loss of genetic variation) may be occurring. Such a result might indicate that broodstock size is too small, or that the rate of mortality is high enough to warrant larger release groups. Similarly, estimates of N_e should be compared within and among groups over time, to determine whether broodstock and juvenile release groups are large enough to ensure a high probability that genetic variation will not be lost as a result of random processes.

It should be noted that the genetic analyses recommended do not directly measure the process of local adaptation. Rather, these analyses provide diagnostic tools to determine whether hatchery and supplementation activities are deficient relative to the maintenance of genetic variation.

- Products:

  1. An evaluation of the success or failure of the program to provide a broad base of genetic variation in the reintroduced stock.

  2. An evaluation of the effectiveness of the program in maintaining genetic variation.

5.3.4 RM&E Objective 4. Determine how harvest opportunities on coho salmon can be optimized for tribal and non-tribal anglers within Nez Perce Treaty Lands.

It is expected that the harvest of coho salmon in the Clearwater River subbasin will occur during fall, after run sizes reach harvestable levels. It is anticipated that excess hatchery fish will be available for harvest long before natural production reaches carrying capacity. Harvest opportunities are likely to develop in different years in different streams, so the regulation of harvest seasons, locations, and methods will be managed opportunistically through an annual review process. Because fisheries will be adaptively managed, and we do not know which year they will begin, we cannot design a specific monitoring plan for an actual fishery at this time. However, we can identify the basic types of monitoring data that will be necessary for the effective management of harvest. Sampling under this objective is designed to address the following management assumptions:

1. Hatchery and natural-origin adult returns can be adequately forecasted to guide harvest opportunities.

2. Hatchery adult returns are produced at a level of abundance adequate to support fisheries in most years with an acceptable level of impact to natural-spawner and broodstock collection.

3. Ocean and Lower Columbia River fisheries do not constrain broodstock and natural escapement.

4. In-basin fisheries do not constrain broodstock and natural production escapement.

The Nez Perce Tribe is likely to manage harvest by zones within the Clearwater Basin. The Nez Perce Tribe divided the Clearwater River subbasin into five harvest zones:

- Zone 1 - Mouth of the Mainstem Clearwater River to Lolo Creek at River Mile (RM) 54.1;

- Zone 2 - Mainstem of the Clearwater River from Lolo Creek to the mouth of the Lochsa River and to Selway Falls (RM 18.6) on the Selway River;

- Zone 3 - The mainstem Selway River above Selway Falls;

- Zone 4 - The mainstem Lochsa River; and

- Zone 5 - The mainstem South Fork Clearwater River.

Utilization of these zones may be appropriate for Chinook as well. Harvest seasons for spring, early fall, and fall Chinook salmon are expected during the period June through

October. Management of Tribal fisheries will provide for the release of all protected species.

5.3.4.1 Task 4.A. Estimate total harvest mortality on hatchery and natural coho salmon from the NPT reintroduction streams.

In most years, coho salmon ocean and in Columbia River harvest would provide the most abundant catch. The collective run passing above Bonneville is supplemented by hatchery production in the middle Columbia River basin. Consistent harvest is not expected from Clearwater, Kooskia, or Dworshak hatcheries until smolt-to-adult survival rates increase from improved conditions in the migration corridor and ocean. In the short term, harvest will focus on the Columbia River harvest zones, and at existing hatcheries in and surrounding the North Fork Clearwater, and Clear Creek.

- Activity 4.A.1. Use harvest-rate estimates for ocean and Columbia River.

Harvest rates (percentage of population harvested) in the ocean and Columbia River are estimated annually by the Pacific Salmon Commission.

- Product: Estimated fraction of coho salmon harvested by age each year (1) in the ocean and (2) within the Columbia River.

- Activity 4.A.2. Survey fishermen in the Clearwater River subbasin to estimate total catch of NPT hatchery and natural coho salmon.

Creel surveys designed to estimate total catch of hatchery and natural fish will be implemented at the time that any fishing seasons for coho salmon are permitted.

- Product: Estimated number of coho salmon harvested by age, and hatchery/natural origin each year within the Clearwater River subbasin.

5.3.4.2 Task 4.B. Determine the influence of release strategies on fish availability for harvest in NPT reintroduction streams.

Release strategies can influence ocean migration patterns, age at maturity, and the locations at which maturing fish congregate as they return. Each of these factors will influence harvest. Patterns of ocean and river harvest will be assessed through recoveries of CWT's.

- Activity 4.B.1. Analyze the age and spatial distribution for freshwater landings of coho salmon to determine how they differ between groups from different release strategies.

When return and harvest numbers of coho salmon reach projected capacities, the recoveries of CWT's will provide an opportunity to analyze proportionate age composition of the catch from a particular brood, and the spatial distribution of catches in freshwater.

The location at which coho salmon are released influences the location at which adults will hold upon their return to the river. Manipulation of release locations is often used as a tool to enhance fisheries in a particular area. Creel surveys in the Clearwater River subbasin will be structured to record catch locations so that influences of release practices on local distribution of adult catch can be analyzed. Such information may be useful to the Nez Perce Tribe in balancing their desire to harvest coho salmon with their desire to enhance natural production.

- Products:

    1. Estimate of difference between treatment groups in the age composition of fish landed in Columbia River fisheries.

    2. Estimated differences between treatment groups in spatial distribution of catches within the Clearwater River subbasin.

5.3.4.3 Task 4.C. Develop run prediction and harvest monitoring to allow harvest of only the surplus fish from the Nez Perce Tribe coho restoration program.

Given that harvest will be managed to take only the fish that are excess to spawner escapement goals, it will be necessary to predict run sizes and manage harvest to target only those fish that are excess.

- Activity 4.C.1. Develop run-size predictor for hatchery and natural fish in each stream.

Analysis of data gathered under other monitoring activities will be used to evaluate alternative approaches to predicting run sizes for each harvest area. Predictors to be evaluated include estimated smolt number passing LGR or John Day Dam, estimated number of jacks returning from the same cohort, number of fish landed in ocean fisheries, and counts of adult coho salmon passing mainstem dams. Development of a run size predictor will be an ongoing process, in which the predictive function will be upgraded each year as information becomes available.

- Product: Procedure for predicting run size separately for hatchery and natural coho salmon returning to NPT streams one year in advance.

5.3.5 RM&E Objective 5. Monitor ecological interactions.

Hatchery reared coho salmon can potentially compete with other fish species for food and space (NMFS 1999) and can serve as hosts for disease and parasites. The organisms and processes which are involved represent biological interactions in which the coho play a direct role. The interactions may have little or no effect on the outcome of supplementation, either because they are benign, can be manipulated or affect other species (Steward 1996). Changes in the program may be necessary if the effects are deleterious. This objective addresses ecological interaction concerns as provided in the National Marine Fisheries Service Biological Opinion on Artificial Propagation in the Columbia River Basin (1999).

Realistically, sufficient funds do not exist to study every stream in detail and answer every uncertainty. We will examine emigration timing of PIT tagged coho from supplemented streams to compare with emergence timing and rearing of juvenile fall Chinook in the lower Clearwater River. This would identify periods of overlap in coho smolt emigration and juvenile fall Chinook rearing. Sampling under this objective is designed to address the following management assumption:

- Natural production of steelhead and Chinook salmon is not negatively affected by coho salmon reintroduction activities.

5.3.5.1 Task 5.A. Monitor the ecological interactions of residual coho salmon, hatchery reared coho, and naturally produced coho juveniles with other fish species.

- Activity 5.A.1. Conduct a literature review of coho salmon ecological interactions with other salmonid species and identify key food and space related limitations for monitoring. Coordinate with other ongoing research to apply study results as appropriate.

- Activity 5.A.2. Determine emigration timing of PIT tagged coho parr and smolts to describe the overlap with juvenile fall Chinook rearing in the lower Clearwater River.

- Activity 5.A.3. Document presence/absence and number of adult coho salmon spawners in the lower mainstem Clearwater River to examine potential competition for spawning sites with fall Chinook salmon.

- Activity 5.A.4. Compare condition factor of steelhead and Chinook salmon in reintroduction streams before and after coho salmon releases. Where possible, assess changes in egg to emigrant or parr to emigrant survival of spring Chinook salmon and steelhead prior to and following the release of juvenile coho salmon.

5.3.6 RM&E Objective 6. Effectively communicate monitoring and evaluation program approach and findings to resource managers.

Timely and thorough communication of the program's status and performance is critical in the adaptive management process at the project level. Adaptive management program framework involves elements of communication throughout the entire M&E program. Common to all M&E plan infrastructure elements are information sharing, information management, and summary reporting. This process will be conducted by the NPT, so those most familiar with the facilities, their design, and the characteristics of the fish being produced will guide the process. This information will then be shared with co-managers through several ongoing regional communication and review processes such as ESA consultation, performance review symposia, and co-management meetings. Activities under this objective are designed to address the following management assumptions:

- Coordination of needed and existing activities within agencies and between all co-managers occurs in an efficient manner.
- Accurate data summary is continual and timely.
- Results are communicated in a timely fashion locally and regionally.
- The M&E program facilitates scientifically sound adaptive management of the coho salmon restoration program.
- Hatchery escapement meets identified broodstock goals.

5.3.6.1 Task 6.A. Facilitate effective data management and dissemination.

We will utilize region-wide data bases that have been developed to centralize data associated with widely used and standardized activities.

o Activity 6.A.1. Provide data summary to StreamNet.

The NPT will provide data summaries of fish population status and select environmental/habitat conditions (adult escapement, juvenile density, stream temperature) to StreamNet on an annual basis. The NPT database will be structured to be compatible with StreamNet, consistent with ongoing NPT contributions to StreamNet.

o Activity 6.A.2. Send PIT tag files to the PIT Tag Information System (PTAGIS).

All PIT tag files will be validated and electronically submitted to the Pacific States Marine Fisheries Commission (PSMFC). PTAGIS will be used to organize tagging and interrogation data from fish marked with PIT tags. Interrogation summary reports will be downloaded and utilized in NPT data analysis.

o Activity 6.A.3. Report Coded-Wire Tagging summary reports to the Coded-Wire Tag (CWT) database.

We will provide fish marking summaries and CWT tag information to the Columbia River Intertribal Fish Commission staff for incorporation into the CWT database. The Coded-Wire Tag database is operated by the PSMFC for the tracking of CWT marking and recovery.

5.3.6.2 Task 6.B Communication of Results and Transfer of Technology.

- Activity 6.B.1 Develop Annual Statement of Work.

A Statement of Work (SOW) will guide annual activities and will be based on the Nez Perce Tribe coho restoration monitoring and evaluation program (Everett & Sprague 2001 Draft). Activities detailed in the SOW for the coho restoration M&E program will be reviewed by the Nez Perce Tribe for scientific validity, programmatic need, and compliance with project objectives. Funding agencies will also review and approve annual SOW's for contractual compliance and obligations.

- Activity 6.B.2 Develop quarterly reports.

The Nez Perce Tribe will communicate M&E status and results through quarterly reports to Bonneville Power Administration. The quarterly reports are a listing of activities conducted and general summary of data collected during the reporting period. Activities are identified by the Statement of Work's objective and task numbers.

- Activity 6.B.3 Develop summary reports.

Summary reports will provide results of population status or supplementation activities that occur on a regular basis that do not require statistical analysis or detailed interpretation. Production/stocking reports will include species, brood source, rearing location, brood year, number released, life stage at release, size at release, release location, release date, and type and number of marks applied. This summary will be updated as fish are released throughout the year and the final version will be distributed annually. Adult escapement will also be communicated through summary reports (weir/ladder capture and redd counts). In-season adult salmon weir/ladder capture reports will be produced on a weekly basis and with a final report distributed annually. Weir reports will include totals of natural and hatchery fish captured by sex and the numbers and disposition of fish kept for broodstock and released for natural production. Redd counts summaries will be included within the NPT DFRM spawning ground summary report distributed annually in January. Estimates of natural juvenile production in relation to overall carrying capacity in reintroduction streams will be prepared for use in determining quantity of NPT production to be outplanted annually. Summary reports will have a wide distribution including those agencies conducting research within affected stream reaches, with special consideration to agencies monitoring juvenile migration and distribution. These reports will be posted electronically.

- Activity 6.B.4. Develop Endangered Species Act Section 7 and 10 Summary Reports.

Endangered Species Act Section 7 and 10 permits require annual summary reports. These reports are required to provide summaries of collection methods used and total number of fish "taken". Take of fall Chinook, steelhead, bull trout by all NPT Department of Fisheries Resources Management research and production projects are covered. Deviations from the permitted activities are highlighted.

- Activity 6.B.5 Develop annual reports.

Annual reports will be developed to provide summary data, data analysis, and data interpretation in relation to coho restoration RM&E program objectives and tasks. The report will include a summary and analysis of all data collected as part of the coho restoration M&E program with recommendations for NPT coho salmon management. Specific questions to be evaluated are:

1. Are the methods being used to collect data appropriate and the most effective to meet M&E objectives?

2. Is the quality (level of statistical power) of data being collected sufficient for management recommendations?

3. Has any of the uncertainty been removed and can any M&E activities be discontinued.

4. Are the M&E findings sufficient to recommend program operation modification prior to five-year review?

Information provided in summary and technical reports will also be included in the annual report. Recommendations will be developed to address critical uncertainties and hypotheses. These reports will be posted electronically.

- Activity 6.B.6. Develop Peer Reviewed Journal Publications

Professional journal publications will be developed. The complexity and scope of the NPTC M&E project prohibits a single publication. Publications will focus on analysis of critical uncertainties that have regional application.

- Activity 6.B.7. Participate in regional conferences and workshops.

NPT staff will attend and present results of the coho restoration M&E at regional workshops. The information summarized in annual reports and other coho restoration program documents will be presented as appropriate at American Fisheries Society meetings. Information on specific components of the coho restoration monitoring and fish population status will be summarized in short presentations (15 to 20 minutes long). Staff will attend technical workshops in order to maintain professional skills, knowledge, and relationships.

  - ☐ Subactivity 6.B.7.1. Attend Idaho American Fisheries Society (AFS) Annual Meeting

  - ☐ Subactivity 6.B.7.2. Attend Western Division (AFS) Annual Meeting.

- ☐ Subactivity 6.B.7.3. Attend Fish Culture Conference.
- ☐ Subactivity 6.B.7.4. Attend Smolt Workshop.
- ☐ Subactivity 6.B.7.5. Attend PIT Tag Workshop.
- ☐ Subactivity 6.B.7.6. Attend the Native Fish and Wildlife Society Annual Meeting.

5.3.6.3 Task 6.C. Develop and maintain open communications with all resource managers.

Coordination of the Nez Perce Tribe coho restoration M&E program activities is a continual process within the NPT and with co-managers in the Columbia River basin. Annual and semi-annual meetings with co-managers in the Clearwater subbasin will be facilitated and attended to coordinated production and research activities.

- o Activity 6.C.1. Facilitate Nez Perce Tribe coho restoration program annual review and operating plan modification.

Annual coho restoration program management review will be facilitated by the Research and Production divisions of NPT. The coho restoration M&E will utilize information from the M&E reports (summary, technical, and annual). Annual review will address:

1. Assessment of data and recommended changes to the risk levels assigned to all of the critical uncertainties.
2. Evaluation of NPT Coho Restoration Program performance in relation to the goals and objectives.
3. Review of recommendations made in the Nez Perce Tribe coho restoration M&E annual report.

- ☐ Subactivity 6.C.1.1. Conduct Annual Operating Plan review with Clearwater River subbasin co-managers.

Results and recommendations developed from the NPT Coho Restoration annual review will be presented at the Annual Operation Plan (AOP) meeting. A draft AOP for the coho restoration program will be coordinated and reviewed with co-managers. This process will be similar to the AOP review conducted for the Nez Perce Tribal Hatchery and will include presentations of M&E results and planned activities.

- o Activity 6.C.2. Attend research and production coordination meetings.

NPTC M&E staff will participate in the meetings between NPT, IDFG, USFWS which plan the production management and outplanting of the Clearwater Anadromous Fish

Hatchery, Dworshak and Kooskia National Fish Hatcheries and research within the Clearwater River subbasin.

- ☐ Subactivity 6.C.2.1. Attend Dworshak coordination meetings.

- ☐ Subactivity 6.C.2.2. Attend Forest Service coordination meeting.

5.3.6.4 Task 6.D. Facilitate Nez Perce Tribal Coho Restoration Program review.

We will implement a five-year review process for incorporating Nez Perce Tribe coho restoration M&E information into the adaptive management process.

- o Activity 6.D.1. Conduct five-year NPT Coho Restoration Program performance review symposium.

Every five years NPT management and technical staff will facilitate a symposium to review NPT Coho restoration performance and status. The purpose of the performance review will be to:

1. Ensure adequate monitoring and evaluation is being conducted to evaluate whether production is meeting its defined purpose and the efficacy of operations relative to improved survival and minimization of adverse impacts.

2. Evaluate the Nez Perce Tribe coho restoration program for consistency with policies.

3. Evaluate the Nez Perce Tribe coho restoration program in terms of performance standards and identification of deficiencies.

In addition to the NPT directed review of the coho restoration program, information from several regional processes will be considered in the adaptive management of the coho restoration program. Information from independent audits of anadromous fish hatchery performance initiated by the Council, using performance measures developed by Independent Hatchery Operations Team (IHOT) and Artificial Production Review (NPPC) will be utilized in the review process. The Nez Perce tribe coho restoration RM&E program will also be coordinated with the Regional RM&E program currently being developed.

Chapter 6: Background Information Used to Guide Coho Salmon Reintroduction

In this chapter:

- Management context
- Preliminary reintroduction results
- Results from the Yakama Nation coho reintroduction program
- Guidance from published literature
- Life history characteristics of Grande Ronde coho salmon
- Integration of data sources

6.1 Management Context

Very little is known about the life history and population biology specific to coho salmon that historically inhabited the Clearwater River Subbasin. This lack of information increases challenges associated with the reintroduction program. In addition, the only donor stocks available for reintroduction efforts are located in the lower Columbia River (LCR). Although adult returns from preliminary reintroduction efforts are promising, it remains to be seen how successful LCR stocks will be at providing the foundation for a stock that must endure a 500 mile migration and emigration, including the passage of eight mainstem dams. Guidance for the proposed program has been derived in large part from four sources:

1. Preliminary results from NPT coho reintroduction efforts in the Clearwater River Subbasin;

2. Results from reintroductions of coho salmon in mid-Columbia River tributaries;

3. Speculation of historical run-timing, abundance, and distribution based on temperature profiles and habitat quality; and

4. Life history characteristics of coho salmon inhabiting the neighboring Grande Ronde River subbasin.

6.2 Preliminary Reintroduction Results

Short-term Clearwater River Subbasin coho reintroduction plans were developed for the *U.S. v Oregon* Production Advisory Committee in 1996 (Ashe and Johnson 1996) and amended in 1997 (Johnson and Ashe 1997). The Clearwater River Subbasin coho reintroduction program has been adopted as part of the Fall Fisheries Agreement developed through *U.S. v Oregon*. The program was authorized by NOAA Fisheries in their Snake River Basin Hatchery Biological Opinion (NOAA 1999).

The NPT coho reintroduction began in 1995 with the release of 622,227 parr originating from Cascade National Fish Hatchery (CNFH; Table 6-1). The program is ongoing and continues to derive the majority of its production from juveniles reared at LCR hatcheries. However, a progressively larger component of Clearwater River Subbasin coho production is obtained using adults returning to the Clearwater River Subbasin collected from Clear Creek at the Kooskia National Fish Hatchery (KNFH). These adults are spawned at the Dworshak National Fish Hatchery (DNFH) where progeny are reared to the smolt stage for acclimation at KNFH and release into Clear Creek. In addition, adults collected at temporary weirs located on Lapwai Creek, the Potlatch River, Meadow Creek (Selway River drainage), and Lolo Creek are spawned at the DNFH, and their progeny are reared for release into Lolo Creek. In recent years production at DNFH has produced 280,000 smolts for release into Clear Creek, while production at CAFH will allow the release of 270,000 presmolts into Lolo Creek in 2004. Hence, the transition from LCR stock coho salmon to CLS coho has already been initiated.

Preliminary results from NPT coho reintroduction efforts indicate that a substantial survival benefit can be realized by acclimating juveniles prior to release and/or using CLS stock as a brood source (Table 6-2). Acclimation, and/or use of CLS broodstock (or some combination of these factors) appears to increase post-release survival to Lower Granite Dam (LGD). Unfortunately, data are insufficient to determine whether the observed survival benefit results primarily from acclimation or from using CLS broodstock. The preliminary results do show a clear survival advantage for smolt versus parr releases. Finally, adult collection facilities that are located lower in the Clearwater River Subbasin appear to decrease losses due to “drop out” between LGD and capture facilities.

To date, the primary focus of preliminary reintroduction efforts has been the formation of a Clearwater Localized Stock (CLS) of coho salmon. Hence, substantial effort has been expended in attempting to capture all returning adult coho salmon. However, weirs on the Potlatch River and Lolo Creek are not 100% efficient, and redd surveys have documented coho salmon redds in these locations (Table 6-3). The presence of these redds suggests that adult coho salmon returning from the release of lower Columbia River hatchery origin juvenile coho salmon can construct redds. However, since the number of adults that constructed the redds is unknown, and since juvenile trapping activities for coho salmon are opportunistic, it is impossible to estimate productivity.

Finally, the number of adult coho passing Lower Granite Dam (LGD) has been increasing steadily since 1997 (Table 6-4; http://www.cbr.washington.edu/dart/dart.html), suggesting that preliminary reintroduction efforts have successful at stimulating adult returns.

Table 6-1. Summary of NPT juvenile coho releases in the Clearwater River subbasin.

Release Year	Life Stage	Brood Source[1]/Hatchery[2]	Number Released	Release Location
1995	Parr	LCR/CNFH	142,456	Potlatch River
	Parr	LCR/CNFH	49,849	Orofino Creek
	Parr	LCR/CNFH	94,777	Eldorado Creek
	Parr	LCR/CNFH	335,145	Meadow Creek (SR[3])
			622,227	
1998	Parr	LCR/BFH	175,000	Potlatch River
	Parr	LCR/BFH	125,000	Eldorado Creek
	Parr	LCR/BFH	150,000	Meadow Creek (SR)
			450,000	
	Smolt	LCR/WNFH, LCR/BFH	244,640	Lapwai Creek
	Smolt	LCR/WNFH, LCR/BFH	231,076	Potlatch River
	Smolt	LCR/WNFH, LCR/BFH	218,501	Clear Creek
			694,217	
1999	Parr	LCR/BFH	175,000	Potlatch River
	Parr	LCR/BFH	125,000	Eldorado Creek
	Parr	LCR/BFH	150,000	Meadow Creek (SR)
			450,000	
	Smolt	LCR/WNFH, LCR/BFH	290,176	Lapwai Creek
	Smolt	LCR/WNFH, LCR/BFH	276,682	Potlatch River
	Smolt	LCR/WNFH, LCR/BFH	245,168	Clear Creek
			812,026	
2000	Parr	LCR/ECNFH, LCR/WNFH	124,470	Eldorado Creek
	Parr	LCR/ECNFH, LCR/WNFH	148,578	Meadow Creek (SFCR4)
	Parr	LCR/ECNFH, LCR/WNFH	149,300	Meadow Creek (SR)
			422,348	
	Smolt	LCR/WNFH	267,102	Lapwai Creek
	Smolt	LCR/WNFH	267,166	Potlatch River
	Smolt	CLS/DNFH	280,750	Clear Creek
			815,018	
2001	Fry	LCR/ECNFH	**23,000**	Mission Creek
	Parr	CLS/CAFH, LCR/ECNFH	140,000	Eldorado Creek
	Parr	LCR/ECNFH	120,000	Meadow Creek (SFCR[4])
	Parr	LCR/ECNFH	85,000	Meadow Creek (SR)
			345,000	
	Smolt	LCR/WNFH, LCR/ECNFH	286,504	Lapwai Creek

	Smolt	LCR/WNFH, LCR/ECNFH	275,688	Potlatch River
	Smolt	CLS/DNFH	30,191	Clear Creek
			629,283	
2002	Fry	LCR/ECNFH	**25,000**	Mission Creek
	Parr	CLS/CAFH, LCR/ECNFH	140,000	Eldorado Creek
	Parr	LCR/ECNFH	120,000	Meadow Creek (SFCR)
	Parr	LCR/ECNFH	85,000	Meadow Creek (SR)
			345,000	
	Smolt	LCR/ECNFH	275,000	Lapwai Creek
	Smolt	LCR/ECNFH	552,298	Potlatch River
	Smolt	CLS/DNFH	236,692	Clear Creek
			1,063,990	
2003	Parr	LCR/CAFH	157,012	O’Hara Creek
	Parr	LCR/CAFH	121,920	Eldorado (Lolo) Creek
	Parr	LCR/CAFH	135,500	Meadow Creek (SFCR)
			414,432	
	Smolt	LCR/ECNFH	274,125	Potlatch River
	Smolt	LCR/ECNFH	279,500	Lapwai Creek
	Smolt	CLS/DNFH	293,879	Clear Creek
			847,504	
2004	Parr	LCR/ECNFH	150,000	Eldorado (Lolo) Creek
	Parr	LCR/ECNFH	75,000	Lolo Creek
	Parr	LCR/ECNFH	75,000	Musselshell Creek
			300,000	
	Smolt	LCR/ECNFH	297,271	Potlatch River
	Smolt	LCR/ECNFH	299,084	Lapwai Creek
	Smolt	CLS/CAFH, LCR/ECNFH	356,323	Clear Creek
			952,678	
2005	Smolt	LCR/ECNFH	275,000	Potlatch River
	Smolt	LCR/ECNFH	275,000	Lapwai Creek
	Smolt	CLS/CAFH, LCR/ECNFH	280,000	Clear Creek
			830,000	

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[1] Refers to progeny from Lower Columbia River (LCR) origin adults, or Clearwater River localized stock (CLS).

[2] Refers to the hatchery facility that reared the juveniles:

CNFH = Cascade National Fish Hatchery
BFH = Bonneville Fish Hatchery
WNFH = Willard National Fish Hatchery
ECNFH = Eagle Creek National Fish Hatchery
DNFH = Dworshak National Fish Hatchery
CAFH = Clearwater Fish Hatchery

[3] SR refers to the Selway River watershed.

[4] SFCR refers to the South Fork Clearwater River watershed.

Table 6-2. Summary of observed survival rates of NPT coho release groups.

Stream	Stock	Life Stage	Survival to LGR (%)[1]	SAR LGR to LGR (%)	Dropout LGR to Trap (%)
Clear Creek	CLS	Smolt	56.2 - 75.0	0.5 - 0.6	49.1
Potlatch River	LCR	Smolt	8.6	1.1	60.0
Lapwai Creek	LCR	Smolt	24.2	0.2	51.5
Meadow Creek SR	CLS	Parr	2.4 - 10.4	NS[2]	100.0
Eldorado Creek	CLS	Parr	5.9 - 8.0	NS[2]	92.0

[1] Calculated using SURPH 2.1 (Lady *et al.* 2001)

[2] Sample size was insufficient for calculation.

Table 6-3. Number of coho salmon redds enumerated in the Potlatch River and Lolo Creek from 1999 through 2003.

Year	Redds		
	Potlatch River	Lolo Creek	Total
1999	11	N/A	11
2000	14	N/A	14
2001	32	0	32
2002	20	0	20
2003	15	1	16

N/A - Redd counts were not conducted in Lolo Creek in 1999 and 2000.

Table 6-4. Counts of adult and jack coho salmon passing LGD from preliminary NPT coho salmon reintroduction efforts.

Year	Adult Coho	Jack Coho	Total
1997	84	10	94
1998	10	1	11
1999	250	42	292
2000	883	35	918
2001	937	111	1,048
2002	247	149	396
2003	1,129	130	1,259
2004*	3,291	97	3,388

*Adult returns as 27 October 2004.

6.3 Yakima Subbasin Coho Reintroduction

The Nez Perce Tribe carefully reviewed information from the Yakama Nation (YN) coho reintroduction program during the development of this plan. Similar to the Clearwater River Subbasin, coho salmon inhabiting tributaries of the mid-Columbia were extirpated in the early 1900’s (Dunnigan 1999). In 1995, the YN began a program to reintroduce coho salmon to the Methow, Wenatchee, and Yakima Rivers (BPA Project 1996-040-000). Also, similar to the NPT reintroduction, no local sources of broodstock and/or juveniles were available for the reintroduction effort, and subsequently the YN relied on juvenile production from LCR coho hatcheries.

The YN program followed a phased reintroduction approach wherein the bulk of initial juvenile releases were acclimated and released in locations with adult capture facilities. Adults returning to the juvenile release location were either retained for broodstock or released to study spawning effectiveness and inter-specific interactions. The remainder of juvenile releases occurred in targeted habitat selected for suitability to coho, minimizing the potential for interspecific interactions, and with adequate access to allow researchers to conduct competition and predation studies. As the results of adult and juvenile interactions became available, juvenile releases shifted to emphasize releases in targeted coho habitat.

The following paragraphs summarize those results from the YN coho reintroduction program that were helpful in guiding NPT efforts; specifically, broodstock development, juvenile release characteristics, predation data, and competition data. Data are summarized from Murdoch et al. (2004).

6.3.1 Broodstock Development

Broodstock development for the YN program was based on the assumption that LCR hatchery origin coho were capable of enduring a prolonged migration to mid-Columbia River tributaries, and that upon return would be capable of spawning naturally and/or return in an abundance that would allow broodstock collection. In 2003 the YN program released 911,422 coho smolts into the Wenatchee River Basin. Of these 96% were Mid-Columbia Brood Coho, and the remaining 4% were LCR coho. Preliminary analysis from the Icicle Creek acclimation site show the SAR of mid-Columbia River origin smolts was 0.51% versus 0.31% for smolts of LCR origin, suggesting that the YN program has realized a survival advantage for “localized” broodstock (Murdoch et. al, In Prep) in fewer than three full generations (nine years) since the program inception.

6.3.2 Acclimation

The YN program relies on “low-tech” facilities for acclimation of all coho salmon smolts. In most cases these acclimation facilities consist of natural impoundments or impoundments constructed for other purposes (e.g., an overflow channel for a gravel pit). The YN program has realized several advantages from this approach; smolts develop a more natural color, are acclimated under a natural temperature regime, introduced to natural foods, imprinted on water in locations targeted for adult returns, and cost has been dramatically reduced compared to the construction of dedicated acclimation facilities. The YN also recognizes that there are some negative aspects of the low-tech acclimation approach including; increased predation on juvenile coho, variability in water availability, accessibility, and potential difficulties in treating disease outbreaks (which has not occurred to date).

6.3.3 Residualization, Predation, and Competition

Despite the fact that coho, steelhead, Chinook salmon, bull trout, and sockeye salmon historically coexisted within tributaries of the mid-Columbia River, the YN was concerned that the reintroduction of coho would decrease survival of other stocks of salmon (including those listed under the Endangered Species Act) that occur in many of the locations targeted for coho reintroduction. Therefore, the YN program included a substantial M&E component aimed at characterizing predation and competition of coho juveniles and adults on ESA listed stocks of Chinook salmon and steelhead. The YN was particularly concerned with the potential for competition and predation to be increased as a result of residual coho. However, despite extensive surveys in 2001 and 2002, no residual coho were observed. Extensive predation studies determined that fish comprise only 0.18% of food consumed by juvenile coho in Nason Creek (a tributary to the Wenatchee River). In study reaches, this resulted in less than 0.14% to 1%[2] of the total juvenile spring Chinook salmon population falling prey to coho predation. Further, YN biologists found that juvenile spring Chinook salmon, steelhead, and coho salmon utilized different microhabitats. Observed differences in habitat use between treatment and control reaches (reaches with and without coho salmon) in 2001 and 2003 were present before coho introduction, and hence could not be attributed to the presence of coho salmon. Observed growth rates of Chinook salmon did not differ between reaches that were occupied by coho salmon and reaches lacking coho salmon, in fact, condition factors for Chinook salmon in reaches containing coho salmon were actually higher. These results are similar to those of Spaulding et al. (1989) who found that juvenile growth rates, densities, and emigration timing of juvenile Chinook and steelhead were unaffected by the presence of coho salmon.

Unfortunately, bull trout interactions have yet to be quantified by the YN study. However, the USFWS expressed the following views regarding coho reintroduction in the mid Columbia (USFWS 2001):

> *"It is generally felt that this supplementation program will not impact bull trout stocks and will likely benefit bull trout and other resident fish. Historically, bull trout probably benefited from the presence of anadromous salmonids. The downstream drift of eggs released from spawning salmon provided food for bull trout and other resident fishes, but more importantly the presence of decaying salmon carcasses greatly benefited juvenile salmon and resident fishes thru nutrient recycling. Generally, in drainages colonized by natural anadromous salmon and steelhead populations the bull trout have successfully co-existed."*

Nonetheless, the same document also urges a cautionary approach to the reintroduction of coho salmon in habitat occupied by bull trout:

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[2] Based on stomach content analyses, which likely overestimate predation due to a conservative estimate of residence time.

> *"…in many areas where bull trout currently exist, habitat conditions have deteriorated and natural predator-prey balances have been upset. Bull trout populations are at or near critically low levels in many areas of the basin. For this reason caution should be exercised in stocking large numbers of hatchery fish near bull trout spawning and rearing areas to avoid the potential for competition or predation on bull trout fry."*

6.4 Guidance from Water Temperature, Habitat Preference, and Life History Data

Based on the availability and characteristics of habitat in the Clearwater River Subbasin, Witty and Cramer (1999) speculated that Clearwater coho were historically as abundant as steelhead, but less abundant than Chinook. Witty and Cramer (1999) suggest that stream gradient and late-fall water temperatures likely imposed the upper limit on coho abundance and productivity. Streams with gradients of 3% or less provide conditions favorable for coho salmon (Reeves et al. 1989). This suggests that the core spawning aggregates of coho salmon likely resided in tributaries of the mainstem Clearwater River and the South Fork Clearwater River.

Habitat availability for juvenile and adult coho salmon can also be described thermally. Adult coho migration slows at water temperatures below 38˚F and halts at temperatures below 35 ˚F (Cramer and Cramer 1994). Coho salmon prefer springs or gravel areas in streams where the flow is one to two feet per second and spawn in water temperatures ranging from 33 to 46˚F (Gribanov 1948). The optimum temperatures for coho salmon egg incubation range from 39 to 52˚F (Davidson and Hutchinson 1938). However, coho salmon sac fry can survive for short duration in water temperatures below 35 ˚F. There is an array of thermal habitats in streams that provide fish the opportunity to survive (Brett 1971, Smith and Li 1983, Ward and Stanford 1982, Berman and Quinn 1991, Hall et al. 1992). Thermal habitats that provide cool water in summer and warm water in winter, may be large or small, and subject to fluctuations related to weather conditions and discharge. Groundwater usually affects small areas, but these areas may be significant for coho spawning and overwintering in the Clearwater River Subbasin. In fact, groundwater may explain the presence of coho because relatively minor differences in temperature can be ecologically relevant (Somero and Hofmann 1997). Several authors including Li et al. (1991 and 1993), Brett (1971), Smith and Li (1983), Ward and Stanford (1982), Berman and Quinn (1991), Hall et al. (1992) Everest and Chapman (1972), Kaya et al. (1977), Gibson (1979), Keller and Talley (1983), Ozaki (1988), and Meisner (1990) describe thermal habitats. The Clearwater River has several large, warm water thermal areas (perhaps most notably Lolo hot springs), and likely hundreds of smaller groundwater thermal areas where coho could spawn allowing egg incubation during winter periods. Although formal surveys have not been completed, the presence of a strong groundwater influence is noted in the Lolo Creek watershed (Lolo National Forest 1999). In addition, a number of locations in the South Fork Clearwater River Subbasin have designated Aquatic Landtype Association (ALTA) ratings of 2, 5, or 18 suggesting that groundwater influence is common (Nez Perce National Forest 1997).

Coho salmon egg development is generally dependent on water temperature, although there is some variation in egg development between coho salmon stocks. Coho salmon eggs hatch in about 137 days when the average water temperature is 36˚F (Semko 1954), 48 days when the average water temperature is 48˚F, and 38 days when the average water temperature is 51˚F (Shapovalov and Taft 1954). Coho salmon fry emerge from the gravel 21 to 40 days after hatching when the average water temperature is 36˚F (Semko 1954; Gribanov 1948). Coho eggs require about 1,900 (˚F) temperature units3 to incubate (Sandercock 1991).

Although coho salmon fry and parr are found in both pool and riffle areas of a stream, they are best adapted to holding in pools (Hartman 1965). Coho salmon fry and parr distribute themselves throughout the stream and once territories are established remain in the same locality for relatively long periods (Hoar 1958). Coho fry and parr often form groups in pools with larger parr at the head of the pool and smaller parr at the back of the pool (Sandercock 1991). Small ponds, including those located in tributaries of the Mainstem Clearwater River and off-channel mine dredge ponds in South Fork Clearwater River tributaries may provide this habitat for coho salmon during winter months.

Coho salmon eggs incubate during winter, and free-swimming fry emerge in the spring. Fry and parr reside in the stream during summer months, and over winter prior to migrating as smolts the next spring. After 15 to 18 months at sea, adult coho salmon return to spawn. Most coho salmon spawn between November and January, but spawning may occur between September and March (Pravdin 1940; Smirnov 1960; Rounsefell and Kelez 1940; Crone and Bond 1976; Neave 1949; Chapman 1965). There is little correlation between the time that coho salmon enter a stream and the date of spawning; early-run coho salmon may spawn early, but many individuals hold for weeks or even months before spawning. However, late-run coho salmon tend to spawn soon after their arrival on spawning grounds (Sandercock 1991).

Coho salmon are the least particular of all Pacific salmon in their choice of spawning areas. Coho salmon may spawn in large rivers or in remote tributaries. Spawning may occur on gravel bars of slow flowing rivers or on white-water riffles of turbulent streams (Foerster 1935). Females generally select a site to spawn at the head of a riffle area where there is good circulation of oxygenated water through the gravel (Shapovalov and Taft 1954).

6.5 Life History Characteristics of Grande Ronde Coho Salmon

Coho salmon inhabiting the Grande Ronde River subbasin were geographically closer to the Clearwater River Subbasin than any other extant stock of coho salmon. Therefore, life history characteristics of the Grande Ronde stock might approximate attributes of the coho salmon stock that historically occupied the Clearwater River Subbasin. Grande Ronde coho salmon began maturing during summer after one winter at sea. Migration toward the Columbia River began during mid-summer, with entry into the Snake River in

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[3] A temperature unit is defined as 1˚F above 32˚F for 24 hours.

September (USACE 1990). Historically, coho were sighted in the lower Grande Ronde River in mid-September (Van Dusen 1905).

Fecundity ranged from 2,700 to 3,000 eggs per female at the Grande Ronde and Wallowa River hatchery stations from 1901 to 1907 and averaged 3,671 eggs per female at the Wenaha station (Van Dusen 1905). Fecundity of Wenaha River stock coho reported by Van Dusen (1905) is unusually high and may be in error (Cramer and Witty 1998), however it is notable that fecundity estimates for Grande Ronde coho salmon are higher than reported for coho salmon in other locations.

In the 1960's, Wallowa River coho began their emigration in late-April to early-May, peak passage at Ice Harbor Dam was June 6, and they reached the Columbia River estuary in mid-May to early-June (Cramer and Witty 1998).

Coho from the Wallowa River were the latest migrants of all yearling salmonids to pass McNary and Ice Harbor dams in 1966 and 1967 (Park and Bentley 1968), a factor that may have contributed to the extinction of the Grande Ronde coho population. Johnson and Sprague (1996) report that the majority of the first coho released in the Clearwater River Subbasin migrated past Lower Granite Dam in June.

Mean length of coho salmon smolts in the Grande Ronde River basin from 1965 to 1966 was 11.7 cm. Gribanov (1948) observed that most coho are 10 cm when they smolt, although coho may migrate at sizes ranging from 3.3 to 15 cm (Shapovalov and Taft 1954; Sumner 1953; Salo and Bayliff 1958; Foerster and Ricker 1953; Andersen and Narver 1975; Armstrong and Argue 1977; Fraser *et al.* 1983; McHenry 1981).

6.6 Integration of Data Sources

Integrating data from sections 6.1 through 6.5 provided substantial guidance for Phase I of the Clearwater River Subbasin in coho reintroduction. Preliminary Clearwater River Subbasin specific data suggests that acclimation provides a substantial survival benefit. These data also suggest that smolt releases are the most effective strategy to stimulate adequate adult returns. Data from the YN program suggests that securing a localized broodstock could provide a substantial survival benefit, and increase the likelihood of program success. Data from preliminary coho releases suggests that locating adult collection facilities lower in the Clearwater River Subbasin may decrease drop out rates, allowing increased recovery of adult coho. Finally, there appears to be ample historically occupied habitat to support naturally spawning coho in tributaries currently targeted for integrated restoration activities, and available data suggest that competition and predation should not be dramatically increased over existing conditions by the presence of coho salmon.

Chapter 7: Limiting Factors

In this chapter:

- Harvest
- Hatcheries
- Hydropower
- Habitat

Salmon experience human-caused mortality throughout their life cycle. Timber harvest, grazing, irrigation, road construction, dam construction, harvest, residential development, and all other activities requiring water withdrawals, or resulting in the degradation of water quality, increase mortality of salmon at various freshwater life history stages (Mundy 1996). The dredging and filling of the estuary, and mixed stock and mixed species harvest in the ocean can increase mortality during the estuary and ocean life history stages. A synopsis of limiting factors in this chapter organizes impacts into four major categories (harvest, habitat, hydrosystem, and hatcheries).

Since coho salmon have been extirpated in the Clearwater River Subbasin, it is difficult to predict how reintroduced stocks will be affected by these factors. Some insight might be gained from using spring Chinook salmon as a surrogate for the expected rates of mortality that can be attributed to these limiting factors. The same factors that limit the sustainability of spring Chinook salmon are expected to limit the productivity of reintroduced coho salmon in the Clearwater River Subbasin.

7.1 Harvest

7.1.1 Ocean Harvest

Since coho have been extirpated from the Snake River there is no means to directly estimate the potential impacts of ocean fisheries on reintroduced Clearwater River Subbasin stocks. However, it is likely that many of the harvest management actions aimed at protecting coastal coho stocks will likewise decrease ocean harvest impacts on Clearwater River Subbasin coho salmon. Harvest restrictions have decreased fishing mortality for Oregon coastal coho stocks from upwards of 80% in the 1970’s and 1980’s to less than 13% after 1994 (ODFW 1998). This decrease in ocean harvest results from a number of regulations:

1. Ocean trolling has been restricted to the use of single barbless hooks to decrease hooking mortality of coho captured incidentally in targeted Chinook fisheries;

2. A limit of four lures has been implemented in troll fisheries; and

3. Certain gear types (e.g., flashers and dodgers) are prohibited.

In addition to restrictive angling regulations, a comprehensive education program has been established to aid fishers in the correct identification of Chinook and coho. The accuracy of run-size predictions has also increased due to better accounting of production releases from federal, state, tribal, and privately operated hatcheries. Finally, managers have implemented research aimed at better quantifying mortality related to incidental harvest of coho salmon in ocean fisheries targeting other species (e.g., hake).

7.1.2 Columbia River Mainstem Harvest

7.1.2.1 Hydrosystem

Although the eight mainstem hydropower dams on the Snake and Columbia rivers are not normally associated with harvesting fish, they are responsible for a large portion of the adult mortality. NMFS (2000) estimates that interdam loss accounts for 50 percent of the mortality of returning natural origin Snake River spring Chinook salmon. This “harvest” rate is used in determining the number of spring Chinook salmon that can be allocated for incidental harvest in the mainstem tribal and sport fisheries (<10 percent). Impacts associated with the hydrosystem are discussed in more detail in Section 7.3. It is expected that hyrosystem related losses of coho salmon will approximate those of spring Chinook salmon.

7.1.2.2 Fisheries

Salmon and steelhead destined for the Snake River Basin are not managed as individual stocks until they reach the mouth of the Snake River. Columbia River fisheries recognize and manage all Snake River Basin tributary runs as an aggregate. For example, under the recently completed biological assessment (CRITFC 1999) and biological opinion (NMFS 2000) discussing Columbia River fisheries, escapement objectives for Snake River Subbasin spring Chinook salmon were identified only for the aggregate of populations originating above Lower Granite Dam and not for populations of individual watersheds such as the Clearwater River Subbasin.

At this time it is difficult to predict how in-basin coho salmon harvest will be managed over the long-term. Currently, coho salmon fisheries primarily target the abundant hatchery origin coho salmon from production facilities in the lower Columbia River. It is likely that Clearwater River Subbasin coho salmon will be managed as an aggregate with a Snake River fishery quota determined by escapement estimates generated from adult counts at the mainstem hydropower facilities. The comanagers will develop a Snake River escapement goal for coho salmon as reintroduction efforts progress. In the interim, the current coho harvest plan, agreed to in the *U.S. v. Oregon* forum provides for a maximum harvest of 50% of all coho salmon destined to return to locations above Bonneville Dam. The 50% that is harvested is split equally among treaty and non-treaty (commercial and recreational fisheries). Harvest occurring above Bonneville Dam is included in the 50% harvest fraction. The remaining 50% of the coho escapement is reserved for broodstock needs, although the agreement also includes language to allow escapement for natural production, should a natural escapement goal be identified. Under those circumstances, the 50% sharing agreement would be applied to coho in excess of broodstock and natural escapement goals. In either case, these fisheries would be subject to the *U.S. v. Oregon* Fall Fisheries Agreement, which limits incidental harvest of ESA-listed stocks. In the case of Snake River coho salmon, listed fall Chinook salmon and steelhead are the two stocks most likely to be impacted by incidental take during coho harvest.

7.2 Hatcheries

Considerable concern has been expressed among the scientific community that hatchery fish can potentially impact natural spawning populations through genetic introgression, disease transmission, and competitive interactions. Most directly, the presence of hatchery fish in mixed-stock fisheries has led to harvest rates that result in overfishing of natural populations. The history of artificial propagation in the Columbia Basin and associated impacts are discussed in detail by Brannon *et al.* (1999). Scientists contributing to the Plan for Analyzing and Testing Hypotheses noted that the potential for negative interaction between naturally-produced fish and hatchery-reared fish during mainstem smolt migration is likely greater for listed Snake River stocks than for downstream stocks because of increased contact between fish during barging and dam passage (Mamorek *et al.* 1996).

In the last ten years, a considerable amount of effort has been directed at reviewing artificial production in the Columbia River Basin and developing recommendations and guidelines for technical and policy reform of hatcheries (NPPC 1999, IHOT 1995). NMFS has completed consultations covering all hatchery production in the Columbia Basin (NMFS 1999). As a result, hatchery management practices have been substantially revised (NMFS 2000). For example, many non-indigenous stocks are being transitioned to native stocks, rearing densities are being reduced, and size-at-release and release locations have been adjusted to decrease competitive interactions with natural populations.

In the 1999 Biological Opinion on Artificial Propagation in the Columbia River Basin, the Clearwater River Subbasin coho reintroduction was described and analyzed by NMFS (1999), who concluded that artificial propagation programs in the Columbia River Basin as described by the action agencies are not likely to jeopardize the continued existence of listed Snake River spring/summer Chinook salmon. In addition, PATH scientists have preliminarily concluded that, relative to the hydrosystem, artificial propagation of spring/summer Chinook salmon has not significantly contributed to declines in natural populations of spring/summer Chinook in upstream areas (Mamorek *et al.* 1996). Although uncertainties remain about the effectiveness of supplementation programs, those uncertainties have to be weighed against the risk of not taking any remedial action. NMFS (2000) determined it is reasonable to expect that the listed ESUs will benefit over time from improvements in artificial propagation and that carefully designed intervention programs will improve the future prospects for survival and recovery.

Since Clearwater River Subbasin coho salmon are a reintroduced stock, it is difficult to predict how they will interact with hatchery and natural origin salmonids with the Snake River Basin. Information from the Yakama Nation (Section 6.3) indicates that competition and predation resulting from the reintroduction of coho salmon is unlikely to negatively impact sympatric salmon stocks. Nonetheless, the coho RM&E plan will evaluate whether negative impacts are occurring.

7.3 Mainstem Snake and Columbia River Hydrosystem

Hydroelectric dams and reservoirs on the lower Snake and Columbia rivers are considered a primary factor in the decline of Snake River anadromous fish runs over the last 30 years (ACCD 2004, CBFWA 1991, CCD 2004, Ecovista 2003, Ecovista 2004a, Ecovista 2004b, Ecovista 2004c, NMFS 1995, ISG 1996). Wild spring Chinook escapement trends in northeastern Oregon streams from 1952-1996 depict relatively stable escapements from the mid-1950s to the early 1970s, then a sharp decline following the completion of four additional mainstem dams (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite). During 1952-96, the aggregate of northeastern Oregon spring Chinook habitat has not undergone any dramatic changes that account for, or coincide with, Snake River stock declines observed in the late 1970s (TAC 1997).

The system of hydropower dams on the Columbia and Snake rivers (known as the Federal Columbia River Power System or FCRPS) has greatly diminished the diversity of habitat once characteristic of this system. The dams severed the continuum of habitat, decreasing riverine habitat in the mainstem and isolating other types of habitat. Dams also altered the natural hydrograph, which further reduced available habitat types and ecosystem processes in those habitats. Slack water reservoirs increase water temperatures, pollutant levels, travel time for migrating salmonids, predator populations, and decrease habitat complexity. Two key consequences of this loss of habitat diversity have been a reduction in the biodiversity of native salmon stocks and the proliferation of non-native species (ISG 1996).

Direct mortality due to the hydroelectric system and associated operations is recognized as one of the most significant sources of mortality for anadromous fishes (Iwamoto *et al*. 1994, Mundy *et al*. 1994, ODFW *et al*. 1990, Quinn and Adams 1996, Raymond 1979). NMFS (2000) estimates that interdam loss accounts for 50 percent of the mortality of returning natural origin Snake River spring Chinook salmon and 22 percent for summer Chinook salmon.

A recent evaluation of 25 years of juvenile survival studies found that an estimated 13-14 percent of emigrating smolts are lost at each lower Snake and Columbia River dam (Bickford and Skalski 2000). Additionally, mortality may be greater for wild smolts, may accumulate as additional dams are encountered, and may vary considerably by year and river section. NMFS (2000) believes that improvements in the hydrosystem (*e.g.*, passage improvements at the dams) are increasing survival of migrating juveniles. For Snake River spring/summer Chinook smolts migrating in river (not transported), the estimated survival through the hydrosystem is now 40-60 percent, compared to 20-40 percent in the 1970s (NMFS 2000). However, delayed mortality is believed to occur in the estuary and ocean as a result of cumulative effects of the hydroelectric system (Mundy *et al*. 1994, Mamorek *et al.* 1996).

Neither the current transport system nor present in-river migration conditions will provide recovery of Snake River spring/summer or fall Chinook (BRWG 1994, NMFS 1995, STFA 1995a, STFA 1995b, ISG 1996). Improvements to the transportation system are also not likely to provide the survival rates necessary to recover Snake River spring/summer Chinook (Mundy *et al*. 1994, Mamorek *et al.* 1996). The analysis of the survival and productivity of Snake River and lower Columbia River Chinook stocks indicates Snake River spring/summer Chinook survival goals can be achieved if a portion of the mainstem migration corridor is restored to a more natural or normative condition (Mamorek *et al*. 1996).

7.4 Habitat

7.4.1 Ocean/Estuary

Many actions in the Pacific Ocean and the Columbia River estuary may be having an adverse effect on the survival of salmon. Filling and dredging, and water quality impacts from large cities, such as Portland, Oregon may have decreased the ability of the estuary to support salmon smolts as they make the transition to salt water. An estimated 65 percent of tidal swamps and marshes in the Columbia River estuary have been lost due to diking and filling (NMFS in review).

A shift in ocean conditions over the past two decades, exacerbated by El Nino events, has impacted Columbia Basin salmon returns (NMFS 2000). Oceanic climate regime shifts and their effect on Pacific Northwest salmon populations are discussed at length by Anderson (1997). Studies detailing the cyclic changes in ocean conditions have been emerging since the early 1990s. Recent studies indicate the warm and cool regimes appear to persist over about two decades, therefore, it is reasonable to expect that ocean conditions are cyclic and will eventually improve (Anderson 1997). There is increasing evidence that a regime shift to favorable ocean conditions for Columbia River salmon has now occurred although confidence in that conclusion will come only after the associated weather patterns have been observed for several years (NMFS 2000).

Another factor affecting salmon is the concentration of predators in the estuary and ocean. Seals and sea lions have been targeted for over a century for preying on Columbia River salmon (Reed 1890) and more recently bird populations in the lower Columbia River have been identified as effective predators of salmon smolts. The world’s largest colony of Caspian terns and the two largest colonies of double-crested cormorants on the west coast of North America have recently become established in the Columbia estuary (NMFS 2000). Efforts are currently underway to relocate the bird populations and these may eventually reduce the bird predation (NMFS 2000).

7.4.2 Freshwater

This section on freshwater habitat contains a more extensive discussion than the other sections in this chapter for several reasons. The Nez Perce Tribe has co-management jurisdiction over the Clearwater River Subbasin and the Tribe has been actively involved in on-the-ground habitat improvements in this area. Freshwater habitat has been identified by the Cumulative Risk Initiative (CRI) project as important in recovering Snake River spring/summer Chinook and is an area that is more manageable than habitat for other life stages (*e.g.*, the ocean).

7.4.2.1 Clearwater River Subbasin

The Clearwater Subbasin Plan (Ecovista 2003; http://www.nwppc.org/fw/subbasinplanning/clearwater/default.asp) contains a detailed description of the subbasin and individual watersheds, which is summarized in the following paragraphs. The Clearwater River Subbasin is located in north central Idaho extending West to the Washington and Idaho border, East along the West slope of the Bitterroot Mountains, North 100 miles to the St. Joe River subbasin, and South 120 miles to the Salmon River subbasin (Maughan 1972 in Cichosz *et al*. 2001). The Clearwater River generally flows westward from the headwaters and enters the Snake River at Lewiston, Idaho, RM 139. The Clearwater River drains approximately 9,645 square miles (Cichosz *et al.* 2001). Major tributaries include the Lochsa River, Selway River, South Fork Clearwater River, and Lapwai Creek. Major land use in the subbasin includes forestry, agriculture, grazing, and mining (CRITFC 1995).

Land ownership in the Clearwater River Subbasin has evolved from exclusive NPT occupancy in the 1800's to more complex land ownership patterns. Currently, the Forest Service owns 59.9 %, the Bureau of Land Management owns 0.8%, 0.5% is owned by the Army Corps of Engineers, 1.6% is owned by the NPT and Bureau of Indian Affairs trust, 4.9% is owned by the State of Idaho, and 32.3% is owned by private individuals or companies. Approximately 27.7% (not including the North Fork) is classified as wilderness and another 14% is undeveloped. Areas protected under the Wild and Scenic Rivers Act include 22 miles of the Middle Fork of the Clearwater River, 62 miles of the Lochsa River, and 91 miles of the Selway River (CBSP 1990).

Land-use practices such as mining and timber harvest have altered the upland and riparian vegetation and have caused stream temperatures to rise during summer months. Mining is centered on the upper South Fork of the Clearwater River, Orofino Creek, and the Potlatch River. Smaller mining operations are located in the Lolo and Mission Creek watersheds (CBSP 1990).

Logging

Most of the federal forest land in the Clearwater River Subbasin was set aside as the Bitterroot Forest Reserve in 1897 (Cichosz et al. 2001). The Clearwater, Nez Perce, St. Joe, and Bitterroot National Forests now comprise most of the forest in the subbasin and logging has been significantly reduced because of ESA listed salmon stocks, concerns with resident salmonids, lack of resolution on the management of remaining roadless areas on the forest, and change in Forest Service management policy (Cichosz *et al.* 2001).

Roads

Road densities are greatest in the central portions of the basin where logging roads predominate, commonly exceeding 3 miles/square mile and often exceeding 5 miles/square mile (Cichosz et al. 2001). However, there is relatively little road development in the eastern portion of the Clearwater River Subbasin. Cichosz *et al.* (2001) note that the Selway-Bitterroot and Gospel-Hump Wilderness Areas contribute to the lack of road development in some areas, as does the local fire history. The distribution of logging roads in the Clearwater subbasin is notably tied to fire history, with most currently existing forest roads located in areas that did not burn during major fires of 1910 and 1917 (Cichosz *et al.* 2001).

Mining

The South Fork Clearwater drainage has a complex mining history that included periods of intense placer, dredge, and hydraulic mining (Paradis et al. 1999b in Cichosz *et al*. 2001), some of which may pose a relatively high ecological hazard. Mining claims are also aggregated in a line extending from the upper Middle Fork and lower Lochsa River northward to Orogrande Creek, then along the upper North Fork to its headwaters including Meadow, Long, Osier, and upper Kelly Creeks (Cichosz *et al*. 2001). Within the North Fork drainage, mining activity was widely dispersed and methods used varied by area and included dredging, hydraulics, draglines, drag shovels, and hand operations (Staley 1940 in Cichosz *et al.* 2001).

Farming

Farming occurs in the western third of the Clearwater River basin on lands below 2,500 feet (Cichosz *et al.* 2001). Total cropland and pasture in the subbasin exceeds 760,000 acres; small grains are the major crop, primarily wheat and barley (Cichosz *et al.* 2001). The 1985 Farm Bill has resulted in replacing farming on over 79,000 highly erodible and other environmentally sensitive acres with long-term approved cover for 10 to 15 years (Cichosz *et al.* 2001).

Ranching

Historical documentation suggests that sheep grazing in the Clearwater River Subbasin began as early as the 1890s increased through the mid 1930s, peaked in 1933, declined sharply by 1949, and remained relatively consistent until the mid 1960s (Cichosz *et al.* 2001). Permits for cattle grazing were not issued in the Clearwater National Forest until 1937, with 25 head permitted; grazing increased to over 400 head by 1943 and continued to increase, reaching 1,199 head by 1960 (Space 1964 in Cichosz *et al.* 2001).

Recreation

Wild and scenic rivers, world class big game hunting and trout fishing, and river rafting can be found in the Selway Bitterroot Wilderness Area, making the Clearwater River Subbasin a recreational resource of national significance (Cichosz *et al.* 2001). Steelhead and Chinook sport fisheries in the Clearwater River Subbasin attract anglers both from within Idaho and out-of-state, and is an important component of the local and state economy (Cichosz *et al.* 2001). Dworshak Reservoir also provides a recreational resource of regional significance.

7.4.3 Habitat Restoration Initiatives in the Clearwater River Subbasin

Habitat restoration activities occurring within the Clearwater River Subbasin are expected to benefit the coho reintroduction program. A number of BPA funded (Table 7-1) and non-BPA funded (Table 7-2) habitat improvement initiatives are occurring in areas that are expected to improve coho salmon survival.

Table 7-1. BPA funded Clearwater River Subbasin habitat improvement projects expected to benefit coho salmon.

BPA Project #	Title/Description
9706000	NPT Clearwater Focus Program
9303501	Enhance Fish, Riparian and Wildlife Habitat within the Red River Watershed
9901600	Protecting and Restoring Big Canyon Creek Watershed
9901700	Rehabilitate Lapwai Creek
9607702	Protecting and Restoring the Lolo Creek Watershed
9607703	Protecting and Restoring the Squaw and Papoose Creek Watersheds
9607704	Final Design for Fish Passage Improvements at Eldorado Falls
9607705	Restore McComas Meadows
9608600	Clearwater Subbasin Focus Watershed Program - ISCC
9901400	Restore Anadromous Fish Habitat in the Little Canyon Creek Subwatershed
9901500	Restore Anadromous Fish Habitat in the Nichols Canyon Subwatershed

7.4.4 Habitat Conditions in the Clearwater River Basin in Relation to Coho Salmon Life History Stage

This section describes limiting habitat factors and the impact to each life history stage for coho salmon. Habitat ratings of excellent, good, fair, and poor are also given for each life history stage. It should be noted that information in sections discussing the life history requirements of coho salmon (particularly regarding stream temperature and gradient preferences) suffer from a lack of knowledge specific to Clearwater River Subbasin coho salmon. It is likely that much of the information derived from peer-reviewed literature is most applicable to coastal coho stocks, and hence may be of limited value in defining habitat constraints within the Clearwater River Subbasin.

Table 7-2. Additional Clearwater River Subbasin habitat improvement initiatives expected to benefit coho salmon.

Agency	Location	Purpose
Natural Resources Conservation Service	Mainstem Clearwater River Watershed	Streambank stabilization Sediment reduction Riparian improvement
State of Idaho	Big Canyon Watershed	Cropland erosion control Riparian Improvement
Bureau of Land Management	Mainstem Clearwater River Watershed	Little Canyon Creek fish passage Stream channel restoration Road rehabilitation
Bureau of Land Management	South Fork Clearwater River Watershed	Riparian fencing Planting Rearing channel construction Stream bank stabilization Road rehabilitation
USFS	South Fork Clearwater River Watershed	Channel stabilization Opening new channels Side channel flow improvement Culvert replacement Stream bank stabilization
USFS/NPT	Lochsa River Watershed	Road obliteration
USFS	Lochsa River Watershed	Migration barrier removal Instream structure placement

7.4.4.1 General Habitat Condition

The Clearwater River Subbasin is pristine or near-pristine compared to other large Columbia River tributaries. Production potential for coho within the Clearwater River Subbasin, however, is unknown. The present capacity of some streams within the Clearwater River Subbasin to produce coho salmon has declined since settlement by white emigrants beginning in the 1850’s (Parkhurst 1950, Murphy 1962, Murphy and Metsger 1962, USFWS 1962, Espinosa 1992, NPT and IDFG 1990). The extent of habitat decline has varied across the drainage.

Habitat decline affecting coho production is prevalent in mainstem tributaries. Historically, mainstem tributaries such as Lapwai Creek, the Potlatch River, and Big Canyon Creek probably supported a disproportionate population of coho because:

1. L:ower elevation stream likely had warmer winter water temperatures;

2. lower elevation streams, in general, have lower stream gradient which provided favorable conditions for side channels and beaver ponds; and

3. these streams possibly had groundwater seeps and springs providing favorable temperatures for incubation. Table 7–3 describes general stream habitat conditions within the Clearwater River basin.

Table 7–3. Stream habitat conditions within the Clearwater River basin.

Subbasin	Drainage Area (Sq. Miles)	Condition of fish habitat
Mainstem	2,783	The mainstem of the Clearwater River and its tributaries below the South Fork have been degraded to varying degrees by timber harvest, road construction, farming, livestock grazing, rural residential development, and occasional municipal pollution. Stream temperatures and sediment loading have increased and stream flows have decreased due to water withdrawals for irrigation. Mainstem flows are controlled to some degree by releases from Dworshak Dam.
South Fork	1,160	Much of the South Fork subbasin has been degraded by gold mining, timber harvest, road building, livestock grazing and farming. Many low gradient streams were mined before and after construction of the Harpster Dam in 1910.
Selway	2,029	Most of the Selway River subbasin is located within the Selway-Bitterroot Wilderness Area, and fish habitat is generally pristine. Lower portions of the subbasin outside of designated wilderness have experienced some impacts from timber harvest and road construction.
Lochsa	1,185	Much of the Lochsa River subbasin is pristine or near-pristine. Timber harvest and road construction have had some adverse impacts on fish habitat.

7.4.4.2 Stream Flows

Clearwater River Subbasin stream flows are typical for the Snake River basin. Discharge is highest in May and high flows continue into June. Low flows occur in August, September and during very cold winter periods. Figures 7–1 through 7–4 depict average monthly flow near the mouth of the Lochsa, Selway, South Fork, and at Spalding in the mainstem Clearwater River. Flows in the mainstem Clearwater River at Spalding are controlled, to a degree, by the operation of Dworshak Dam. In recent years, as shown in Figure 7–4, flows are lower during the spring run-off, and higher during the August and September periods to aid in the migration of juvenile fall Chinook salmon and adult steelhead in the lower Snake and Clearwater rivers.

Stream flows in the Clearwater River Subbasin are not typical of coastal coho streams. Coastal streams often experience high flow during winter months when eggs and sac fry are in the gravel. High flows during winter months may affect coho salmon eggs and fry in lower Clearwater River Subbasin tributaries such as Lapwai Creek, but these flows do not occur on an annual basis. High winter flows seldom affect coho eggs and sac fry in mid-to-high elevation tributaries. Coho fry are free swimming during periods of high flows in most Clearwater River Subbasin tributaries. Backwaters, side channels, ponds, and instream structures provide sanctuary areas for free swimming coho fry during high water periods.

7.4.4.3 Adult Migration

Adult coho migrate at temperatures above 38˚F (3.3˚C), and migration slows as water temperatures drop below 38˚F (3.3˚C; Cramer and Cramer 1994). For this reason, coho must reach natal streams before stream temperatures fall below 38˚F (3.3˚C). Figures 7–5 and 7–6 depict maximum and minimum stream temperature during the fall adult migration period at Spalding, and Figures 7–7 and 7-8 show stream temperature during the fall adult migration period at Orofino. Flows from Dworshak Reservoir affect stream temperatures in the mainstem Clearwater River. However, stream temperatures in the lower Clearwater River would not discourage adult coho migration. Stream temperatures above the mouth of the North Fork Clearwater River during the last half of November would discourage coho migration. However, coho migration should be completed by mid-November.

7.4.4.4 Spawning and Egg Incubation

The Nez Perce Tribe has collected fairly extensive temperature information in Newsome and Mill creeks which are tributaries of the South Fork. These streams are representative of mid and upper-watershed streams, especially streams in the South Fork subbasin. Figures 7–9 and 7–10 depict average water temperatures in Newsome and Mill creeks from 1990 through 1993. Water temperatures in Newsome and Mill creeks during the coho spawning and egg incubation period are shown on Figure 7–11. Figure 7–8 shows that water temperatures are in the “preferred” temperature range for spawning only during early October. Eggs and sac fry are in a “tolerable” temperature range during much of November, late February, March and into April. Water temperatures, at least in Newsome and Mill creeks, are questionable for the survival of coho. However, ground water seep and spring areas may provide micro-habitats that provide favorable conditions for winter survival. While formal thermal surveys have not been pursued, the presence of a strong groundwater influence is noted in the Lolo Creek watershed (Lolo National Forest 1999). In addition, a number of locations in the South Fork Clearwater River subbasin have Aquatic Landtype Association (ALTA) ratings of 2, 5, or 18 suggesting that groundwater influence is common (Nez Perce National Forest 1997).

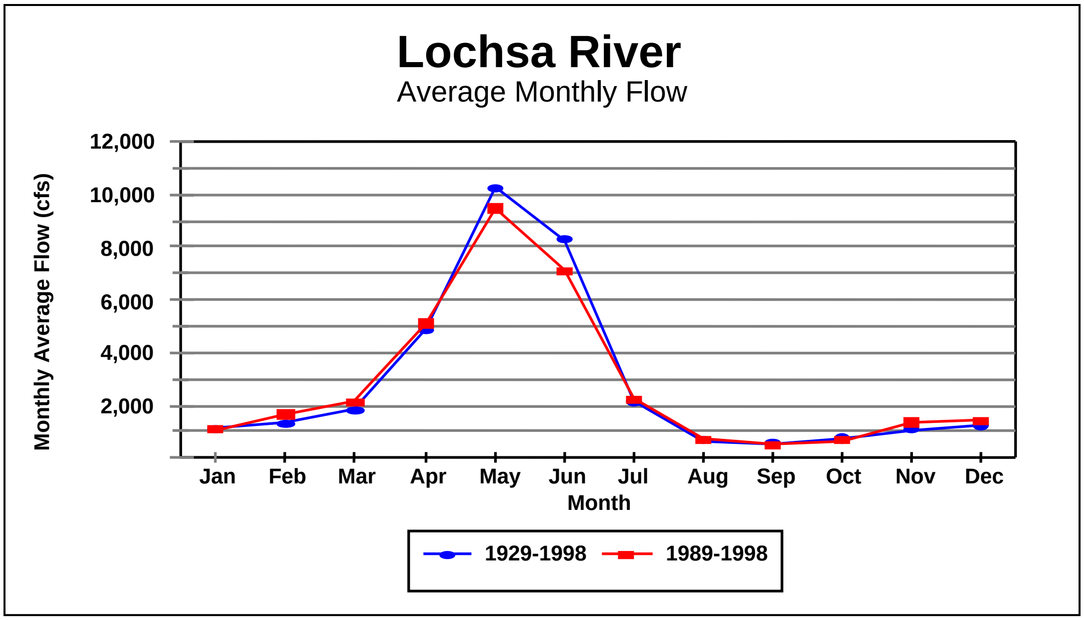

Figure 7-1. Monthly average flow of the Lochsa River at Lowell.

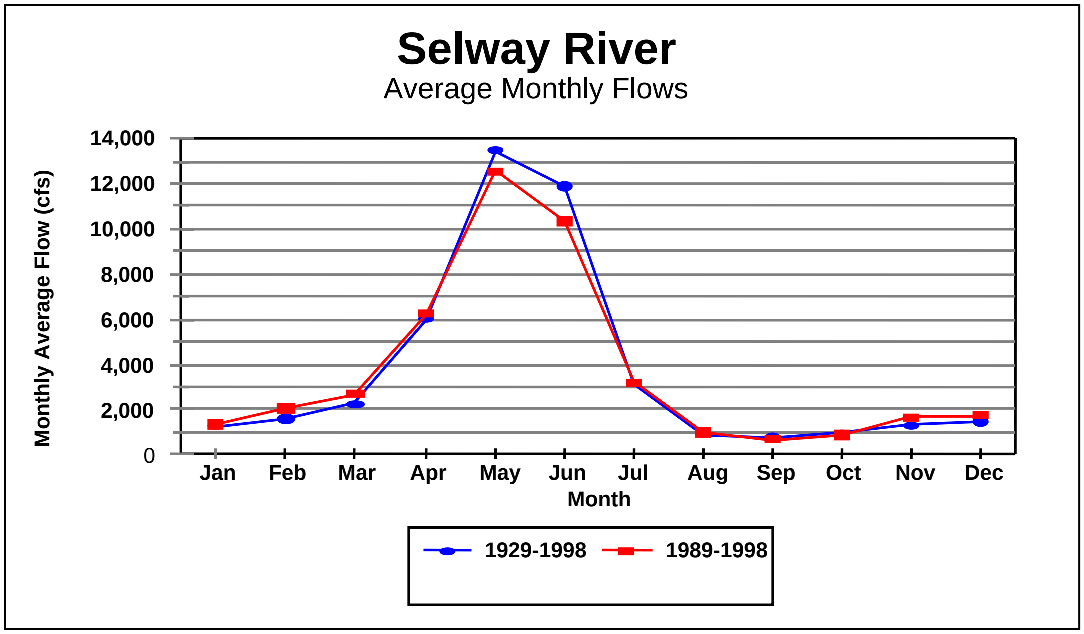

Figure 7-2. Monthly average flow of the Selway River at Lowell.

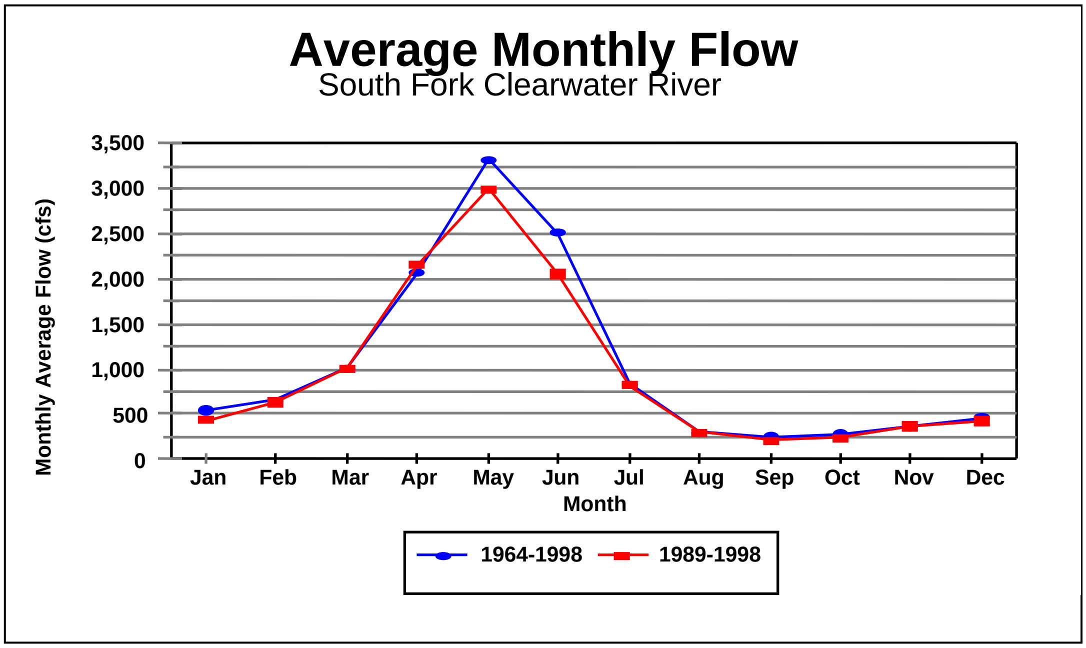

Figure 7-3. Monthly average flow of the South Fork at Stites.

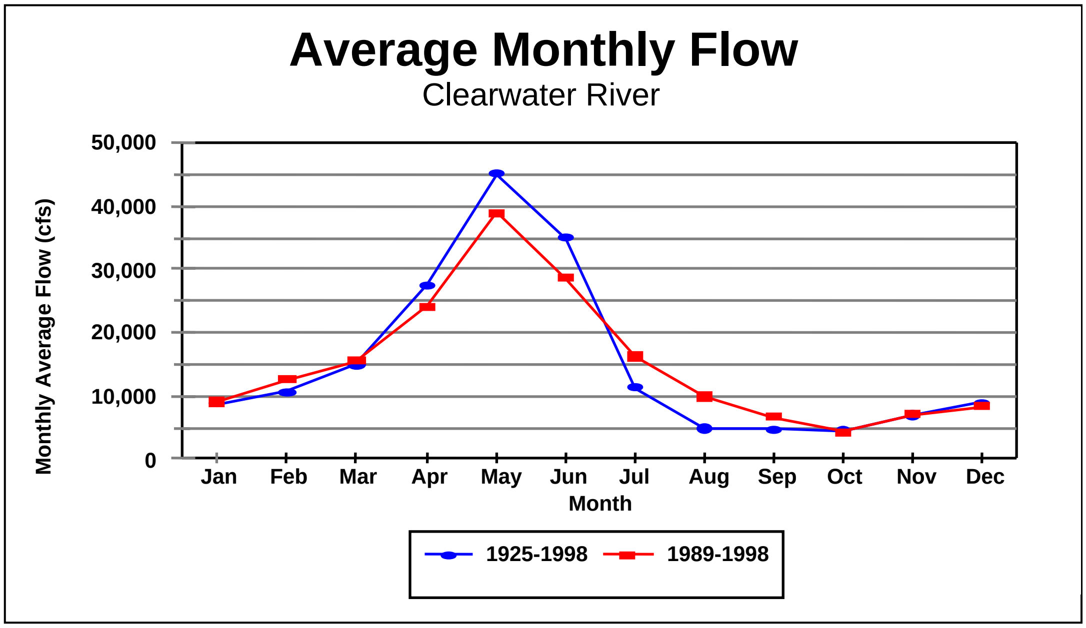

Figure 7-4. Monthly average flow of the Mainstem at Spalding.

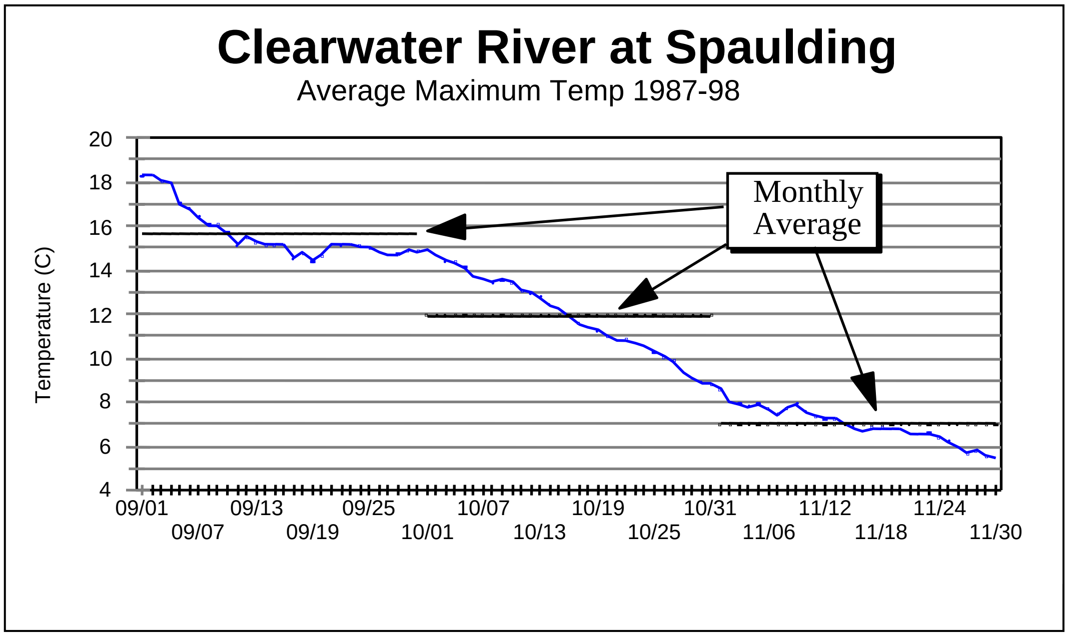

Figure 7-5. Average maximum water temperature in the Mainstem Clearwater River at Spaulding, September 1 through November 30 for an 11 year period.

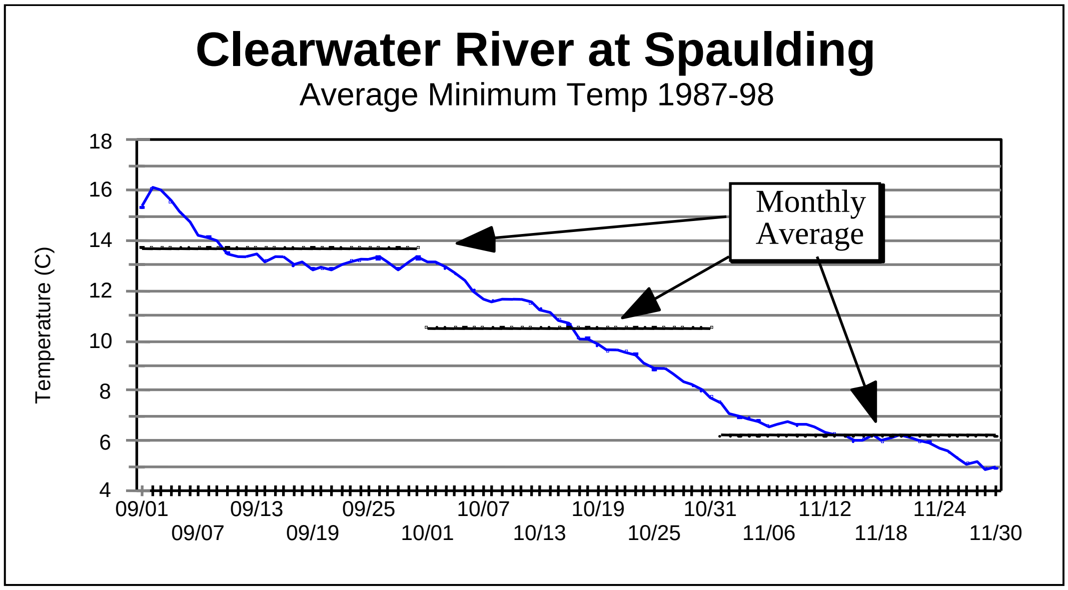

Figure 7-6. Average minimum water temperature in the Mainstem Clearwater River at Spaulding, September 1 through November 30 for an 11 year period.

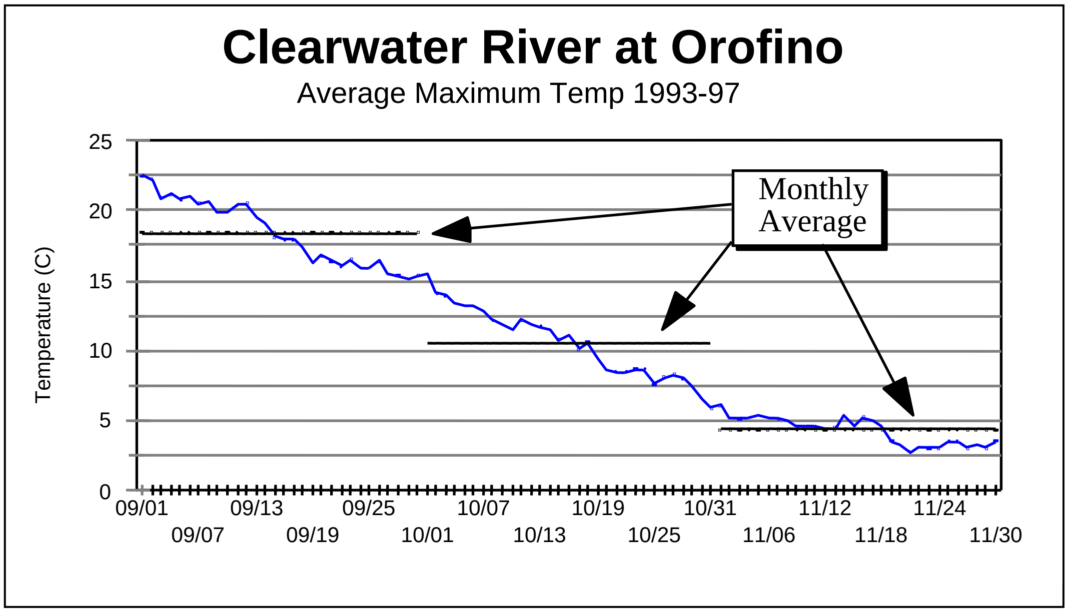

Figure 7-7. Average maximum water temperature in the Mainstem Clearwater River at Orofino, September 1 through November 30 for a 4 year period.

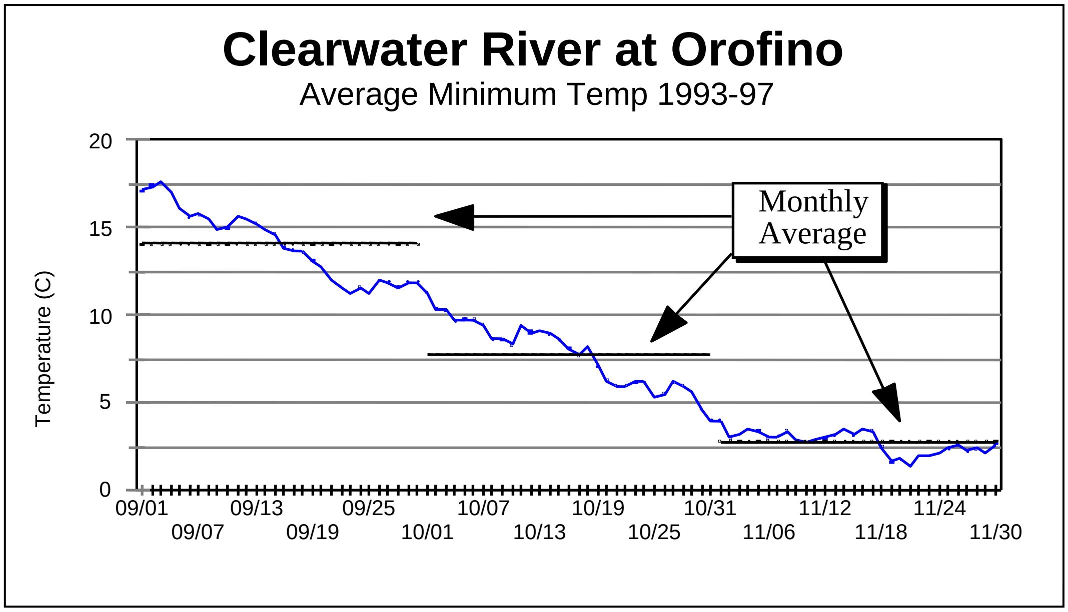

Figure 7-8. Average minimum water temperature in the Mainstem Clearwater River at Orofino, September 1 through November 30 for a 4 year period.

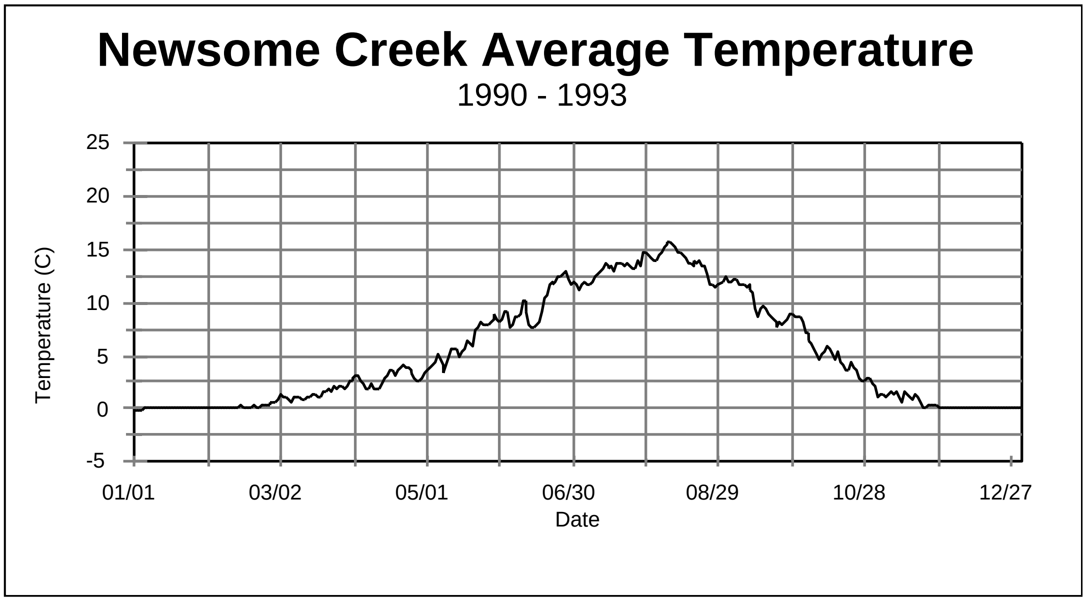

Figure 7-9. Average water temperatures in Newsome Creek during the period 1990 through 1993.

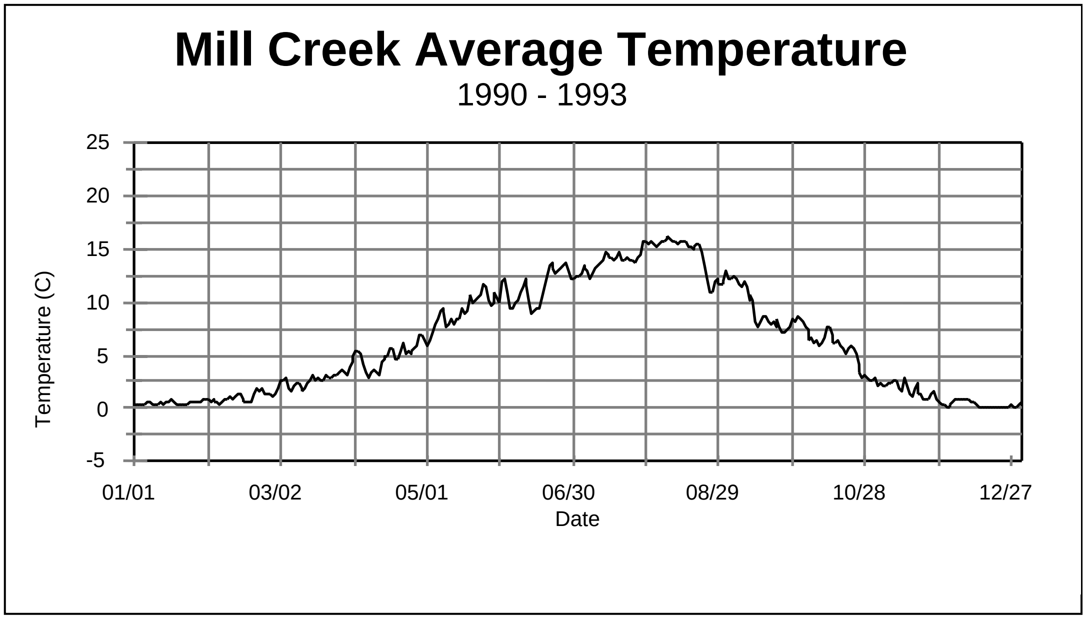

Figure 7-10. Average water temperatures in Mill Creek during the period 1990 through 1993.

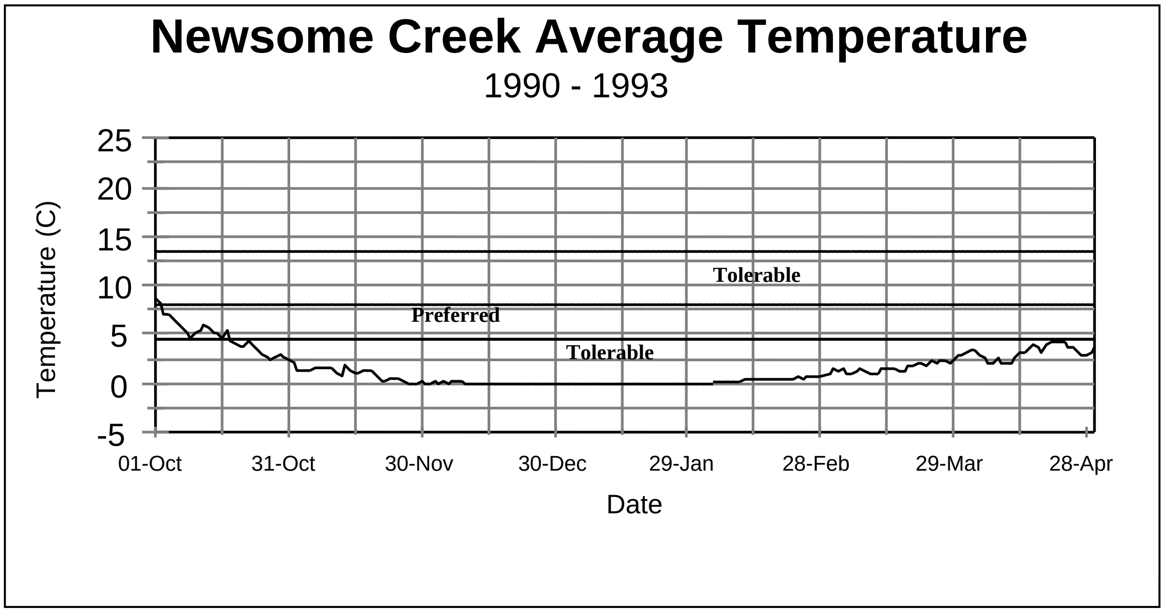

Figure 7-11. Tolerable and preferred temperature ranges for coho salmon.

7.4.4.5 Stream Gradient

Reeves et al. (1989) identifies stream gradient as a major factor controlling coho salmon populations. Streams with gradient of 3% or less are more likely to have side channels, back water areas and a higher pool-to-riffle frequency favored by coho.

Many tributaries of the Selway and Lochsa subbasins have gradients in excess of 3%, however many of these streams have low gradient meadow type habitat in upper reaches that could support coho. Meadow Creek, a tributary of the Selway River, is an example of a stream with meadow type habitat preferred by coho. In the case of Meadow Creek, however, it is questionable whether coho navigate past natural cascades in lower reaches to access the meadow habitat. General observations of stream gradients in the Clearwater River Subbasin suggest that the South Fork of the Clearwater River has more stream reaches with a gradient less than 3% than other Clearwater River Subbasin tributaries.

7.5 Aquatic Species Richness

There are 36 species of fish inhabiting the Clearwater River Subbasin, including 21 native species, three of which have required reintroduction efforts (Tables 7–4 and 7-5; Cichosz *et al.* 2001). Introduced sport or forage species are also found in the Clearwater River Subbasin and primarily include centrarchids, ictalurids, and salmonids (Table 7–6; Cichosz *et al.* 2001).

Table 7-4. Reintroduced native fishes present in the Clearwater River Subbasin.

Common Name	Scientific Name
Chinook Salmon (Spring)	*Oncorhynchus tshawytscha*
Chinook Salmon (Fall)	*Oncorhynchus tshawytscha*
Coho Salmon	*Oncorhynchus kisutch*

Table 7-5. Native fishes of the Clearwater River Subbasin.

Common Name	Scientific Name
Pacific Lamprey	*Lampetra tridentata*
Steelhead/Redband Trout	*Oncorhynchus mykiss*
Westslope Cutthroat Trout	*Oncorhynchus clarki lewisi*
Bull Trout	*Salvelinus confluentus*
Mountain Whitefish	*Prosopium williamsoni*
Northern pikeminnow	*Ptychocheilus oregonensis*
Chiselmouth	*Acrocheilus alutaceus*
Peamouth	*Mylocheilus caurinus*
Longnose Dace	*Rhinichthys cataractae*
Speckled Dace	*Rhinichthys osculus*
Redside shiner	*Richardsonius balteatus*
Largescale sucker	*Catostomus machrocheilus*
Bridgelip Sucker	*Catostomus columbianus*
Sandroller	*Percopsis transmontana*
Mottled Sculpin	*Cottus bairdi*
Shorthead sculpin	*Cottus confusus*
Paiute sculpin	*Cottus beldingi*
Torrent sculpin	*Cottus rhotheus*

Table 7-6. Exotic fishes present in the Clearwater River Subbasin.

Common Name	Scientific Name
Rainbow Trout	*Oncorhynchus mykiss*
Kokanee	*Oncorhynchus nerka*
Brook Trout	*Salvelinus fontinalis*
Golden Trout	*Salmo aguabonita*
Arctic Grayling	*Thymallus arcticus*
Tiger Muskie	*Esox lucius x E. masquinongy*
Carp	*Cyprinus carpio*
Channel catfish	*Ictalurus natalis*
Black Bullhead	*Ictalurus melas*
Brown bullhead	*Ictalurus nebulosus*
Smallmouth bass	*Micropterus dolomieu*
Largemouth bass	*Micropterus salmoides*
Bluegill	*Lepomis macrochirus*
Pumpkinseed	*Lepomis gibbosus*
Black crappie	*Pomoxis nigromaculatus*
Yellow Perch	*Perca flavescens*

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Appendix A: Project Management – Recommendations of the APRE (Council Document 99-15, NPCC 1999)

The Artificial Production Review (APR; NPCC 1999) recommends 10 guidelines for the management of artificial production facilities. The following paragraphs detail how these principles were applied in the compilation of this Master Plan.

1. "The manner of use and the value of artificial production must be considered in the context of the environment in which it will be used."

The primary goal of this program is the re-establishment of naturally spawning aggregates of coho salmon within targeted historical coho habitat. This program recognizes that the primary cause for the demise of coho salmon in the Clearwater River Subbasin was the construction of the Harpster and Lower Clearwater Dams, however overfishing and habitat degradation likely contributed to substantial reductions in abundance prior to extirpation. While the Harpster and Lower Clearwater Dams have been removed, eight mainstem hydropower facilities as well as Dworshak Dam have been constructed that will continue to impose mortality on Clearwater River Subbasin coho salmon during both juvenile emigration and adult immigration. Nonetheless, reintroduction efforts to date have indicated that hatchery production can result in a replacement rate greater than one (Section 6.2). Habitat degradation and harvest will continue to impact the survival of Clearwater River Subbasin coho, and it is unknown whether these impacts in addition to dam related mortality will allow sustainable natural production. The success of this program relies on recent and ongoing extensive habitat restoration efforts (Section 7.4). Targeted fisheries for coho do not currently exist within the Clearwater River Subbasin. However, incidental and direct ocean and in-river harvest will impact Clearwater River Subbasin coho. Estimating the effects of harvest is a key component of the RM&E plan for the coho project (Chapter 5).

This project views artificial propagation as a means to offset mortality in the egg to presmolt or smolt life history stage to compensate for mortality at later life history stages. As such, hatchery production will be unlikely, on its own, to successfully achieve restoration. The indicators of success and failure, as well as the triggers for implementation of Phase II explicitly recognize that program success relies on survival rates throughout the life cycle of the fish. Therefore these indicators and triggers focus on life cycle productivity (Section 3.6).

2. "Artificial production must be implemented within an experimental, adaptive management design that includes an aggressive program to evaluate benefits and address scientific uncertainties."

Very little is known regarding the historical abundance, distribution, and habitat requirements of Clearwater River Subbasin coho salmon. As such, this project is based on an adaptive management framework that uses limited initial releases of juvenile coho salmon in natural production areas that can be closely monitored to estimate adult escapement, juvenile production, productivity, and interspecific competitive impacts. The results of limited releases in targeted habitat will guide the number and distribution of juvenile releases in Phase II of the program, which focuses directly on supplementation.

Program benefits will be measured as nutrient enrichment (number and distribution of carcasses), adult escapement past LGD, tributary specific escapement, and eventually harvest. Risks such as disease transmission and interspecific competition and predation are specifically addressed in the RM&E program (Chapter 5).

3. "Hatcheries must be operated in a manner that recognizes that they exist within ecological systems whose behavior is constrained by larger-scale basin, regional, and global factors."

Currently, this program relies on four separate hatcheries and one satellite acclimation facility for spawning, rearing, and acclimation (Section 3.2). While reliance on facilities operated by multiple agencies introduces uncertainty to the program, it also ensures that co-managers are involved at every stage of planning.

4. "A diversity of life history types and species needs to be maintained in order to sustain a system of populations in the face of environmental variation."

The NPT Clearwater River Subbasin coho reintroduction program is based on the fact that coho salmon were a natural and important contributor to ecosystem processes within the Clearwater River Subbasin (Section 2.3). Reintroduction of coho salmon, if successful, will increase species diversity.

5. "Naturally selected populations should provide the model for successful artificially reared populations, in regard to population structure, mating protocol, behavior, growth, morphology, nutrient cycling, and other biological characteristics."

Unfortunately, there are no sources of Clearwater River Subbasin or even Snake River coho for use as broodstock. One of the greatest uncertainties associated with this effort is the reliance on hatchery origin coho salmon production from Lower Columbia River (LCR) hatcheries. However, the reintroduction is structured to take advantage of the beneficial effects of natural selection as a means to foster the emergence of a "localized" stock of coho salmon. To do so, the program will utilize adult returns from first generation LCR smolt transfers as broodstock. In turn, progeny from this broodstock will be used to supplement targeted coho habitat within the Clearwater River Subbasin. This strategy is intended to maintain genetic exchange with LCR source stocks in order to minimize the random loss of genetic variation, while at the same time employing only the progeny of adults that have successfully returned to the Clearwater River Subbasin as broodstock for supplementation activities.

6. “The entities authorizing or managing a production facility or program should explicitly identify whether the artificial propagation product is intended for the purpose of augmentation, mitigation, restoration, preservation, research, or some combination of these purposes for each population of fish addressed.”

This program, if successful, will serve multiple purposes. Initially (Phase I), this program will focus on broodstock development. Once a localized broodstock is available, Phase II will be triggered, wherein the emphasis of the program will shift towards restoration. If supplementation activities are successful at establishing sustainable natural production (defined as adult to adult replacement equal to or greater than one), hatchery efforts will either cease, or be reprogrammed to serve a harvest function.

7. “Decisions on the use of the artificial production tool need to be made in the context of deciding on fish and wildlife goals, objectives and strategies at the subbasin and province levels.”

Initially, Clearwater River Subbasin reintroduction efforts were possible as a result of a regional evaluation of LCR coho production through the U.S. v. Oregon forum. Mangers agreed that LCR coho production could appropriately be used in upriver areas. This agreement fits very well within the context of the recent APRE review (NPCC 2003) that suggests:
“Hatcheries could be used to enhance biodiversity by producing a wider variety of salmonid species and life histories. Greater species and life history diversity makes sense ecologically and could provide greater harvest opportunities by enhancing adult returns over a longer time period.”

The APRE also points out inequities in production that are particularly apparent for coho salmon:

> *“A sizeable majority of Columbia River Basin hatchery production takes place in the lower three provinces. Unfortunately, the communities most affected by the construction of the dams do not share equally in this production.”*

The Clearwater Subbasin Plan (EcoVista 2002), lists an escapement goal of 14,000 adult coho past Lower Granite Dam. This number is consistent with the Tribal Restoration Plan (CRITFC 1996)

8. “Appropriate risk management needs to be maintained in using the tool of artificial propagation.”

Several risks/uncertainties have been identified in the drafting of the Master Plan. Of greatest concern is the potential for coho reintroduction activities to undermine efforts to restore spring Chinook, steelhead, and bull trout populations within the Clearwater River Subbasin. Recent experimental evidence from Yakama Nation coho reintroduction in the mid-Columbia (Section 6.3) suggests that interspecific competition and predation between coho and spring Chinook and steelhead are unlikely to be deleterious. Nonetheless, the RM&E program (Chapter 5) includes specific measures to determine whether the health of spring Chinook salmon and steelhead are negatively effected by the reintroduction of coho. Unfortunately, few data exist to predict the effect of coho reintroduction on sympatric bull trout populations. However, the USFWS expressed the following views regarding coho reintroduction in the upper Columbia (USFWS 2001):

> *"It is generally felt that this supplementation program will not impact bull trout stocks and will likely benefit bull trout and other resident fish. Historically, bull trout probably benefited from the presence of anadromous salmonids. The downstream drift of eggs released from spawning salmon provided food for bull trout and other resident fishes, but more importantly the presence of decaying salmon carcasses greatly benefited juvenile salmon and resident fishes thru nutrient recycling. Generally, in drainages colonized by natural anadromous salmon and steelhead populations the bull trout have successfully co-existed."*

Nonetheless, the same document also urges a cautionary approach to the reintroduction of coho salmon in habitat occupied by bull trout:

> *"…in many areas where bull trout currently exist, habitat conditions have deteriorated and natural predator-prey balances have been upset. Bull trout populations are at or near critically low levels in many areas of the basin. For this reason caution should be exercised in stocking large numbers of hatchery fish near bull trout spawning and rearing areas to avoid the potential for competition or predation on bull trout fry."*

9. "Production for harvest is a legitimate management objective of artificial production, but to minimize adverse impacts on natural populations, harvest rates and practices must be dictated by the requirements to sustain naturally spawning populations."

If this program is successful in establishing sustainable natural production of coho salmon within the Clearwater River Subbasin, it is likely that a harvest program will be investigated. There is no detail in his document regarding the scope of harvest, which is a deliberate omission as data are unavailable to estimate the success of natural coho production in the Clearwater River Subbasin. However, in the event that a harvest component is deemed feasible, maintenance of sustainable natural production will remain the highest program priority.

10. "Federal and other legal mandates and obligations for fish protection, mitigation, and enhancement must be fully addressed."

The relationship of the proposed program to existing legal and conservation mandates is established in Tables 1-1 and 1-2. In addition to consistency with these mandates, this program, if successful, will serve a mitigation mandate that has not been achieved to date - the reintroduction of coho salmon to historically occupied habitats of the Clearwater River Subbasin.

This mandate has a legal basis in treaties signed between the federal government and the NPT (see Section 2.4), as well as a scientific basis established under principle seven above.

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Stand- and landscape-scale selection of large trees by fishers in the Rocky Mountains of Montana and Idaho

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Stand- and landscape-scale selection of large trees by fishers in the Rocky Mountains of Montana and Idaho

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ABSTRACT

The fisher (*Pekania pennanti; formerly known as Martes pennanti*) is a North American endemic mustelid with a geographic distribution that spans much of the boreal forests of North America. In the Northern Rocky Mountain (NRM) fishers have been the focus of Endangered Species Act (ESA) listing decisions. Habitat studies of West Coast fishers in California have consistently identified late-successional forests as important, providing direct implications for forest management and fisher conservation. In the NRM range very little is known about the habitat selection patterns of fishers relative to forest age and species composition, yet ESA petitioners have repeatedly listed habitat loss and destruction as the primary threat to fisher persistence. Between 2002 and 2006 we studied NRM fishers in the Clearwater sub-basin and eastern slope of the Bitterroot-Selway Ecosystem in Idaho and Montana. We used radio-telemetry locations from collared fishers to document fisher habitat use. We developed candidate models describing tree size, species composition, canopy closure, structural diversity, and topography to assess patterns of habitat selection relative to topographic and vegetative predictor variables measured at both stand and landscape scales. Support for these models was evaluated using Akaike Information Criteria. Fishers disproportionately used both stand sites and regional landscapes characterized by large diameter trees and avoided areas with ponderosa (a shade-intolerant species characteristic of xeric sites in the NRM) and lodgepole pine according to our best supported model. These results are consistent with other studies in the western US and Canada where large trees were deemed important, although we show that this selection in the Rocky Mountains occurs at multiple scales. These results highlight the importance of late-successional forests, consistent with a recent conservation strategy for fishers, and the importance of both stand- and landscape-level factors when directing forest management of fisher habitat in the US Rocky Mountains.

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1. Introduction

In the last part of the 19th century and the early part of the 20th century trapping and habitat alteration caused the extirpation of fisher (*Pekania pennanti*; formerly known as *Martes pennanti*) populations throughout the United States (Zielinski et al., 1995; Lewis and Stinson, 1998). Foresters and wildlife biologists reintroduced fishers in Washington, Oregon, Montana, Idaho, Wisconsin, West Virginia, Massachusetts, Vermont, New York and Connecticut, while augmenting populations in other regions (Powell, 1993; Powell et al., 2012). Some of these reintroductions have produced populations large enough to sustain harvests, especially in the east and mid-west of the United States and Canada (Lewis and Stinson, 1998). However, other fisher populations persist at low numbers, and remain at potentially high risk for extirpation. Limiting factors for fisher recovery include direct mortality from trapping, urban and recreational development, disease, anticoagulant rodenticide poisoning, habitat alterations (e.g., timber management and large wildfires) leading to increased fragmentation and changed forest structure, and direct and indirect impacts from road corridors (Weckwerth and Wright, 1968; Lewis and Zielinski, 1996; Weir and Corbould, 2008; Zielinski et al., 2005; Purcell et al., 2009; Gabriel et al., 2012).

Due to low abundance and documented threats, fishers have been petitioned for listing under the US Endangered Species Act in both the West Coast of the United States (California, Washington, and Oregon) and the US Rocky Mountains (Carlton, 1994;

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Greenwald et al., 2000). The listing of the West Coast Distinct Population Segment of fishers was considered “warranted but precluded by higher priority actions” and this population was placed on a “candidate list” (USFWS, 2004). The United States Fish and Wildlife Service (USFWS) is currently reviewing candidate species and an updated decision is imminent. Petitioners for the Northern Rocky Mountain (NRM) population of fishers specifically argued that disease and habitat loss from logging and fire have threatened preferred habitat of fishers. Specifically, petitioners were concerned that silvicultural treatments may alter structural diversity and reduce critical cover for fishers. While the USFWS ruled that the NRM Distinct Population Segment was a “listable entity”, they decided that potential factors that may affect habitat and range of fishers were not significant in magnitude to warrant listing (USFWS, 2011).

Several studies have investigated fisher habitat relationships in the West Coast population mostly with respect to fishers’ use of resting structures. Resting structures are thought to be important as they provide protection from predators and moderate thermal conditions in both summer and winter (Kilpatrick and Rego, 1994; Purcell et al., 2009). Zielinski et al. (2004) studied fisher resting locations within home ranges (3rd order selection sensu Johnson (1980)) in the Coastal Mountains and Sierra Nevada of California. They found that standing California black oak (*Quercus kelloggii*) and Douglas-fir (*Pseudotsuga menziesii*) of the largest diameter available were used in each study area, respectively, and recommended forest management practices aimed at retention and recruitment of large trees, dense canopies, and structural diversity. Purcell et al. (2009) used similar methods in the southern Sierra Nevada and found fishers selected resting sites according to canopy cover, large trees and snags, and on steep slopes close to streams. They also found fishers selected for resting sites in snags with advanced stages of decay and trees with large diameter at breast height (DBH, diameter measured at 1.4 m) at sites with a high variability of tree sizes. Purcell et al. (2009) echoed the management recommendations of Zielinski et al. (2004), highlighting the importance of large trees (e.g., mean maximum DBH in stands with fisher resting sites was 141.9 cm) and snags in stands with a minimum of 61% canopy cover and complex forest structure.

In British Columbia, Weir and Harestad (2003) found fishers selected habitat at multiple scales (i.e., from elements to stands) depending on denning, foraging, or resting behavioral states. Their results generally paralleled those of other studies, showing selection for forest overstory, coarse woody debris, and high structural diversity at the patch and stand scales. Weir and Harestad (2003) suggested that fishers can occupy heterogeneous, or patchy, landscapes that contain critical structural elements for foraging, hunting, denning and resting; thus managers can lessen negative effects of habitat alterations at large spatial scales by keeping critical elements at smaller scales. Aubry et al. (2013) conducted a meta-analysis of fisher habitat selection surrounding resting sites in 8 study areas from north-central British Columbia to the southern Sierra Nevada in California. They found that fishers selected for rest site areas that were on steeper slopes, in cooler microclimates, had dense overhead cover, in stands with greater volume of logs, and had a greater number of large trees and snags (Aubry et al., 2013).

In contrast to the well-studied West Coast populations, very little is known about fisher habitat preferences in the Rocky Mountains of the United States. Jones and Garton (1994) showed that in central Idaho subalpine fir (*Abies lasiocarpa*) and grand fir (*Abies grandis*) old-growth forests were extensively used in the summer, while both young and old-growth forest were selected during winter. They also showed that fishers selected forest riparian habitat for resting, hunting, and travel. Jones and Garton (1994) further demonstrated that fishers did not use non-forested habitats, although the authors noted that some of their prey choices (based on a diet study) would only be found in sparsely forested habitats, suggesting forays into more open stands.

We initiated this study to examine the environmental features selected by NRM fishers at both the stand and landscape scales in the Clearwater River basin and the adjacent eastern slope of the Bitterroot-Selway Ecosystem, within the Rocky Mountains of Idaho and Montana (Fig. 1). This study area is one of few areas containing fishers with a native genetic lineage within the NRM (Vinkey et al., 2006; Schwartz, 2007; Schwartz et al., 2012). Other than

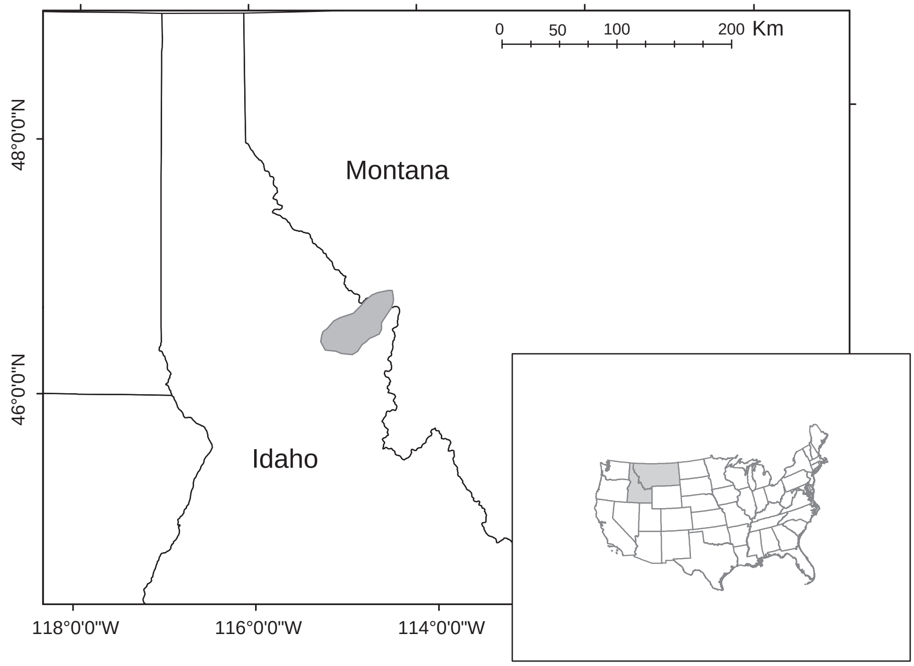

Fig. 1. Map of the study area (gray) in the Rocky Mountains of Montana and Idaho, where fishers were studies from 2002 to 2006.

the study of Jones and Garton (1994) little scientific information is available regarding fishers' use of forests in this area, likely due in part to the difficulties in accessing the greater Selway-Bitterroot Ecosystem, which contains one of the largest designated Wilderness areas in the contiguous United States. This lack of information has hindered forest management as questions concerning fisher habitat requirements have been used to legally challenge forest management activities (e.g., Idaho Sporting Congress, Inc. v. Rittenhouse, 2002; Lands Council v. McNair, 2008).

2. Methods

2.1. Study area

We studied Northern Rocky Mountain fishers in portions of north-east Idaho and west-central Montana straddled by the Bitterroot Mountain divide near Lolo Pass (Fig. 1). Our study area included approximately 100 miles of the Highway 12 corridor, which paralleled the Lochsa and Clearwater Rivers in Idaho and Lolo Creek in Montana. In the winter, the warm, moist maritime air from the Pacific penetrates into this sub-basin, resulting in a mean annual precipitation of approximately 200 cm per year (measured at Lolo Pass) and occasional years exceeding 250 cm. The abnormally high moisture (considering distance from a substantial body of water) leads to a refugia ecosystem characterized by grand fir, western red cedar (*Thuja plicata*), and hemlock (*Tsuga* spp.) stands at high and middle elevation. Intermixed with these typically coastal stands are xeric and mesic stands consisting of Douglas fir, subalpine fir, lodgepole (*Pinus contorta*) and ponderosa pine (*Pinus ponderosa*) – a more typical ecotype of the intermountain west. The area has been considered an important Pleistocene refugium based on geology, phytogeography, and phylogenetics of several key species (Daubenmire, 1975; Carstens et al., 2005; Mullen et al., 2010). The wet climate, mesic vegetation, large amounts of structure, and the presence of late successional forest stands allows the Clearwater River sub-basin to support a resident population of fishers.

2.2. Trapping, handling and telemetry monitoring

Between January 2002 and March 2006 we studied fishers by deploying conventional VHF radio-telemetry collars (150–154 MHz, Holohil MI-2 collar, Carp, Ontario; collar weight ~45 g) on a subset of 34 fishers captured within the study area (Appendix A). We captured animals using both log-cabin traps (Copeland et al., 2007) hand constructed from natural materials in the study area, and single-door box traps (1.0 × 0.3 × 0.3 m; Tomahawk Trap Co., Tomahawk, Wisconsin). Trap doors were fit with a trap-transmitter (Telonics TBT-600HC, Telonics Inc., Mesa, AZ) used to signal when the door is shut allowing remote monitoring on a daily basis.

We immobilized captured fishers with a ketamine/xylazine mixture (22 mg ml^{-1} ketamine/kg and 10 mg ml^{-1} xylazine per animal) administered with a jab stick. Once anesthetized, ophthalmic ointment was placed onto the fisher's eyes for protection, and a small hood was fit over its face. While under the dissociative anesthetic fishers were instrumented with the radiocollar, weighed, physically examined, and tagged at the base of the anterior edge of the ear using Dalton Rototags (Dalton Supplies Ltd., Nettlebed, England). A small tissue punch and hair sample (~50 hairs) was collected for DNA analysis (Vinkey et al., 2006; Knaus et al., 2011). We conducted all trapping and handling procedures under Institutional Animal Care and Use Committee oversight and under scientific collecting permits (#011211 from Idaho Fish and Game and #1520 from Montana Fish Wildlife and Parks).

During the winters of 2002 and 2003, all captured fishers (11 males, 6 females) were instrumented with radio-telemetry collars. Due to limited monitoring resources and the difficulty associated with locating male fishers, collaring from 2004 onward was limited to females, and collars were removed from re-captured males. Incentive for focusing data collection on adult female fishers included the importance of adult female survival in driving fisher population dynamics (sensitivity = 0.71; M. Schwartz unpublished data). In total, 23 males and 11 females were captured during the study, and data from nine females were used for this habitat analysis (two juvenile females were never relocated).

Radio-tagged fishers were located by one of three techniques. The primary method (64% of locations) involved using ground telemetry to detect an individual fisher at distance and subsequently walking into the stand where the fisher was present. If the fisher was resting the technician circled the stand and noted the group of trees where the fisher was located, therefore eliminating telemetry error. We rarely visually observed the fisher using this method. Secondary methods included aerial telemetry (27%) and ground triangulation (9%; White and Garrott, 1990), where locations could be attributed to specific structural elements in a stand. Locations where we could not localize a structure in a stand, or where researchers could not be at 90 degree angles from one another at distances less than 100 m, were discarded.

2.3. Vegetation and physical sampling

We sampled used and available habitat associated with telemetry locations and randomly selected locations within 10 km of Highway 12, which bisected the study area along the major drainage basin (Fig. 1). To minimize the degree of contamination of our available sample with habitats actually used by fishers (Johnson et al., 2006), we deployed non-invasive genetic sampling devices at each random location (see Zielinski et al., 2007; Kendall and McKelvey, 2008; Wasserman et al., 2010 for details on this device). Non-invasive snares were set for 2 periods of 14 days. Upon return, when hair was present, the sample was removed and placed in a 50 mm plastic centrifuge vial filled with 6–16 mesh silica desiccant (Fisher Scientific, Pittsburg PA, USA), and Standard species identification approaches were subsequently followed in a genetics laboratory (Schwartz and Monfort, 2008). During the summer of 2004 we deployed 74 devices at randomly selected sites within 10 km of Highway 12 to characterize habitat availability regardless of landscape designation (e.g., Wilderness, roadless, or managed) or access issues. We used those stations that did not detect a fisher ($n = 67$) as a sample of available habitat points, although admit that fisher may have been present, but not detected.

At each used and available location we recorded habitat characteristics at multiple, nested scales. Broadly we characterized the heterogeneity in habitat characteristics at used and available locations at two scales: a stand scale describing features in the immediate vicinity of the location and a landscape scale describing features within a 1 km surrounding radius. For stand-level measurements, vegetation sampling plots of several sizes were centered around locations and additional topographic variables (slope, aspect, elevation, distance to edge of patch, type of edge, distance to water, and snow depth) were recorded to characterize the stand and available elements (Table 1). At the largest plot size (36 m radius), we estimated tree density and basal area. We also recorded the tree species present, DBH, and whether cavities or snags were present. Within a mid-sized plot (18 m radius) we established line intercept transects from plot center in each cardinal direction and measured DBH of trees greater than 1 m, species, length, and log decay (Sollins index of log decay; Sollins, 1982) of downed trees, stumps, snags, and ground cover. Logs were defined as horizontal trees >8 cm DBH and >2 m long. For all snags we

Table 1
A list of habitat variables measured at sites of fisher use and at random sties in the Rocky Mountains of Montana and Idaho, 2002–2006. Vegetation was measured at a plot level and a landscape level (1 km buffer), structural elements were noted at a plot level, and physical variables were estimated at both scales. DBH is diameter of a tree measured at 1.4 m. TPI is an index of landscape convexity.

Categories	Specific variables	Subcategories
Vegetation (Plot level)	DBH	Max, Mean, Standard Deviation
	Tree count	Total, Grand fir (*Abies grandis*), Subalpine fir (*Abies lasiocarpa*), Larch (*Larix occidentalis*), Lodgepole pine (*Pinus contorta*), Ponderosa pine (*Pinus ponderosa*), Engelmann spruce (*Picea engelmannii*), Douglas fir (*Pseudotsuga menziesii*), Western red cedar (*Thuja plicata*), Mountain hemlock (*Tsuga mertensiana*)
	Shrub	Count
Vegetation (Landscape level – 1 km buffer GIS)	Tree size	Sapling, small, medium, large
	Grass	Proportion of buffer
Structural	Cavity	Presence, Count
	Logs	Mean DBH, count, volume
	Canopy	Density (field measured), Buffered 1 k (low, mid, high)
	Snags	Max DBH, Count
	Stumps	Presence
Physical	Point	Elevation, Slope, Aspect
	I km Buffer	TPI, Slope, Roughness

noted if cavities were present. At this mid-scale we also calculated mean canopy cover (hereafter canopy cover) by measuring canopy cover at the center and at each end of the transects using a spherical convex canopy densitometer (Forest Densiometers, Oklahoma, USA). Lastly, we established a 9-m radius plot and measured shrub and understory variables. We recorded the shrub species between 0.5 m and 2 m in height and the approximate ground cover at the plot center and in each of the cardinal directions 9 m from plot center using a gridded meter square box. Within the 1 m^2 box we estimated cover of nonvascular plants, graminoids, forbs, and shrubs.

To characterize landscape-scale heterogeneity, we quantified a suite of GIS-based metrics describing features within a 1 km radius of locations. We generally followed Squires et al. (2008) and characterized a set of topographic and vegetative variables using point estimates at each location as well as mean estimates within 1000-m radius buffer surrounding each location. We used a 30 m digital elevation model (US Geological Survey, 2000) to characterize elevation, slope, aspect, topographic position, and roughness. Slope and aspect were derived using the Spatial Analyst extension for ArcGIS Desktop 9.2 (ESRI, Redlands, CA, USA), and we transformed aspect into an index of the SSW-NNE axis using the cosine of the angle minus 35° (Cushman and Wallin, 2002). We calculated a continuous topographic position index (TPI) that indexed landscape convexity (positive values indicative of ridges) versus concavity (negative values suggesting drainages). We used the TPI extension (v. 1.3a; Jenness, 2006) for ArcView 3.2a to estimate TPI at a 1 km neighborhood scale surrounding each location. We estimated roughness as the ratio of 3-dimensional surface area to 2-dimensional surface area (Jenness, 2004) using the Surface Areas and Ratios feature of the Elevation Grid v 1.2 extension for ArcView 3.2.

We used the US Forest Service's Northern Region Vegetation Mapping Project layers (VMAP v. 6; Brewer et al., 2004) to characterize land cover type, canopy closure, and tree size according to the proportionate area of each of several categories per variable within 1000-m circular landscapes surrounding point locations. We simplified the VMAP species composition layer into four cover type categories to parsimoniously characterize study area vegetation as grass, shrubs, shade-intolerant forest (included single-species and mixed stands of ponderosa pine, Douglas fir, western larch (*Larix occidentalis*), and lodgepole pine) and shade-tolerant forest (included single-species and mixed stands of grand fir, subalpine fir, Englemann spruce, western red cedar, and mountain hemlock). We characterized canopy closure and tree size layers in forested habitats using canopy closure categories of low (10–24.9%), medium (25–59.9%), and high (>60%) canopy closure and tree size categories of saplings (0–13 cm DBH), small (13–25 cm), medium (25–38 cm), and large (>38 cm; Brewer et al., 2004).

2.4. Data analyses and model selection

We evaluated fisher habitat preferences by comparing the suite of vegetative and physical resources at used fisher telemetry locations to those at randomly available sites. All statistical analyses were conducted in Stata 10 (StataCorp, 2007). We began analyses with an information-theoretic model selection approach (Burnham and Anderson, 2002) to assess the relative evidence for five basic habitat factors shown to drive fisher habitat selection in a recent meta-analysis (Aubry et al., 2013). We selected this approach as a first step to avoid over-fitting our modest data set with the full suite of possible models available, and instead explore the relative support among few biologically meaningful hypotheses (Burnham and Anderson, 2002). For each of the five habitat factors, we developed sets of 5–15 *a priori* candidate models containing combinations of predictor variables that best characterized the resources of hypothesized importance (Table 2).

First, we developed candidate models describing tree size at both stand and landscape-scales as a means of assessing the support for large trees as key components of fisher resting and denning habitat (Aubry et al., 2013; Zielinski et al., 2004, 2006; Purcell et al., 2009; Table 2). Second, we used species composition models differentiating tree species indicative of both mesic and xeric microclimates (Zielinski et al., 2004; Purcell et al., 2009; Aubry et al., 2013). Third, we evaluated models characterizing canopy closure at multiple scales (Weir and Harestad, 2003; Zielinski et al., 2004; Raley et al., 2012), and fourth, we separately tested models parameterizing structural diversity as predictive of fisher habitat selection, including quantification of snags and tree cavities to assess the evidence for thermal and other cover as provided by these structural components (Buskirk and Powell, 1994; Raley et al., 2012; Table 2). Lastly, we compared topographic models that explained fisher resting and denning habitat in previous studies, including variables regarding slope, aspect, and topographic position (Table 2). We used Akaike Information Criteria (AIC) to assess the relative support for each of these hypothesized drivers of fisher habitat selection, as quantified by both ΔAIC differences between each model and the lowest model score, as well as AIC model weights (*w*; Burnham and Anderson, 2002). We used the variables from the most supported models in each of the 5 analysis per habitat factor to build and evaluate 30 composite models that

Table 2
Five sets of *a priori* candidate models containing combinations of predictor variables that best characterized the resources of hypothesized importance of fishers in the Rocky Mountains of Montana and Idaho, 2002–2006. Variables in bold were most supported. Landscape variables were evaluated at the 1 km scale.

Model	Variables	ll (model)	df	AIC	ΔAIC	wAIC
Habitat factor 1: Importance of large trees						
M1a	Maximum DBH in trees in the stand	−55.7826	2	115.5651	4.3909	0.0632
M1b	Mean DBH in trees in the stand	−65.0273	2	134.0545	22.8803	0.0000
M1c	Standard deviation in DBH in trees in the stand	−57.9918	2	119.9836	8.8094	0.0069
M1d	**Maximum DBH + Proportion of large trees (landscape)**	**−52.5871**	**3**	**111.1742**	**0**	**0.5677**
M1e	Mean DBH + Proportion of large trees in landscape	−59.5949	3	125.1899	14.0157	0.0005
M1f	Standard Deviation in DBH + Prop. of large trees (landscape)	−53.0383	3	112.0767	0.9025	0.3615
M1 g	Proportion of large trees (landscape)	−62.2423	2	128.4846	17.3104	0.0001
Habitat factor 2: Importance of species composition						
Model	Variables	ll (model)	df	AIC	ΔAIC	wAIC
M5a	Number of grand fir	−70.6549	2	145.3099	7.4264	0.0114
M5b	Number of western red cedar	−71.2118	2	146.4236	8.5401	0.0065
M5c	Number of ponderosa pine	−67.7906	2	139.5813	1.6978	0.1999
M5d	Number of Douglas fir	−72.9638	2	149.9276	12.0441	0.0011
M5e	**Number of lodgepole pine + Number of ponderosa pine**	**−65.9417**	**3**	**137.8835**	**0**	**0.4672**
M5f	**Number of ponderosa pine + Number of western red cedar**	**−66.3769**	**3**	**138.7538**	**0.8703**	**0.3023**
M5 g	Number of western red cedar + Number of grand fir	−69.6425	3	145.285	7.4015	0.0115
Habitat factor 3: Importance of canopy cover						
M2a	Canopy cover	−55.6711	2	115.3422	3.878	0.0733
M2b	Canopy cover + Canopy cover^2	−55.5635	3	117.1269	5.6627	0.0300
M2c	**Proportion of high canopy cover (landscape)**	**−53.7321**	**2**	**111.4642**	**0**	**0.5096**
M2d	Canopy cover + Proportion of high canopy cover (landscape)	−53.3215	3	112.643	1.1788	0.2827
M2e	Canopy cover + Canopy cover^2 + Prop. of high canopy cover (landscape)	−53.3179	4	114.6357	3.1715	0.1044
Habitat factor 4: Importance of structure						
M3a	Presence of snags	−72.5473	2	149.0946	5.2354	0.0299
M3b	Presence of tree cavities	−70.7687	2	145.5373	1.6781	0.1770
M3c	Total log volume	−73.2393	2	150.4786	6.6194	0.0150
M3d	**Presence of snags + Presence of tree cavities**	**−68.9296**	**3**	**143.8592**	**0**	**0.4096**
M3e	Presence of snags + Total log volume	−72.1173	3	150.2346	6.3754	0.0169
M3f	Presence of tree cavities + Total log volume	−70.3796	3	146.7592	2.9	0.0961
M3 g	Presence of snags + Presence of tree cavities + Total log volume	−68.4015	4	144.803	0.9438	0.2555
Habitat factor 5: Importance of topography						
M4a	TPI	−69.7269	2	143.4537	6.7773	0.0186
M4b	Slope	−73.1455	2	150.291	13.6146	0.0006
M4c	Aspect	−73.6048	2	151.2095	14.5331	0.0004
M4d	Slope (landscape)	−70.888	2	145.776	9.0996	0.0058
M4e	TPI + Slope	−69.0009	3	144.0018	7.3254	0.0141
M4f	TPI + Aspect	−69.7166	3	145.4332	8.7568	0.0069
M4g	TPI + Slope (landscape)	−68.0464	3	142.0928	5.4164	0.0367
M4h	Slope + Aspect	−73.1387	3	152.2773	15.6009	0.0002
M4i	Slope + Slope (landscape)	−67.0479	3	140.0958	3.4194	0.0996
M4j	Aspect + Slope (landscape)	−70.8752	3	147.7504	11.074	0.0022
M4k	TPI + Slope + Aspect	−68.995	4	145.99	9.3136	0.0052
M4l	**TPI + Slope + Slope (landscape)**	**−64.3382**	**4**	**136.6764**	**0**	**0.5507**
M4m	TPI + Aspect + Slope (landscape)	−68.0461	4	144.0922	7.4158	0.0135
M4n	Aspect + Slope + Slope (landscape)	−66.9754	4	141.9508	5.2744	0.0394
M4o	TPI + Slope + Slope (landscape) + Aspect	−64.3217	5	138.6435	1.9671	0.2060

compared the relative support for combinations of each of our broad habitat factors of tree size, species composition, canopy cover, structural diversity, and topography as drivers of fisher habitat selection.

Following this information-theoretic approach to model selection, we conducted *post hoc* exploratory analyses of univariate and multivariate relationships of all measured variables as potential drivers of habitat selection. These analyses were conducted to explore all relationships in the data for this poorly studied population of fishers, and consider alternate multivariable models for explaining fisher habitat beyond those developed *a priori*. We used Wald statistics (z) to assess the univariate importance of all vegetation and physical variables measured and then conducted multivariable model selection on the subset of variables with weak univariate significance ($p < 0.25$), following Hosmer and Lemeshow (2000). We used a manual forward stepping approach to assess multivariable models according to both individual variable Wald statistics and the effects of multicollinearity among moderately ($r < 0.7$) correlated variables as evidenced by variance inflation and changing of coefficient signs (Hosmer and Lemeshow, 2000; Copeland et al., 2007). We evaluated overall model fit using receiver operating characteristic (ROC) curves which have been shown to be a conservative indicator of RSF performance and predictive power (Cumming, 2000; Boyce et al., 2002) and the likelihood ratio chi-squared test.

3. Results

We first evaluated variables associated with large trees at stand and landscape scales (Fig. 2). The model with most support included both maximum DBH at the stand scale and the proportion of large trees within the landscape scale (Table 2). We subsequently evaluated tree species composition variables and found that a model showing avoidance of both ponderosa and lodgepole pine species was the most supported, suggesting avoidance of xeric stands. A univariate model including the proportion of high density canopy cover within 1-km landscapes was the most supported

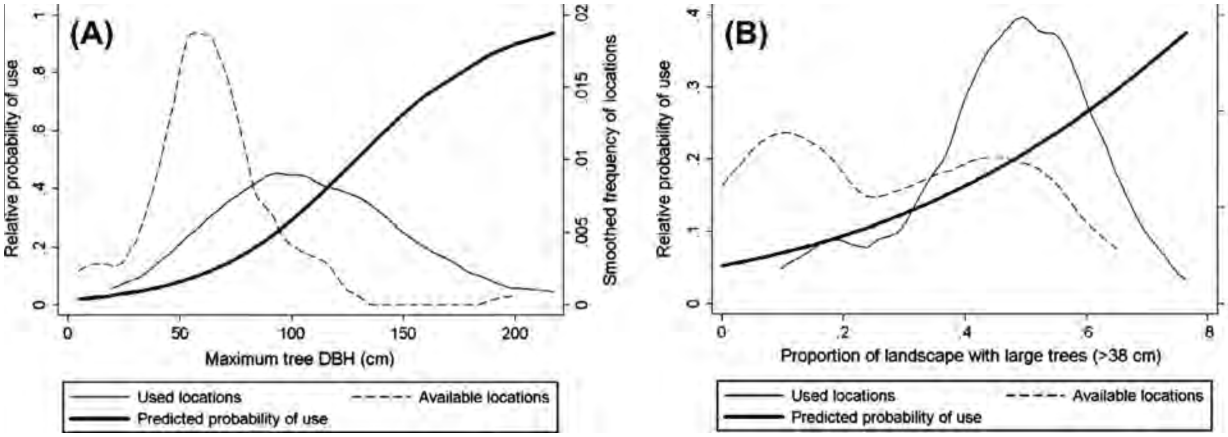

Fig. 2. Kernel smoothed densities of used and available locations according to (a) stand-scale maximum tree DBH measurements within the plots and (b) landscape-scale measurements of the proportion of large (>38 cm) within 1000 m circular radii from plot centers, as well as the respective corresponding predicted probabilities of use by fishers from the best model describing fisher habitat selection in the Rocky Mountains of Montana and Idaho, 2002–2006.

model characterizing canopy closure (Table 2). Comparing the stand structure models, the most supported model included snags and tree cavities present (Table 2). Lastly, of the 15 topographic models assessed, the most supported model included TPI, and two scales of slope measured both locally at the plot center and as an average within a 1-km radius (Table 2).

We combined the top models describing each of these five basic habitat factors to create 30 additional models representing all possible combinations of these factors. The most supported model contained two factors: tree size and species composition. Specifically, this model revealed selection for large maximum tree DBH ($\beta = 0.031$, $P < 0.001$), high proportion of large trees in a 1 km buffer ($\beta = 3.097$, $P = 0.048$), and avoidance of stands with ponderosa pine and lodgepole pine ($\beta = -0.375$, $P = 0.09$ and $\beta = -0.002$, $P = 0.97$; Tables 3 and 4).

Our *post hoc* analysis began with univariate analysis of all recorded variables and revealed several statistically significant relationships (Appendix B). As found by our model selection approach above, fishers preferred sites with trees of larger maximum DBH ($Z = 4.63$, $p < 0.001$). They preferred sites with large standard deviations in DBH ($Z = 4.63$, $p < 0.001$), though this variable was highly correlated with DBH Max ($r = 0.91$). Among tree species, the most preferred species was grand fir ($Z = 2.23$, $p = 0.026$). Stand structure and complexity variables revealed fisher selection for sites with large logs ($Z = 2.22$, $p = 0.027$) and presence of tree cavities ($Z = 2.23$, $p = 0.026$). Consistent with the need for structure, there was also selection against grass cover across a 1 km buffer ($p = 0.031$; $Z = -2.16$). Topographic variables were also important. At the stand level fishers selected for lower elevations ($Z = -4.18$, $p < 0.001$), while at the landscape scale fishers selected steeper slopes ($Z = 2.26$, $p = 0.024$) higher surface roughness ($Z = 2.21$, $p = 0.027$), and concave, or drainage-like, topographical positions ($Z = -2.53$, $p = 0.011$).

A manual stepping multivariable model selection approach produced a nearly identical best model as reached by the information theoretic approach, differing only in its exclusion of the lodgepole pine variable (Appendix B). Generally both exercises indicated that fishers selected sites with larger diameter trees, in landscapes with large trees, while avoiding stands of primarily xeric species composition. The predictive capacity of the model was good, with a pseudo-$R^2 = 0.33$ and ROC = 0.86, and a significant likelihood ratio chi squared = 48.3 (Appendix B).

Table 3
Comparison of the most supported habitat factors (see Table 2) combined to assess the relative importance of large trees, canopy cover, structure, topography, and species composition for fishers in the Rocky Mountains of Montana and Idaho, 2002–2006. Thirty models were evaluated (all combinations of models 1–5, removing those nested models where addition of a new variable did not improve the AIC score by two points as in Arnold, 2010), but only the top 10 models (ranked by AIC) are displayed here.

Model	ll (Model)	df	AIC	BIC	Work	ΔAIC	wAIC
Large Trees + Species Composition	−49.445	5	108.890	122.392	1	0	0.234
Large Trees	−52.587	3	111.174	119.276	0.3191	2.2845	0.075
Large Trees + Canopy Cover	−51.866	4	111.733	122.535	0.241352	2.843	0.057
Large Trees + Canopy Cover + Topography	−49.169	7	112.338	131.242	0.178298	3.4486	0.042
Large Trees + Topography	−50.251	6	112.502	128.705	0.164269	3.6125	0.038
Large Trees + Structure	−52.572	4	113.144	123.946	0.119171	4.2544	0.028
Large Trees + Canopy Cover + Structure	−51.863	5	113.727	127.229	0.089046	4.8372	0.021
Large Trees + Canopy Cover + Structure + Topo	−49.164	8	114.328	135.932	0.065924	5.4385	0.015
Large Trees + Structure + Topography	−50.226	7	114.452	133.355	0.06197	5.5622	0.015

Table 4
Variables that comprise the best supported model of fishers habitat use in the Rocky Mountains of Montana and Idaho considers variables including the size of trees and tree species composition. Support for this model is seen in Table 4.

Variable	Coefficient	Standard error	Z	$P > z$	95% CI	
Maximum DBH (stand)	0.031	0.008	3.66	0	0.0143	0.0474
Proportion of large trees (landscape)	3.097	1.568	1.98	0.048	0.0237	6.1700
Mean Number of Lodgepole Pine (stand)	−0.002	0.060	−0.04	0.968	−0.1200	0.1152
Mean Number of Ponderosa Pine (stand)	−0.375	0.222	−1.69	0.090	−0.8097	0.0592
ConstantConstant	−3.977	0.919	−4.33	0	−5.7783	−2.1757

4. Discussion

4.1. Habitat selection

Perhaps the most compelling result from this study was the consistent selection by female fishers for large trees at both stand and landscape scales. Our best multivariable model contained both maximum DBH at the stand level and a proportion of large tress within 1 km circular landscapes. Large trees occur in many settings throughout the study area, including remnant stands surrounded by forests that are highly altered by recent and historical logging, landscapes with large trees only in riparian areas, and patches of large trees embedded in wilderness and other highly inaccessible lands. However, it appears in our study area that the most preferred stands with large DBH trees (average maximum DBH in used habitats = 107.77 cm versus 64.224 cm in unused habitats) also occur in landscapes with large trees (used landscapes were composed of 47% large tree stands versus 29% in available landscapes). Thus, we recommend that silvicultural treatments of stands consider not only the retention of large trees, but consider the larger landscape when managing for fishers.

Maximum DBH best explained the differentiation between used and available habitats, yet it was highly correlated with mean DBH and the variation (standard deviation) in DBH. While the top model characterizing tree size included DBH max and proportion of a landscape with large size trees, the next most supported model contained the standard deviation in tree size at the stand scale and the proportion of large trees at the landscape scale (Table 2). This suggests that stands most used by fishers are those mature forests with both large and smaller trees, consistent with evidence that fishers need cover for hunting efficiency or predator escape purposes. These results are similar to Jones and Garton (1994) who found fishers selecting mature and old growth forests during the summer in Idaho. Yet, during the winter, they found fishers using a wider array of habitats, although still selecting for the larger diameter trees compared to random (Jones and Garton, 1994). Zielinski et al. (2004) studied West Coast fisher habitat selection at resting locations in the Coastal Mountains and Sierra Nevada of California. They found that standing trees of California black oak and Douglas-fir of the largest diameter available were used in each area, respectively. In their Sierra study area their resource selection function showed that fishers selected sites nearby water, on steeper slopes, with larger maximum DBH trees at sites with more variable tree DBH than random. They interpreted these results to suggest that managers can maintain fisher resting habitat by retaining large trees and using forest management practices that aid in the recruitment of trees that achieve the largest sizes. They also recommend increasing structural diversity at these sites. We concur with these forest management recommendations in reference to NRM fishers as well. Similarly, Purcell et al. (2009) found fishers selected sites with larger DBH trees and higher variance in the DBH of trees. This is consistent with a recent meta-analysis of 8 studies by Aubry et al. (2013) where there were significant summary effects sizes in mean DBH of live conifers $\geqslant 10$ cm DBH, and mean DBH of live hardwoods $\geqslant 10$ cm DBH, suggesting fishers' selection for larger diameter trees.

Our modeling efforts also showed tree species selection with avoidance of ponderosa pine and lodgepole pine stands. Ponderosa pine is generally considered a semiarid or xeric species although at mid-elevations and in more northern latitudes ponderosa pine can be an early seral stage of Douglas-fir or grand fir forest (Barrett, 1988; Keeling et al., 2006). In other moist forests the species is found on drier south facing aspects (Graham and Jain, 2005). Lodgepole pine is widely distributed throughout the study area, although it is generally considered a pioneer species first colonizing after a fire and then dominating early seral stages through rapid juvenile growth (Coops and Waring, 2011). Fishers likely avoid the ponderosa pine stands as they reflect the drier environments in the study area and generally have less understory cover to offer protection (Graham and Jain, 2005; Keeling et al., 2006). Avoidance of lodgepole pine is likely related to the relatively small diameter of even the oldest trees (i.e., mature sizes of lodgepoles in the Northern US Rocky Mountains is between 18 and 33 cm DBH; Burns and Honkala, 1990). This is consistent with evidence for fisher's selection for western red cedar stands, a species with large DBH and associated with wetter, more structure filled environments. In our preliminary evaluations of species composition, models characterizing selection for western red cedar were nearly equivalent to those describing selection against ponderosa pine (delta AIC = 0.87).

Interestingly, abundance of western red cedar and grand fir may be higher now than in historical times when western white pine (*Pinus monticola*) dominated moist, mid-elevation forests. However, this major element of inland northwest forests was substantially reduced in abundance due to white pine blister rust (*Cronartium ribicola*), mountain pine beetles (*Dendroctonus ponderosae*), and fire exclusion (Loehman et al., 2011). In fact, western white pine is now at less than 5% of historical range in the inland northwest; instead of being the dominant species in many stands it is widely scattered with limited natural regeneration potential (Harvey et al., 2008). Current management objectives are to restore western white pine ecosystems, which may have significant ramifications for fishers given our findings, as young white pine stands may not have the structural diversity in the understory, and be too open at maturity. On the other hand, the cones may serve as an important food source for small mammals, a primary food resource for fishers, and burned pine snags can persist for decades potentially providing denning habitat for female fishers. Thus, we recommend initiation of extensive studies of the potential impacts of white pine restoration on this rare species.

Structure and cover have been considered critical elements for fisher habitat (Raley et al., 2012; Weir and Corbould, 2010; Truex and Zielinski, 2013). In our initial models to characterize structure, the most supported model was the landscape model with a high proportion of stands with high canopy cover. Weir and Corbould (2010) found that fishers selected stands with greater than 30% canopy cover; Purcell et al. (2009) found canopy cover was the most important variable at predicting fisher resting sites; and Zielinski et al. (2004) showed that higher average canopy cover was critical for predicting fisher resting habitat. Alternatively at the stand scale we did not detect an effect of canopy cover on habitat selection by female fishers. This may be an effect of our study area, a mesic environment where relatively high canopy cover is ubiquitous and stands have ample mean canopy cover (e.g., our random locations had greater than 50% canopy cover) meeting threshold requirements. A similar area with dense forests, the Hoopa Valley of California, also did not show canopy cover being a limiting factor.

With our initial forest structure models we found the most support for fishers selecting structure in the form of stands with abundant snags and cavities. This is consistent with Zielinski et al. (2004) where the presence of conifer snags was significant. We recommend retention of large decadent trees and snags in areas with large trees to provide denning habitat for female fishers. While we identified univariate patterns of selection for variables that indicate structure, we also found avoidance of variables such as landscapes with a high proportion of grass, suggesting the corollary – avoidance of open areas - is also true. This is similar to results from Weir and Corbould (2010), where fishers avoided open areas, non-forested ecosystems, and areas with recent logging.

We evaluated 15 topographic models, as topographic features have been important for predicting fisher occurrence elsewhere (Purcell et al., 2009; Zielinski et al., 2004; Aubry et al., 2013). Both Purcell et al. (2009) and Zielinski et al. (2004) showed the importance of steep slopes for predicting fisher habitat use. Our most supported initial model contained both slope and TPI suggesting fishers' selection for steeper slopes and more concave environments, although neither was retained in our final multivariable models. TPI likely is a surrogate for moisture as fishers are selecting for wetter environments where vegetation is typically denser and larger.

4.2. Limitations of study

Fishers proved to be very difficult to detect and monitor in our study area, even when fitted with radio-collars, as the study area is largely roadless and mostly designated as federal Wilderness (the Selway-Bitterroot Wilderness alone is >500,000 ha). We culled male detections from our analysis as we were concerned about the bias introduced by not detecting males for months at a time, suggesting they often had lengthy movements beyond our study area. For example, one juvenile male captured in a trap in January 2005 was incidentally detected in June 2006 in a hair-snare device 91.5 km from the original trap site, across the Selway-Bitterroot Wilderness. Newer and lighter satellite based telemetry will improve our ability to study fishers in the future in these remote landscapes (e.g., Brown et al., 2012). Although even the newest satellite-based approaches will not be a panacea for the study of fishers given the dense vegetation, use of remote habitats in the Rocky Mountains, and the species penchants for using tree cavities and rock piles, which shield satellite communication. Fortunately, instrumented females exhibited much smaller areas of movement, with an average use area of 9.1 km^2. In the future we hope to combine satellite telemetry with remote download stations to improve our study of female fisher habitat use.

Our sample size was very limited. Despite the fact that this area likely has one of the densest populations of fishers in the US Rocky Mountains, we were only able to capture 11 females over 4 years, indicative of the relatively low density typical of this species in the Rocky Mountains. We opted to maximize sample size by lumping all locations across all females. This approach prevented us from making assertions regarding individual or annual differences. We also may have missed detection of selected habitat features that were of small selection effect or proportionate availability, yet important to fisher habitat selection. While we would normally be reluctant to present data sets of this modest size, there are almost no available data on fishers in the Rocky Mountains, except Jones and Garton (1994) who radiocollared 13 fishers in Idaho between 1985 and 1988 and obtained 88 observations at resting sites, comparable to the size of our dataset.

5. Conclusions and management implications

One of the most pressing questions regarding fisher management in the Rocky Mountains is the degree to which fishers are sensitive to habitat modification at a scale larger than the stand or the specific element in the stand. In this study, we found that females are indeed selecting habitat at two scales: a stand scale as indicated by stands that have large mean and maximum DBH trees (as well as a large variation in tree size) and a landscape scale as indicated by the preference for landscapes with a high proportion of large trees. Thus, it appears that while fishers can be detected in riparian stringers that bisect open landscapes, this habitat may not be sufficient for persistence. The converse is also likely true. Landscapes that do not have variation in large trees, snags, and cavities, and drier landscapes (i.e., landscapes with ponderosa and lodgepole pine) are probably not sufficient for fisher persistence either.

Forest activities that promote the growth of multi-stage stands with ample structure and variation in tree widths and ages will provide the best habitat for fishers. Retaining trees that have decadence, disease, or defects will help provide some of this habitat. These recommendations may be resisted as forests implement fuel treatments that often aim to limit the availability of ladder fuels. Fortunately, preferred habitat appears to be in moister topographic settings that create mesic stands, which should prove more resistant to wildfire and require less fuel treatments (Spies et al., 2006). Agee (2003) estimated fire return intervals of 75 years for mesic stands in Washington State and Camp et al. (1997) estimated that some mesic stands had a fire interval greater than 150 years. Similarly, according to Cilimburg and Short (2005), the mean fire return interval across 51 fire studies in the moist montane forests of western Montana and northern Idaho was 78 years. On balance this suggests that fire was not a large part of these wetter ecosystems except during extreme droughts. Purcell et al. (2009) and Spencer et al. (2008) noted that fuel treatments in California would have direct, negative impacts on fisher habitat suitability; however, these negative effects may be offset by the reduction in large fire risk. They suggested that the recovery of canopy cover from forestry treatments and wildfire may be relatively fast compared to the growth of large trees that would be removed should fire occur (Purcell et al., 2009).

Fishers clearly avoided openings such as clearcuts, open areas, and grassy slopes which were selected against in all of our models. They also avoided uniform early seral forests, like many of the lodgepole pine stands seen in the study area. Overall, our results suggest that the maintenance of suitable habitat for fishers will take planning at multiple scales with a focus on maintaining large trees in mesic forests.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foreco.2013.05.014.

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UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
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October 23, 2019

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Dear Ms. Coffey, Ms. Gray and Mr. Mainzer:

RE: Recent average abundance of Snake River steelhead relative to the Adaptive Management Implementation Plan Early Warning Indicators.

In consultation with your agencies, NOAA Fisheries adopted abundance-based Early Warning Indicators and Significant Decline Triggers as part of an Adaptive Management Implementation Plan (AMIP) which was first incorporated into the 2010 Supplemental Federal Columbia River Power System Biological Opinion (May 20, 2010). Consistent with the AMIP, and after receiving input from the Regional Implementation and Oversight Group (RIOG), an abundance and trend (rate of decline) metric was formally added on December 13, 2010. The AMIP, including both the Early Warning and Significant Decline triggers and the abundance and trend metric, was also included in the 2014 and 2019 biological opinions on the operation of the Columbia River System.

The purpose of this letter is to inform you that the Early Warning Indicator (based on the abundance and trend metrics) has been triggered for Snake River (SR) steelhead based on the run reconstruction estimates of natural origin adult steelhead at Lower Granite Dam, as updated to include the 2018-19 migration (Figure 1). This indicator is triggered if the four-year average abundance falls below the lowest 50 percent of returns, and the trend in abundance (defined as the slope of the last five years of annual abundance estimates) falls into the lowest ten percent abundance trends in the base period (i.e., if 90 percent of the slopes were more positive than this number). For SR steelhead, the corresponding AMIP abundance and trend metrics are a four-year average abundance of 17,975 and a slope of -0.233. The four-year average abundance of SR steelhead ending in 2018-19 is 17,705 (less than the 50th percentile) and the trend has a slope of 0.-408 (more negative than the lowest 10th percentile abundance trend).[1]

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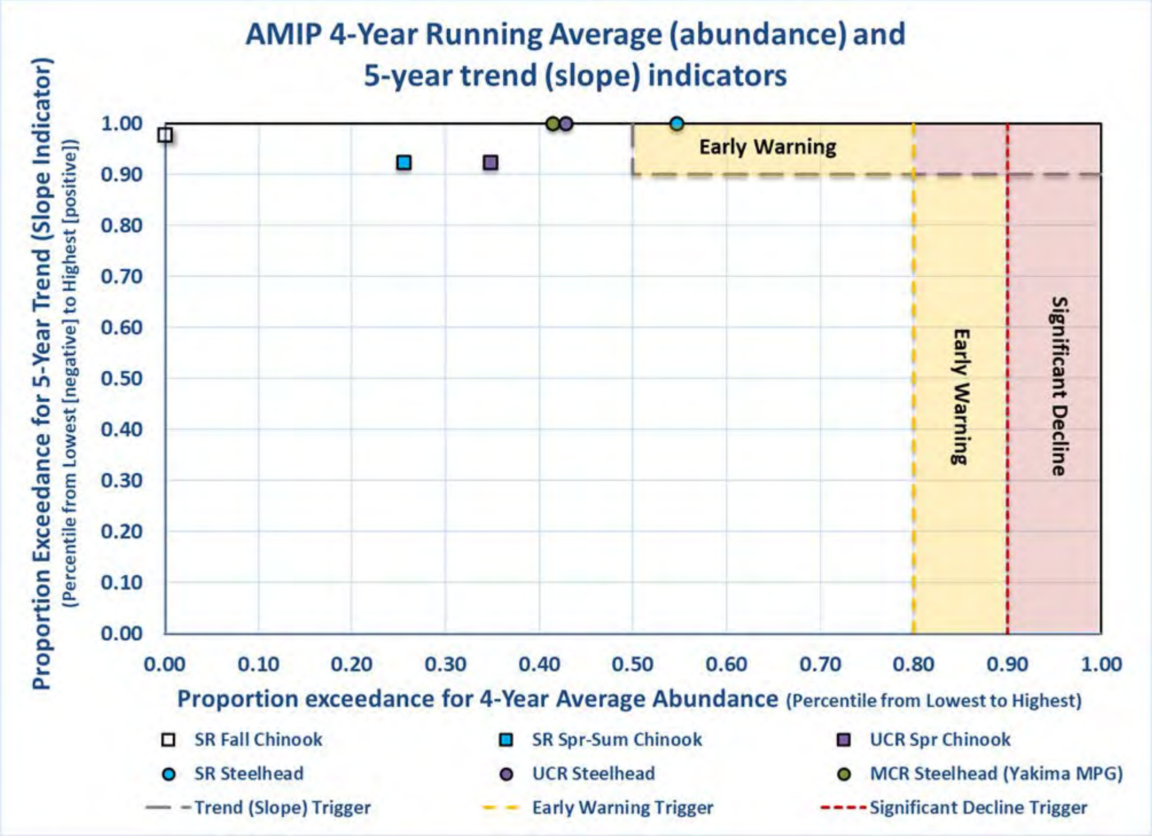
[1] Upper Columbia and Middle Columbia River (Yakima River Major Population Group) steelhead are experiencing similar declines in average abundance and abundance trends, but did not trigger the early warning indicator using the base periods established pursuant to the 2009 AMIP.

The 4-year average abundance (17,705) is well above the abundance based 20th percentile Early Warning and 10th percentile Significant Decline triggers. As intended, the trend (slope) indicator, is highly sensitive to declining abundance. In 2014-15, an estimated 45,789 naturally produced steelhead passed Lower Granite Dam [the highest number since this data series began in the mid-1980s], five years later, only 8,182 passed the project [the lowest return since the 1994-95 and 1995-96 migrations]. The high return in 2014-15, coupled with the poor ocean conditions experienced beginning with the 2015 smolt outmigration, appear to be the primary cause for this indicator being triggered as Columbia River System operations, harvest, and other potential causative factors have been relatively stable during this period.

Figure 1. Proportion exceedance for four-year average abundance and five-year trends (slope) for Snake River spring-summer Chinook salmon, fall Chinook salmon, and steelhead (at Lower Granite Dam); Upper Columbia River spring Chinook salmon (at Rock Island Dam) and steelhead (at Priest Rapids Dam); and Mid-Columbia River steelhead (Yakima MPG) compared to AMIP Early Warning and Significant Decline Triggers.



Based on these findings, NOAA Fisheries believes that further consideration is warranted and propose that we implement the AMIP process triggered by this Early Warning Indicator for SR steelhead to determine 1) if there is a likelihood of triggering the Significant Decline Trigger in the next one to two years, and 2) if additional actions are warranted to further protect the species. This would need to be accomplished in 120 days per the AMIP procedures.[2] Our approach consists of the following steps.

1) Evaluate the status of Snake River steelhead, including estimating a new four-year average abundance estimate, by mid-January, after the 2019 dam counts are available (about 90 percent of SR steelhead pass Lower Granite Dam by December 31 each year), assuming recent ratios of naturally produced adult estimates to total dam counts.
2) Determine the potential (the abundance required) for reaching the Significant Decline Trigger in 2019-20 or 2020-21. This analysis would be based on previous year's abundance, coupled with any preseason forecast information that may be available, including relevant ocean condition indicators.
3) If the analysis reveals a likelihood of reaching the Significant Decline Trigger in 2019-20 or 2020-21, initiate a review of potential Rapid Response Actions and initiate appropriate actions as outlined in the AMIP.

Please let me know if you concur with the approach. We will inform the RIOG of this event and share the results of our analysis under actions 1 and 2 above as soon as they are available.

Also, we note that several Rapid Response Actions identified in the AMIP, which are likely to increase abundance and productivity, or have the potential to do so, have already been implemented in recent years. First, in 2019 the Action Agencies implemented the flexible spill operation at the eight mainstem lower Snake and lower Columbia River Dams, generally increasing spill levels, which some hypothesize will reduce latent mortality and thereby improve productivity by 25 percent or more (see our 2019 CRSO biological opinion). Second, the transport start date was moved earlier beginning in 2018 (from May 1 to April 24) which increases the rate at which steelhead are transported. Because transported steelhead often return at higher rates than bypassed fish, this would be expected to increase adult steelhead returns (see 2019 CRSO biological opinion). Lastly, harvest managers curtailed recreational steelhead fisheries in 2019 beyond what was required by the sliding scale harvest agreement.

Please contact Ritchie Graves of my staff if you have any questions.

Sincerely,

Barry A. Thom
Regional Administrator

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[2] An Early Warning Indicator: This indicator will alert NOAA Fisheries and the Action Agencies to a decline in a species' abundance level for natural-origin adults that warrants further scrutiny because it indicates that a Significant Decline (see below) may be reached in one to two years. The indicator for each species will be a running four-year mean of adult abundances that falls below a 20% likelihood of occurrence.

Within 120 days of NOAA Fisheries' determining that the Early Warning Indicator abundance levels have been observed, the Action Agencies, in coordination with NOAA Fisheries, the RIOG, and other regional parties will determine whether the species in question is likely to decline to a level that will trip the Significant Decline Trigger. This evaluation will be based on additional indicators and predictors of status (e.g., jack counts, ocean conditions, and habitat disturbances). If the early implementation of Rapid Response Action(s) is warranted, the evaluation will determine which actions to take. The Action Agencies will implement the Rapid Response Actions as soon as practicable, but no later than 12 months from the date the indicator is observed. [2009 AMIP, p. 12]

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Management and Conservation Article

White-Headed Woodpecker Nesting Ecology After Wildfire

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ABSTRACT Within forests susceptible to wildfire and insect infestations, land managers need to balance dead tree removal and habitat requirements for wildlife species associated with snags. We used Mahalanobis distance methods to develop predictive models of white-headed woodpecker (*Picoides albolarvatus*) nesting habitat in postfire ponderosa pine (*Pinus ponderosa*)-dominated landscapes on the Fremont-Winema National Forests in south central Oregon, USA. The 1-km radius (314 ha) surrounding 45 nest sites was open-canopied before fire and a mosaic of burn severities after wildfire. The 1-ha surrounding nests of white-headed woodpeckers had fewer live trees per hectare and more decayed and larger diameter snags than at non-nest sites. The leading cause of nest failure seemed to be predation. Habitat and abiotic features were not associated with nest survival. High daily survival rates and little variation within habitat features among nest locations suggest white-headed woodpeckers were consistently selecting high suitability habitats. Management activities that open the forest canopy and create conditions conducive to a mosaic burn pattern will probably provide suitable white-headed woodpecker nesting habitat after wildfire. When making postfire salvage logging decisions, we suggest that retention of larger, more decayed snags will provide nesting habitat in recently burned forests.

KEY WORDS habitat suitability model, Mahalanobis distance, nest-site selection, nest survival, ponderosa pine, snags, white-headed woodpecker, wildfire.

Wildfire is the dominant natural disturbance in forested landscapes of western North America. Fire regimes, which characterize the frequency and severity of naturally occurring wildfire, vary by vegetation type, latitude, and elevation (Agee 1993, Schoennagel et al. 2004). Mixed-severity regimes that include surface and stand-replacing fires characterize higher latitude, more mesic ponderosa pine (*Pinus ponderosa*) forests (Schoennagel et al. 2004). Decades of fire suppression, logging, and grazing have increased fuel accumulation and altered fire regimes in drier forests resulting in more frequent and larger high-severity fires (Covington and Moore 1994, Fulé et al. 2002, Noss et al. 2006). Climate also has played a major role in altering the size, frequency, and severity of wildfire across forest types (Schoennagel et al. 2004).

In addition to tree mortality caused by wildfire, increases in tree mortality from bark beetle (*Dendroctonus* spp.) infestations are anticipated as a result of changing climates (Logan et al. 2003). Increased tree mortality from fire and insects will create more opportunities for salvage logging. Salvage logging removes dead, dying, damaged, or weakened trees that provide nesting and foraging habitat for woodpeckers and other cavity-nesting species (Saab et al. 2002, 2007; Hutto and Gallo 2006). Thus, land managers face challenges implementing fire management policies, while concurrently meeting the requirements of existing laws to maintain wildlife habitat for species associated with dead trees.

The white-headed woodpecker (*Picoides albolarvatus*) is listed as a sensitive or critical species by the United States Forest Service and by the states of Oregon, Idaho, and Washington, USA (Garrett et al. 1996). In addition, the white-headed woodpecker is listed as a Continental Watch-list Species in the North American Landbird Conservation Plan (Rich et al. 2004). It is considered unique from other woodpecker species in its habitat use, seeming to be associated with burned landscapes despite its reliance on mature, cone-producing pines for foraging during winter (Raphael and White 1984). Large, decayed ponderosa pine snags are frequently used as nesting sites by cavity-nesting birds after prescribed fire (Bagne et al. 2008). Habitat degradation, primarily due to conversion from pine- (*Pinus* spp.) to fir (*Abies* spp.)-dominated forests and removal of snags, has contributed to population declines of white-headed woodpeckers (Garrett et al. 1996). As such, management decisions before and after wildfire may influence nesting habitat suitability and quality for this cavity-nesting species. Despite the influence of forest management on their populations, little is known about habitat associations in postwildfire forests (but see Raphael and White 1984). Information on nest survival after wildfire, in particular, seems to be lacking from the literature.

Our goal was to evaluate white-headed woodpecker nesting ecology in postfire landscapes and to provide decision support tools to guide management of white-headed woodpecker habitat. Models based solely on

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Table 1. Characteristics of white-headed woodpecker nesting areas and postfire landscapes with eigenvector scores from partitioned Mahalanobis distance (D^2) models in postfire landscapes on the Fremont-Winema National Forests, Oregon, USA, 2003–2007.

				Nesting habitat		Postfire landscapes		
Variable	Class	Scale	Description	$\bar{x}$	SD	$\bar{x}$	SD	Eigenvector values for partitioned D^2
Cover class	Prefire	Landscape[a]	% of landscape with >40% canopy cover	29.2	6.5	25.7	11.8	0.21
Quadratic mean diam	Prefire	Nest site[b]	Average of quadratic mean diam (cm) of live trees	29.2	6.5	31.8	6.1	0.02
Differential normalized burn ratio (ΔNBR)	Postfire	Landscape[a]	% of landscape with moderate to high burn severity (>270 ΔNBR)	38.0	13.8	31.0	16.5	0.73
Interspersion and juxtaposition index of ΔNBR	Postfire	Landscape[a]	Measure of patch adjacency using unburned, low, and moderate to high severity categories. No. close to zero indicate uneven patch adjacency and no. close to 100 indicate equal patch adjacency	45.4	13.3	54.6	15.6	0.65

[a] A 1-km radius around nest-site.

[b] A 1-ha plot centered on nest-site.

remotely sensed data can predict potential woodpecker habitat over larger areas (Russell et al. 2007). However, field-collected data are useful for refining potential habitat by identifying specific features important for nesting sites. Our objectives were to 1) develop landscape-scale habitat suitability models for white-headed woodpeckers that can be used to predict potential nesting habitat after wildfire, 2) identify specific features important for nest-site selection after wildfire, and 3) determine whether habitat features important for nest selection also influence nest survival.

STUDY AREA

The Toolbox and Silver fires on the Fremont-Winema National Forests in south central Oregon, USA, burned approximately 34,398 ha in 2002 between 1,500 m and 1,800 m in elevation (42°57′N, 121°0′W). Both fires were mixed-severity, stand-replacing fires typical of current-condition forests and resulted in a mosaic of burned patches across the landscape. More than 90% of the burned area was dominated by ponderosa pine (Landscape Ecology, Modeling, Mapping, and Analysis [LEMMA] 2008); other conifer species present included lodgepole pine (*Pinus contorta*) and white fir (*Abies concolor*). Land ownership within the fire boundaries included private, state, Bureau of Land Management, and United States Forest Service. Timber harvest and livestock grazing were prevalent on the forest landscape prior to the Silver and Toolbox fires. We searched for white-headed woodpeckers within 12 study units that ranged from 24 ha to 111 ha (60.2 ± 8.4; $\bar{x}$ ± SD) within the burned area of Fremont-Winema National Forests; the total area we surveyed annually was approximately 840 ha.

METHODS

Nest Surveys

Fremont-Winema National Forests selected survey units within burn areas by using remotely sensed vegetation characteristics and burn severity to include areas of high snag densities suitable for tree harvest and potentially suitable habitat for local woodpeckers based on previous research (Saab et al. 2009). We located white-headed woodpecker nests by using systematic searching and playback surveys along belt transects (0.4 × 1.0 km) distributed systematically to cover entire survey units (Dudley and Saab 2003). We surveyed all transects in all units once a year during May and early June 2003–2007, in calm, dry weather conditions. Survey effort (hr) was similar among years. Playback surveys consisted of 30 seconds of woodpecker (*Picoides* spp.) calling and drumming followed by 30 seconds of silence, repeated 3 times every 200 m along the transect line. We observed detected birds to locate cavities and considered a nest cavity occupied if it contained eggs or young.

We monitored nests by using an electronic camera mounted to a telescoping pole (TreeTop II; Sandpiper Technologies, Inc., Manteca, CA) at 3–4-day intervals. At each visit, we recorded reproductive data, including time, date, nest stage, and number of eggs or young until the nest failed or fledged ≥1 young. We determined nest fate as successful if we observed the cavity empty after the expected fledging date, there was no sign of depredation in or around the nest tree, and previous nest visits had shown the nestlings to be exhibiting prefledging signs (e.g., large size, advanced feather development, adult-like vocalizations, and head protruding from cavity entrance). We assumed cause of nest failure was predation if the nest showed signs of depredation or was empty before estimated fledging dates for that nest. We assumed cause of failure as abandoned if we found dead nestlings in the nest cavity.

Remotely Sensed Forest Characteristics

Habitat conditions before fire may influence woodpecker distributions in postfire landscapes because prefire conditions may function as an index to postfire snag densities and diameters (Saab et al. 2002, Russell et al. 2007, Vierling et al. 2008). Therefore, we used remotely sensed data from pre- and postfire coverages to assess forest variables that we assumed represented white-headed woodpecker habitat requirements at nest-sites (1 ha) and within a 1-km radius (314 ha) of nests (Table 1). We defined landscape nesting habitat as the area within a 1-km radius of a nest site because this area corresponds with the home range of many woodpecker species, including white-headed woodpeckers (Dixon 1995*a, b*; Saab et al. 2004).

To estimate prefire conditions, we acquired Gradient Nearest Neighbor (GNN) forest vegetation data for east Cascades, southern Oregon (Ohmann and Gregory 2002, LEMMA 2008). Gradient Nearest Neighbor is a predictive mapping product that provides spatially explicit species composition and forest structure data in a digital landscape map. Accuracy assessments of the GNN resulted in a 0.75 and 0.46 correlation coefficient for canopy cover and quadratic mean diameter, respectively, indicating that the GNN layer had moderate predictive ability (LEMMA 2008). We eliminated remnant forests (<10% canopy closure) and sapling–pole forests (<25-cm quadratic mean diam) from the GNN data to generate a layer of potential white-headed woodpecker habitat. We then reclassified these GNN data into open forests (10–40% canopy cover) and moderate- to high-cover forests (>40% canopy cover). We calculated the percentage of moderate- to high-cover forest within 1 km of each nest. We also used GNN data to calculate an average quadratic mean diameter of conifers near (1 ha) nest-sites.

To characterize postfire conditions, we obtained burn severity data from the United States Forest Service Remote Sensing Applications Center. We calculated burn severity as the change in the normalized burn ratio (ΔNBR) between pre- and postfire Landsat Thematic Mapper images (Cocke et al. 2005, Key and Benson 2006). We reclassified ΔNBR scores as unburned (−900 to 99), low-severity (100–269), and moderate- to high-severity (>270) burns and calculated the percentage of moderate- to high-severity burn within 1 km surrounding each nest (Key and Benson 2006, Russell et al. 2006). Using Program FRAGSTATS (McGarigal and Marks 1995), we also calculated an interspersion and juxtaposition index that describes the landscape configuration of burn severity patches by measuring the intermixing of patches based on the relative proportion of edges between patch types (i.e., unburned, low, or moderate-high severity). Interspersion and juxtaposition index values close to zero indicate unequal adjacency among patches or a landscape where size, shape, and distribution of patch types vary widely. Values closer to 100 indicate equal adjacency among patches or a landscape that contains similar sizes, shapes, and distribution of patch types. Intermediate values represent a mosaic of patches that vary somewhat in size, shape, or distribution. Resolution of all geographic data was 30 m.

Habitat Suitability Model

We used locations of 45 white-headed woodpecker nests to model characteristics of nesting habitat by using partitioned Mahalanobis distance (D^2; Browning et al. 2005, Rotenberry et al. 2006). We selected this technique because D^2 consistently performed better than other competing models for modeling presence-only data (Farber and Kadmon 2003, Tsoar et al. 2007). Conceptually, D^2 compares the similarity between each known nesting area and ideal nesting habitat conditions (Farber and Kadmon 2003). Ideal conditions are calculated as mean values for all variables selected from all occupied nest locations and assume the sample reflects optimal habitat distribution of the species in the sampled area (Rotenberry et al. 2006). Because uncertainty exists in defining optimum conditions for white-headed woodpeckers, we partitioned D^2 into separate components to identify a minimum, rather than optimum, set of habitat requirements for occupancy. We selected variables included in modeling minimum habitat requirements from features identified as important for woodpeckers in previous research (Saab et al. 2009). We restricted our observation to variable ratio to 10:1 (Rotenberry et al. 2006). We performed a principal components (PC) analysis on the 4 selected habitat variables and partitioned D^2 following Browning et al. (2005) and Rotenberry et al. (2006). We selected the partition associated with the PC axis with the smallest eigenvalue, because that value represents the combination of variables that best explains the minimum consistent relationships in white-headed woodpecker nesting distribution. We evaluated eigenvector values associated with the selected PC axis to identify habitat characteristics important for describing white-headed woodpecker habitat.

Using the partitioned model, we calculated D^2 for each pixel in the Silver and Toolbox fires to produce a habitat suitability map. From the D^2 values, we calculated a p-value, which is an index to habitat similarity and is analogous to the probability of nesting occupancy from a logistic regression but should not be interpreted for statistical inference (Rotenberry et al. 2006). We assigned each pixel in the study area a habitat similarity index score based on how similar the habitat features were to white-headed woodpecker nesting features. Scores were relative; higher numbers indicated greater similarity to white-headed woodpecker habitat. Managers may choose a threshold value to identify suitable nesting habitat for focusing management. In this context, values at or above the threshold represent potential white-headed woodpecker habitat. We identified a useful threshold for management as the maximized predictive gain obtained by selecting the similarity index that represented the greatest number of nesting sites in the smallest geographic area (Browning et al. 2005). However, we provide habitat similarity values in intervals of 0.10 so that other thresholds can be selected depending on management objectives.

To assess our model, we used a jackknife procedure for resampling that holds out one observation at a time and reruns the analysis for all observations in the data set. The removed observation is then scored by the model from which it was excluded. We assessed the mean similarity index assigned to all observations when excluded from model building to determine whether any of our data points were unduly influencing our model (Browning et al. 2005). We used Program SAS for all analyses (SAS Institute, Cary, NC) and used the code provided by Rotenberry et al. (2006) to calculate D^2 and associated similarity index values.

Nest-Site Selection

We generated random non-nest points within survey units using a Geographic Information System and random point generator. We proportionally distributed within-year ran-

Table 2. Candidate models and selection results of habitat features at the nest-site scale (1 ha) influencing nest-site selection of white-headed woodpeckers on the Fremont-Winema National Forests, Oregon, USA, 2003–2007.

Model	$-2\log(L)$	K[a]	AIC$_c$[b]	ΔAIC$_c$[c]	w_i[d]
Live trees/ha, decay	139.32	3	145.64	0.00	0.50
Live trees/ha, decay, nest tree dbh	137.23	4	145.71	0.07	0.48
Live trees/ha, nest tree dbh	145.95	3	152.26	6.63	0.02
Snags/ha, decay	155.41	3	161.73	16.09	0.00
Snags/ha, decay, nest tree dbh	153.83	4	162.30	16.67	0.00
Canopy cover, nest tree dbh	164.43	3	170.74	25.11	0.00
Canopy cover, nest tree dbh, snags/ha	162.85	4	171.33	25.69	0.00
Snags/ha, nest tree dbh	165.08	3	171.39	25.75	0.00
Intercept only	169.39	1	171.49	25.85	0.00
Canopy cover, snags/ha	165.87	3	172.18	26.55	0.00

[a] No. of model parameters.

[b] Akaike's Information Criterion with a second order correction for small sample sizes.

[c] AIC$_c$ differences, or the difference in AIC$_c$ values between model i and the model with the lowest AIC$_c$ value.

[d] Akaike wt, or the wt of evidence in favor of model i being the best model among the models in the set.

dom points across units based on unit size and points were located >100 m apart to prevent overlapping vegetation plots. We selected the nearest available tree to the randomly generated point (snag or live tree $\geq$15 cm dbh) as the focal tree and centered in the vegetation plot. We measured habitat characteristics in the field at 45 white-headed woodpecker nests and 87 randomly selected non-nest locations. We calculated mean diameter at breast height of the nest or non-nest snag. We calculated density of snags and live trees ($\geq$23 cm dbh and >1.37 m in ht for snags and trees) per hectare after wildfire from 2 intersecting 100-m belt transects centered on the nest or non-nest snag (Appendix A). We defined snags as having no green needles. We also recorded the decay class (1–4) of nest or non-nest center trees where higher numbers equated to more decay (Bull et al. 1997). Using a 3 × 3-pixel (0.81-ha) moving window, we calculated the average quadratic mean diameter and prefire canopy cover from GNN data for nest and non-nest locations (Appendix A).

To identify site-based features important for nest-site selection, we used logistic regression to compare field-collected data from nest and non-nest locations (Hosmer and Lemeshow 2000). We identified a set of a priori candidate models based on species habitat requirements from the literature (Table 2). We used Akaike's Information Criterion with a second order correction for small sample sizes (AIC$_c$) to select the most parsimonious model and considered all models with ΔAIC$_c$ values <2.0 as having strong support for the data (Burnham and Anderson 2002). We calculated Akaike weights (w_i) to quantify support for individual models in relation to the other models in the set. Because there was more than one model with strong support for the data, we averaged estimates across models weighted by w_i (Burnham and Anderson 2002).

We assessed receiver operating characteristic (ROC) curves to evaluate the ability of our averaged nest-site selection model to distinguish between nests and non-nest locations. Receiver operating characteristic curves evaluate the relationship between true positives (correctly classified nests) and false positives (non-nests classified as nests) at different probability of nest occupancy thresholds. The area under the ROC curve (AUC) is an index to the discriminatory power of the model (Swets 1988, Russell et al. 2007). An AUC value of 0.5 indicates no discrimination and an AUC value of 1.0 indicates perfect discrimination; in general, AUC values >0.7 reflect moderately good accuracy of the model (Swets 1988).

Nest Survival

We modeled nest survival as a function of abiotic and biotic covariates. To assess abiotic factors related to nest survival, we obtained precipitation and temperature data from the Silver Creek Snowpack Telemetry station (Natural Resources Conservation Service 2008). We recorded precipitation as the cumulative yearly precipitation on the end date for each nest visit interval. We recorded temperature as the maximum temperature for each nest visit interval. We also evaluated the influence of year and nest age on nest survival where nest age was the number of days after nest initiation. We measured biotic factors at the nest site (dbh, decay and ht of nest snag, and densities of snags and trees) and landscape scales (percentage of canopy cover $\geq$40% from GNN data and % of moderate to high burn severity from ΔNBR data).

We used generalized nonlinear mixed models to evaluate the influence of fixed and random factors on nest survival, which allowed us to calculate a daily survival rate as a function of several covariates (Dinsmore et al. 2002, Rotella et al. 2004, Shaffer 2004). We used PROC GENMOD in SAS (SAS Institute), following code provided in Rotella et al. (2004, appendix 3), for nest survival analysis. We evaluated 5 models of nest survival based on hypotheses about the influence of biotic and abiotic factors (Table 3). We used AIC$_c$ to select the most parsimonious model and considered the model with ΔAIC$_c$ values <2.0 as having the strongest support for the data (Burnham and Anderson 2002). We calculated w_i to quantify support for individual models in relation to the other models in the set.

RESULTS

Eigenvalues for the first 3 PCs accounted for approximately 88% of variation in the data set (Table 4). For D^2 modeling, we used the last axis, PC4, which represented minimum

Table 3. Candidate models and supporting hypotheses comparing random, biotic, or abiotic influences on nest survival of white-headed woodpeckers on the Fremont-Winema National Forests, Oregon, USA, 2003–2007.

Model	Variable	Alternative hypothesis
Random	Intercept only	Nest survival is random; probably due to random predation events.
Abiotic and temporal	Precipitation, temp, yr, season date, nest age	There is more variation at nest sites in abiotic factors than nest characteristics; thus, abiotic factors may have the strongest influence on nest survival.
Fine scale	Snag dbh, snag decay, tree densities, nest ht	Factors influencing nest selection will be consistent with those influencing nest survival. Physical features may provide greater protection from predators.
Coarse scale	% canopy cover class, % ΔNBR[a], IJ NBR[b]	Factors associated with nest occupancy will be consistent with those associated with nest survival. A mosaic of burn severities and open-canopied forests will provide diverse foraging options.
Combination	Precipitation, temp, nest ht, IJ NBR[b]	Higher temp, lower precipitation, higher nests, and a landscape mosaic of burn severities may increase nest survival because of good environmental conditions, protection from predators, and diverse foraging options.

[a] Differential normalized burn ratio. We reclassified ΔNBR scores as unburned (−900 to 99), low-severity (100–269), and moderate- to high-severity (>270) burns and calculated the percentage of moderate- to high-severity burn within 1 km surrounding each nest.

[b] Interspersion and juxtaposition index that describes the landscape configuration of burn severity patches by measuring the intermixing of patches based on the relative proportion of edges between patch types (i.e., unburned, low, or moderate-high severity).

habitat requirements for white-headed woodpeckers. Evaluation of the eigenvector values associated with PC4 indicated that the percent moderate to high burn severity, interspersion and juxtaposition of burn severities (patch adjacency), and percent moderate to high canopy cover before wildfire best described the similarities within 1 km of nests (Table 1). The quadratic mean diameter of prefire, live trees at the nest-site scale (1 ha) was not a good descriptor of white-headed woodpecker habitat. Specifically, white-headed woodpecker habitat was characterized by approximately 37% of the landscape as moderate to high burn severity, moderate levels of burn patch adjacency (interspersion and juxtaposition [IJ] index = 45), and approximately 30% of the landscape with ≥40% canopy cover prefire. The IJ value indicated that patches of different burn severities were typically intermixed with each other rather than occupying a few large areas.

Using our partitioned model, mean similarity index score was 0.50 ± 0.25 (SD; range <0.001–0.88) for known nest areas and 0.43 ± 0.32 (range 0.00–0.99) for postfire landscapes. Although we would expect all known nests to have high similarity scores, in fact, D^2 values are affected by the sampling variance. Thus, nest sites distant from the mean will have lower values (Rotenberry et al. 2006). Application of our model to the area of the Toolbox and Silver fires identified areas of similarity to white-headed woodpecker nest sites (Fig. 1). Based on a similarity index threshold of 0.29, which maximized the number of known nests in the smallest geographic area (Fig. 2), 82% of occupied sites had an index score of ≥0.29, whereas only 61% of the study area was in this same range. The jackknife procedure of leave one out for model assessment produced a mean habitat similarity index of 0.45 ± 0.26. Less than half of the study area (46%) had index values at or above this average. When excluded from analysis, 76% of nest sites had a similarity index greater than our probability threshold of 0.29.

Table 4. Eigenvalues and associated proportion of variance of the correlation matrix from principle components analysis of characteristics describing white-headed woodpecker nesting habitat on the Fremont-Winema National Forests, Oregon, USA, 2003–2007.

Partition	Eigenvalue	Proportion
4	0.48	0.12
3	0.76	0.19
2	1.10	0.27
1	1.65	0.42

There was strong support for 2 models and minimal support for a third model of nest selection (Table 2). The averaged model for predicting nest site selection by white-headed woodpeckers included the variables density of live trees postfire ($\beta = -0.03$, CI = −0.05 to −0.01), decay class ($\beta = 1.00$, CI = 0.28–1.73), and diameter at breast height of nest trees ($\beta = 0.02$, CI = 0.0004–0.04). Specifically, the relative probability of nest selection increased as the number of live trees decreased and the snag decay class and nest tree diameter at breast height increased. Nest sites had a higher proportion of snags with decay class 3 than did non-nest sites (Appendix B). We found no relationship of nest selection with snag density or prefire canopy closure. An AUC value of 0.77 for our model of nest selection indicated it had moderately good discriminatory power.

Only 16% of monitored nests failed to fledge young, with ≥67% assumed to have failed due to predation. Daily survival rate was high (0.993), resulting in nest success of 0.76 over a presumed 40-day nesting period. The best model among the candidate models for evaluating nest survival ($\Delta AIC_c < 2.0$) was the intercept-only model (Table 5), which indicates that none of the combinations of abiotic or habitat features we considered explained patterns in nest survival better than random.

DISCUSSION

Open-canopied ponderosa pine forests before fire and a mosaic of burn severities within 1 km of nests characterized white-headed woodpecker nest sites in postfire areas on the Fremont-Winema National Forests. Larger, more decayed snags and fewer live trees near (within 1 ha) a snag after fire were important for selection of nest sites. Even so, none of these features seemed to influence nest survival. Relatively high daily survival rates compared with other cavity-nesting birds (Saab et al. 2007) and little variation within habitat features among nest locations suggest white-headed wood-

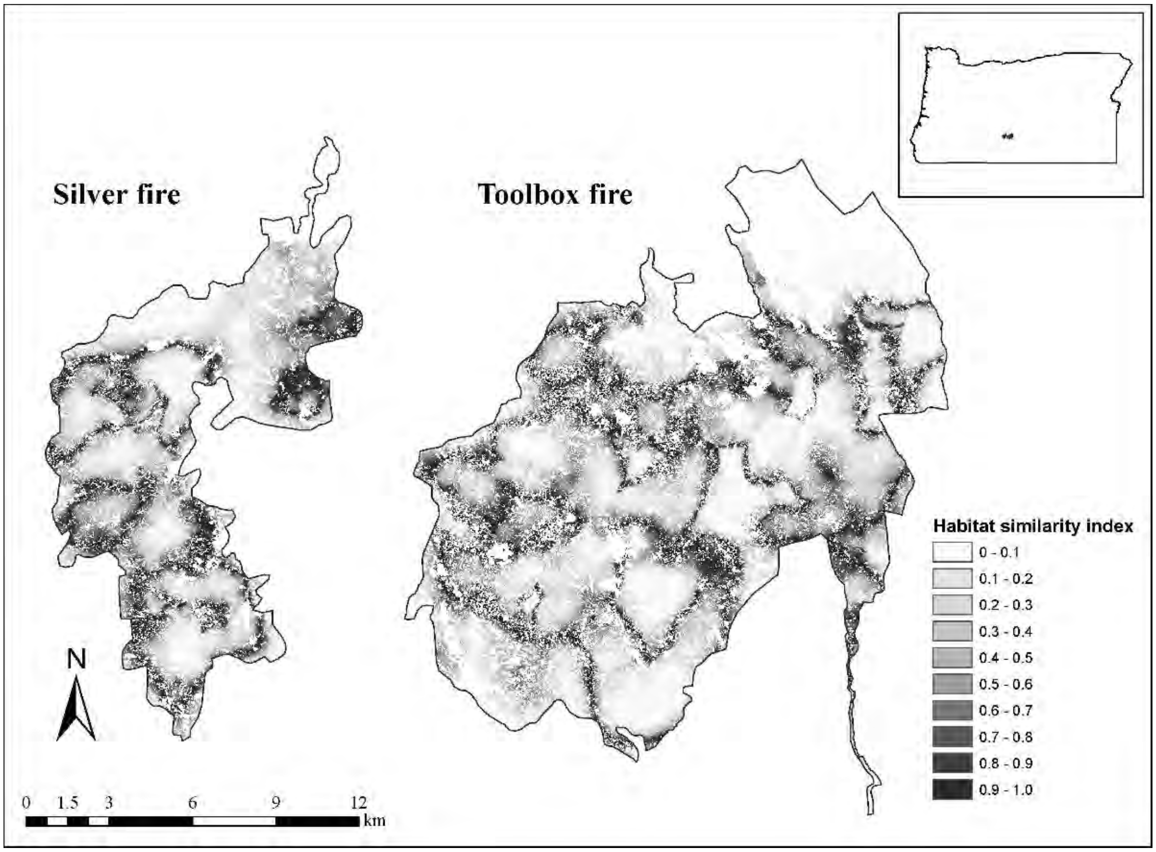

Figure 1. Partitioned habitat suitability model for white-headed woodpeckers on the Toolbox and Silver fires, Fremont-Winema National Forests, Oregon, USA, 2003–2007. The habitat similarity index represents similarity on an increasing 0–1 scale, with 1 representing environmental conditions identical to the mean conditions surrounding 45 white-headed woodpecker nests. We eliminated white areas from consideration because they did not represent potential white-headed woodpecker habitat (forest with <10% canopy closure or trees <25 cm quadratic mean diam). Curvilinear patterns in the map are an artifact of the interspersion and juxtaposition index related to areas of relative patch (burn intensity) homogeneity.

peckers were consistently selecting high suitability habitats. White-headed woodpeckers are typically found in open-canopied pine forests with mature, cone-producing trees that white-headed woodpeckers rely on during winter (Milne and Hejl 1989, Garrett et al. 1996). Our models suggest that these characteristics probably remain important for identifying white-headed woodpecker habitat after wildfire, as long as most of the landscape was not subjected to a stand replacing burn. A mosaic of burn severities across the landscape may, in fact, improve white-headed woodpecker habitat by opening forest canopies in the higher-severity burn areas, while retaining decayed snags created before wildfire and live, cone-producing trees in unburned or low-severity burn areas.

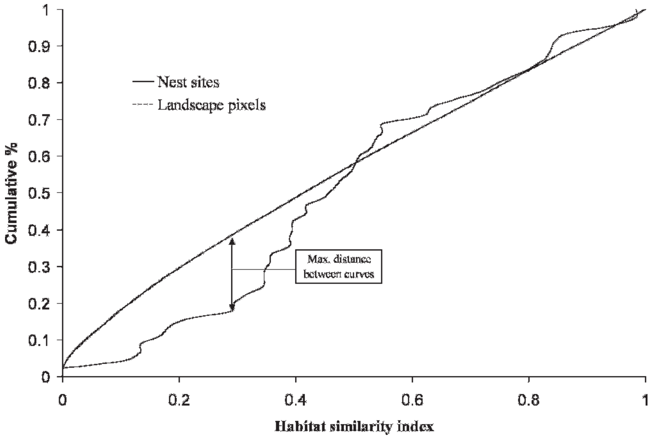

Figure 2. Habitat similarity index for white-headed woodpeckers based on 45 nest locations (within a 1-km radius of nest trees) compared with burned landscapes on the Toolbox and Silver fires on the Fremont-Winema National Forests, Oregon, USA. A similarity index of 0.29 maximizes the predictive gain (i.e., max. distance between curves) of our white-headed woodpecker habitat model in postfire landscapes and represents the greatest number of known nesting sites across the smallest portion of the landscape.

Using the Mahalanobis distance technique allowed us to identify areas that were most similar to known white-headed woodpecker nesting areas; however, it does not imply biological significance of the features considered. For example, although white-headed woodpeckers are typically found in stands with large trees, our measure of live tree diameter (QMD) was not a good descriptor for modeling white-headed woodpecker habitat (Milne and Hejl 1989, Dixon 1995*a*). There may have been considerable variation in QMD within and among nest sites resulting from the spatial distribution of large trees. In addition, we had less confidence associated with QMD values within the GNN data, suggesting that this structural forest feature may be difficult to measure remotely (LEMMA 2008).

Our D^2 model and habitat similarity index may be useful as a remote-sensing tool for targeting management or

Table 5. Model results of white-headed woodpecker nest survival from 45 nests and 313 intervals on the Fremont-Winema National Forests, Oregon, USA, 2003–2007.

Model	K^a	$-2\log(L)$	$AIC_c{}^b$	$\Delta AIC_c{}^c$	$w_i{}^d$
Intercept only (null)	1	67.38	69.38	0.00	0.76
Abiotic and temporal	5	62.94	73.00	3.61	0.12
Coarse scale	4	66.64	74.68	5.29	0.05
Combination	5	64.74	74.80	5.41	0.05
Fine scale	5	67.09	77.15	7.77	0.02

[a] No. of model parameters.

[b] Akaike's Information Criterion with a second order correction for small sample sizes.

[c] AIC_c differences, or the difference in AIC_c values between model *i* and the model with the lowest AIC_c value.

[d] Akaike wt, or the wt of evidence in favor of model *i* being the best model among the models in the set.

white-headed woodpecker surveying activities in postfire landscapes. Managers may choose to use our similarity threshold of 0.29, which maximizes potential habitat within the smallest geographic range, or adjust this threshold based on management objectives. For example, if a management goal is to identify only those areas considered highly suitable for white-headed woodpecker nest occupancy, a higher similarity index threshold of 0.5 (representing 42% of the study area) or 0.7 (21% of the study area) could be used. Model assessment indicated that none of the known nests unduly influenced the model but, depending on the threshold selected, a large portion of the study area might be classified as suitable habitat. Because our model was not validated in other postfire landscapes, we recommend field-testing the model before using it to guide management decisions.

We recommend focusing surveys for white-headed woodpeckers on areas with fewer live trees within 1 ha and larger, more decayed snags, based on the good discriminatory power of our nest-site selection model. Although the size of snags selected by white-headed woodpeckers may vary locally based on availability, in unburned areas of the Winema National Forest, mean diameter at breast height of nest trees was 80 cm, which was at the upper range of availability on our study area (Dixon 1995*b*). Thus, we recommend management for white-headed woodpeckers focus on larger snags within any given area.

Although snag density is often an important feature for cavity-nesting birds (Russell et al. 2007), our results and those of others (Saab and Dudley 1998, Bagne et al. 2008) indicate white-headed woodpeckers may rely more on decay condition than density of snags. Snags created by fire have lower retention rates than trees killed more slowly by insect or disease and fire-killed snags may not reach levels of decay favored by white-headed woodpeckers until 2–3 years postfire (Lowell and Cahill 1996, Russell et al. 2006). Concurrently, 4–6 years postfire, other benefits of fire to cavity-nesting birds, such as changes to forest structure, invertebrate availability, and predator communities, decline (Covert-Bratland et al. 2006, Saab et al. 2007). Therefore, snags existing before wildfire, if retained, or those with more advanced decay seem to be critical habitat components in postfire landscapes, especially in the first few years after fire.

Our search area was primarily in high-severity burn areas; thus, almost all nesting and random sites were in high-severity burned patches. Nests tended to have fewer live trees per hectare at the nest-site scale than random. In fact, 79% of our nesting sites had no live trees ($\geq$23 cm dbh) in the nest-site vegetation plot, which suggests white-headed woodpeckers tended to select nest snags $\geq$50 m from the unburned or low intensity burned areas that contain live trees. Forests with live trees tend to have more abundant and complex predator assemblages than do high-severity burned areas (Saab and Vierling 2001). For example, golden-mantled ground squirrels (*Spermophilus lateralis*) and yellow-pine chipmunks (*Neotamias amoenus*) are known predators on white-headed woodpecker nests (R. W. Frenzel, Deschutes National Forest, unpublished data). Golden-mantled ground squirrel densities are positively related to down wood volume, and yellow-pine chipmunk densities are positively related to shrub cover (Smith and Maguire 2004). Both wood volume and shrub cover are less in postfire habitats. Thus, nest placement in high-severity burned areas may be a viable strategy to reduce nest predation, as long as unburned or low-severity burned areas are available within the landscape for foraging.

Nest-site selection is probably adaptive such that a species will select habitat features conducive to successful nesting attempts, and we found little variation within selected habitat features at nest sites (Clark and Shutler 1999). Thus, it is not surprising that we failed to identify biotic factors influencing nest survival of white-headed woodpeckers. Predation seemed to be the leading cause of nest failure on our study area. Assuming a relationship between habitat features and predator communities, we would expect nest-site selection choices to influence nest survival. Our results, however, suggest predation was opportunistic. Our daily nest survival rate of 0.993 was high compared with other cavity-nesting birds (range 0.980–0.998; Saab et al. 2007), and our period survival rate of 0.76 was higher than nest success reported for white-headed woodpeckers in unburned forests of central Oregon (range 39.3–60.8; R. W. Frenzel, unpublished data). High survival rates regardless of physical or environmental factors suggest white-headed woodpeckers were occupying high-quality nesting sites.

MANAGEMENT IMPLICATIONS

Selective thinning and prescribed fire are often used in drier ponderosa pine forests of the southwestern United States to open forest canopies and reduce fuel loads for restoration of low-intensity fire regimes (Finney 2001, Fulé et al. 2001). Managing for mixed-severity fire regimes characteristic of more mesic, higher latitude ponderosa pine forests is more complicated and often dependent on climatic variation (Schoennagel et al. 2004). Our results indicate that prefire management activities that open forest canopies and create forest conditions conducive to a mosaic burn pattern by wildfire may encourage white-headed woodpecker nest occupation. Where white-headed woodpecker habitat is a management priority, we recommend opening of the forest canopy within stands containing medium- and larger diameter (>23 cm dbh) mature trees and snags.

To retain wildlife habitat during postfire salvage logging, forest managers historically have used guidelines based on snag distributions and densities. However, this approach has been criticized for failing to capture other wildlife habitat requirements such as snag composition (Bagne et al. 2008). Our results support consideration of snag characteristics when managing for wildlife habitat features after fire. Features of snags important to woodpeckers include larger diameters and more advanced decay. We recommend retention of snags created before wildfire, because these snags are probably of more value to white-headed woodpeckers in the early years after fire than are snags created after wildfire.

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Appendix A. Summary statistics of linear habitat features used in nest site selection analysis of white-headed woodpecker at 45 nest sites (Used) and 87 non-nest sites (Random) on the Fremont-Winema National Forests, Oregon, USA, 2003–2007. All features are at the nest-site scale (1 ha).

	Used			Random		
Variable	$\bar{x}$	SE	Range	$\bar{x}$	SE	Range
Snags/ha	102.6	8.4	15–250	89.9	6.0	16–229
Nest tree dbh	40.1	2.7	18–80	34.1	2.1	15–95
Trees/ha	6.3	2.3	0–83	32.0	4.4	0–171
Prefire canopy cover (%)	39.4	1.4	22–66	42.3	1.3	1–75

Appendix B. Decay class statistics and descriptions for 45 nest trees (Used) of white-headed woodpeckers and 87 random trees (Random) on the Fremont-Winema National Forests, Oregon, USA, 2003–2007.

Decay class	Used	Random	Description
1	31	78	Snags that recently died, typically had little decay, and retained their bark, branches, and top
2	4	8	Snags with some evidence of decay and had lost some bark, branches, and often a portion of the top
3	10	0	Snags that had extensive decay, were missing the bark and most of the branches, and had a broken top
4	0	1	Burnt snag; almost entire outer shell was case-hardened by fire; looked like charcoal