Overview Plan

(Updated: April 14, 2021)

T3 Watershed Experiment

(aka) Large-Scale Integrated Management Experiment
on the Olympic Experimental State Forest

An integrated, place-based study of ecosystem sustainability on the Olympic Peninsula

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Executive Summary

This document describes the broad overarching concepts behind a major new collaboration between two State of Washington institutions, the WA Department of Natural Resources (DNR) and the University of Washington (UW); also involving other academic and federal research agencies and diverse stakeholders. The collaboration, referred to most commonly as the T3 Watershed Experiment, has resulted in the creation of an 8000 ha (20,000 acre) study of 16 watersheds mainly in the Clearwater River drainage on the outer Washington Coast of the Olympic Peninsula and a new, broad ecosystem sustainability framework that links people (community) and their environment as elements of an ecosystem that are better considered as an interconnected whole. This framework underpins the design and interpretation of the study. An adaptive-management study of this kind is needed to evaluate how management of public forest lands can evolve to address societal needs in this unprecedented time of social, economic, and environmental change. The need for innovation and evidence-based learning to support changes cannot be understated. Learning and adaptation follow thoughtful analyses of changing conditions, current practice, and potential alternatives. We are also exploring better ways to engage with diverse stakeholders in an approach called learning-based collaboration. We believe that broadening who participates in learning through new collaborative approaches will help uncover innovative solutions and improve the future debate and decisions.

A sustainability-science framework is used to organize and implement an initial series of study modules focused on: (A) learning-based collaboration approach and application; (B) alternatives to current DNR riparian management; and (C) alternatives to current DNR upland management. More modules are in development at this time and will be added as funding and time permit, including study modules on social and economic measures and forest-management operational efficiency. A range of affiliated studies are described in this document which address specific response parameters; these components link this overarching study to other existing programs at UW and DNR and to independent, grant-funded efforts. This overview describes the four management strategies (suite of practices as experimental treatments at the watershed scale) to be compared in the T3 Watershed Experiment. Specifics on how each strategy will be applied in riparian and upland areas, and associated hypotheses and tests will be found in the formal study module plans with peer reviews. In general, strategies are based on current practice, no-action controls, and alternatives that seek to increase integration of revenue production with other environmental and community benefits that might be considered in the future. A series of learning workshops with stakeholders organized by Angie Thomson with EnviroIssues will follow. One strategy, “Alternative-2 inspired integration” is based on stakeholder inputs over the last 4 years and will have riparian and upland activities to be open to some revision based on input. The study is only possible because of: (1) DNR’s commitment to apply science-based adaptive management to continuously improve management of the working State forests; and (2) UW’s commitment to provide sustainability science and education to solve problems of utmost importance to Washington State’s residents.

Introduction

The concept of this study emerged from a collaborative effort initiated in 2015 between the Olympic Natural Resources Center (ONRC) of the University of Washington (UW) and the Washington Department of Natural Resources (DNR) and now involves other academic and federal research agencies and diverse stakeholders (Appendix 4). It was first described in a Study Proposal (Bormann and Minkova 2016), titled the "Large-scale integrated management experiment on the Olympic Experimental State Forest." We are now calling it the T3 Watershed Experiment.[1]

The study is centered on improving management of public forest land. The study compares the current DNR forest management strategy against a variety of potential alternative strategies on a large watershed-scale. It also compares a variety of within-strategy, upland and riparian silvicultural prescriptions at stand, reach, and sub-watershed catchment scales. Watersheds were provided by the DNR on the Olympic Experimental State Forest (OESF), which has an explicit objective for learning and experimenting with innovative silviculture to integrate multiple management objectives. Resources for the study largely come from the Washington State Legislature with additional grants and in-kind support of the participating organizations. Some alternative strategies may be applicable to other public and private ownerships. Alternative strategies were derived from far-ranging discussions with stakeholders, managers, and scientists, and are designed to address priorities of different constituencies, where stakeholders can see their ideas being tried as part of a study. The overall goal is to address this core question:

> *Will a higher sustainable level of both ecological and community wellbeing (including revenue for beneficiaries) emerge from an array of land management strategies implemented and compared across the OESF landscape?*

This broad goal creates the space to explore new ways to integrate disparate views of success through a scientific framework centered on ecosystem sustainability (Fig. 1), which is defined as the maintenance or improvement, largely through learning-based collaboration, of the co-equal and interdependent goals or community and environment wellbeing (see Glossary).

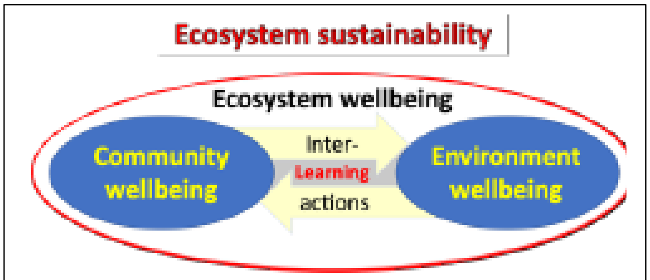

Figure 1. The ecosystem sustainability framework based on a co-equal focus on community and environment wellbeing, and on learning to guide innovation and adaptation (see Bormann et al. 2018).

We expect the ideas, observations and data emerging from the development and implementation of this study to improve the debate and decision making underlying continual improvement of management of DNR trust lands, as well

[1] T3 refers to Type-3 watershed, which Washington Department of Natural Resources classifies as the drainage above the outflow of the smallest class of fish-bearing streams (Type-3 streams).

as other public forest lands, including lands administered by the USDA Forest Service under the Northwest Forest Plan. The emphasis on learning and place-based community and environment wellbeing is integral to collaboration processes and foundations of trust among cooperators, and this is a core focus of the study in addition to providing evidence for decisions that also may have value beyond the Olympic Peninsula.

This overview document briefly describes the sustainability science and the broad watershed design that underlie the study plans for riparian and upland silviculture modules.

Ecosystem Sustainability Science

The study of ecosystem sustainability with traditional discipline-oriented science has been challenging given the breadth of goals, perspectives, disciplines, and supporting, provisioning, regulating, and cultural services involved (e.g., Kirchoff 2019). Simply moving traditional biophysical disciplines into an integrated ecosystem perspective has proven quite difficult due to the myriad of complex interactions that ensue. When ecosystem sustainability is broadened to include a human element, the task becomes even harder. A major problem is the goal of ecosystem sustainability, defined so broadly, seems to defy easy connection to an integrated set of knowledge pools (e.g., within and between biophysical and social science disciplines, and importantly science-based methods to provide new knowledge, especially about innovative, integrated solutions, appear limited). Science assessments have aided political and agency decisions (e.g., FEMAT 1993). Integrative social-ecological systems research has been expanding, especially with modeling[2]. Status and trends monitoring do occur for some management plans (e.g. Northwest Forest Plan, Washington Forest Practices Habitat Conservation Plan, Washington State Trust Lands Habitat Conservation Plan), but does not evaluate innovative solutions because it is only applied to current practices[3]. Traditional field trials have most often been focused on current practices and have been increasingly rare in the Pacific Northwest[4]. Further, these trials mostly evaluate strategy outcomes against the previously articulated goals of the current management plan[5]. We argue, that operational field trials based on sustainability science can provide a way to develop and expose innovative practice, and focus experimentation at broader, socio-economic-political scales.

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[2] Integrative efforts have emerged, such as coupled human-environmental systems research (Ostrom 2009). These studies most often help identify system elements and interactions and lead to studies that compare modeled outcomes, useful for assessments supporting decisionmaking. Sometimes, these modeling efforts include small stakeholder groups that can bring in values perspectives (scenario planning; e.g., Rawluk et al. 2018) and consideration of agents driving decisions (agent-based modeling; e.g., Bonabeau 2002).

[3] Other aspects of the scientific method are rarely adopted as well. For example, thoughtful questions and expectations (that relate to science-based hypothesis testing) are rarely articulated in advance.

[4] Only a couple of the 12 large-scale experiments described in Peterson and Anderson (2009) continue to be actively monitored.

[5] For DNR, these are quite specific goals of revenue production for beneficiaries and environmental constraints as articulated in the State Trust Lands Habitat Conservation Plan (DNR 1997).

To address these issues, the UW's Washington rural ecosystem sustainability team (WREST) developed a framework (Fig. 1), building on concepts from the millennium ecosystem assessment [https://www.millenniumassessment.org/en/index.html], and more specifically from the associated academic discourse (Figs 3 and 4) to address this problem and apply it to the OESF T3 Watershed Experiment. The WREST framework starts with traditional measures of success (for state trust lands on the OESF: producing revenue for trust beneficiaries and applying environmental regulations and agreements[6]) and adds additional measures of community and environment wellbeing. These measures are identified by integrating biophysical and social sciences and engaging with collaborators. Environment wellbeing, for example, can be broadened beyond the welfare of a few species of concern to the whole ecosystem. For example, current DNR management objectives do not directly include many factors important to the local community including: plants important to tribes, florals, elk populations, hunting and recreation desires, cedar abundance, neotropical birds, pollinators, nitrogen fixation, soil organic matter, aesthetics, to mention a few.

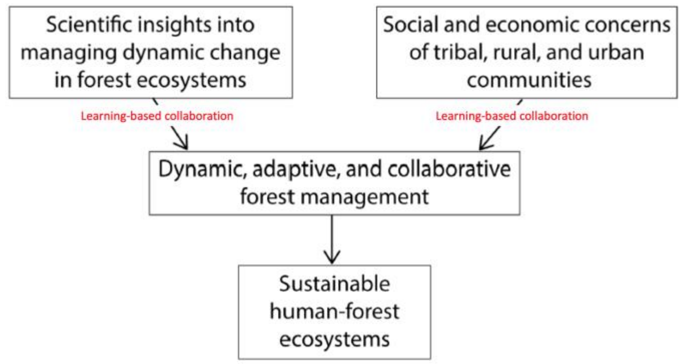


Figure 3. The human-forest ecosystem model (Olson et al. 2017; learning-based collaboration process step added here).

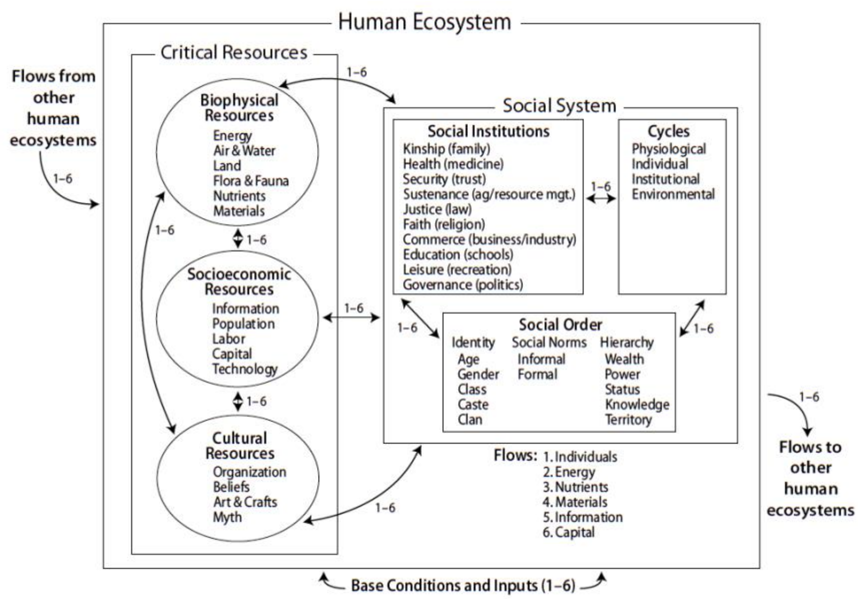
The WREST framework also draws on recent scholarship focused on ecosystem wellbeing in the search for appropriate metrics. For example, the Burch et. al. (2017) human ecosystem model presents a holistic view of the key elements of ecosystem wellbeing (Fig. 4). There is a large literature on human wellbeing. For example, Breslow et al. (2016), define human wellbeing as "*a state of being with others and the environment, which arises when human needs are met, when individuals and communities can act meaningfully to pursue their goals, and when individuals and communities enjoy a satisfactory quality of life."* The authors develop a multitude of general attributes and indicators to asses this (e.g., access, stewardship, aesthetics, cultural identity, job quality, recreation, education, governance, economy, equity, …). Multi-party collaboration has been emerging as a powerful way to build trust among people with widely different perspectives and trust of agencies to a lesser extent (Margerum 2008).

[6] This includes the DNR habitat conservation plan, state forest practices, and miscellaneous agreements. Standard DNR management provides important community and environmental wellbeing to nearby communities, both directly (small taxing districts, hospitals) and indirectly (e.g., associated economic activities and support for statewide schools and universities). One question is whether DNR management is currently improving community and environment wellbeing in ways they do not track or take credit for, and if so do they find ways to fine-tune management to better meet them.

Collaborative groups however, have rarely employed formal structured learning practices beyond some limited monitoring of individual practices.

To apply these ideas—with quite limited resources—to our place-based outer coastal Washington (greater OESF) ecosystem, the human-forest ecosystem framework is adopted focusing on the key process of learning-based collaboration (Fig. 3). A learning-based collaboration approach that includes formal experimentation and is grounded in various social sciences that engages with key stakeholders (such as scientists, elected officials, practitioners, activists, residents, and others) will help to: (1) identify place-based metrics of community and environment wellbeing; (2) guide changes to experimental treatments where possible; (3) create incentives for greater stakeholder participation in the study, including participation in scientific steps if possible; and (4) provide stronger evidence for a more informed debate about any potential policy change.

Figure 4. The human ecosystem model (Burch et al. 2017).



Specific steps for engaging stakeholders in the planning and initial implementation of the T3 study are:

- Producing peer-reviewed science plans for riparian and upland study modules as a form of collaboration and science stakeholder engagement.
- Meeting existing commitments to reconnect with already-engaged public stakeholders (environmental and timber groups, Tribes, and the WA Legislature) and expand the invitation to other interested parties; and

- Collecting useful information during stakeholder engagement sessions that can:
  - Form the basis for revising treatment evaluation criteria beyond the DNR objectives of providing revenue and meeting ESA to achieve a broader, initial set of ecosystem wellbeing metrics,
  - Obtain ecosystem wellbeing ideas that could be incorporated (without duress) into post-harvest treatments and monitoring,
  - Have stakeholders assist in the core study itself, including discussing questions, expectations, and monitoring, and working with collected data;
  - Be published in a peer-reviewed journal;
  - Provide a learning and growth experience and financial support to students; and
  - Involve seasoned facilitators to cross train PIs, students, and others.

Study Design

This study compares experimental treatments at both entire- and sub-watershed scales to address the core question and generally support and frame the debate about future directions of forest management on public lands. An overview of the concepts supporting the chosen experimental treatments is provided below. Additional detail including specific questions, hypotheses, and measures is found in study plans for riparian and upland modules.

Watershed-wide experimental treatments are landscape-management strategies that include entered areas (receiving active management pulses of various kinds) as well as areas unentered at least though the first pulse. Nested within watershed strategies are multiple experimental silvicultural prescription treatments applied in upland and riparian areas within the watershed (stands, sub-watershed catchments, and stream reaches). Some prescriptions will preclude management activity to provide no-action controls. This two-scale approach nests sub-watershed prescription treatments within entire-watershed strategy treatments.

The choice of watershed-wide strategies reflects our core question and a desire to be relevant to future DNR and other public forestland decisions. To this end, we compare the current DNR strategy (how the OESF is expected to be managed through the next 10 years) with 3 potential alternative strategies, some that incorporate novel prescriptions that can be compared at smaller scales (Fig. 5; Table 1). One of the strategy alternatives is no-action control, which is included to track and reduce effects of environmental background changes. Although some stakeholders may view this as a legitimate strategy, DNR cannot given its legal mandates regarding revenue production for trusts. To connect to many of the community wellbeing concerns, representative watershed responses will be extrapolated to the entire DNR ownership in the OESF. Difference stakeholder groups may align with different strategies or prescriptions. We are not seeking single solutions that everyone will agree with, rather we hope that stakeholders will spark innovations, find individual approaches that work best for them conceptually, tolerate approaches that others support as part of the study, and then consider new conclusions after seeing all approaches unfolding on the ground side by side.

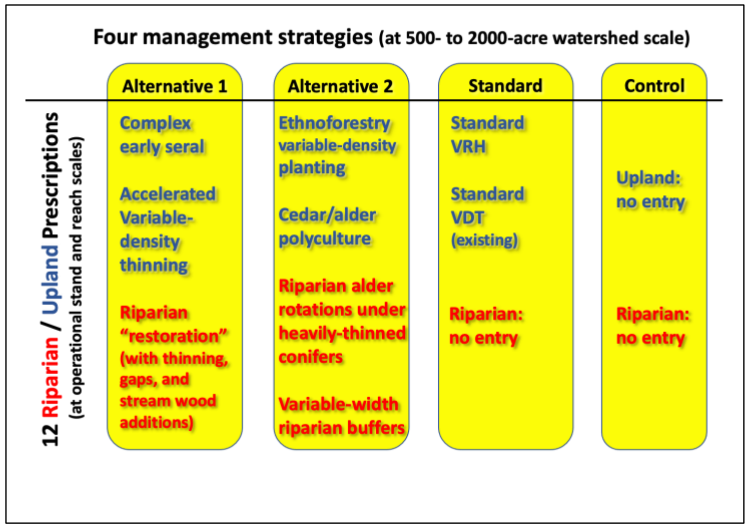


Figure 5. The various sub-watershed upland and riparian silvicultural prescriptions constituting the four management strategies.

The core question asks if integration between community and environment wellbeing can be increased. We're interested in the degree but also the kinds of integration that's possible. The goals of multiple-resource integration inclusive of community wellbeing outcomes have long been recognized in forest management, for example in the Multiple-Use Sustained Yield Act (1960) for federal lands, yet have proven elusive for most forest management agencies. A central need is to help evaluate potential changes to the degree and type of integrated objectives managers seek and find ways to implement them. Integration is the goal of increasing the total number of objectives that can be met simultaneously or efficiently through time or space. A base level of integration focused on concepts of forest ecological integrity has been sought with fixed, permanent reserves focused on individual sets of objectives, such as federal late-successional or riparian reserves.[7] Reserves that allow some secondary cross-objective activity (usually subservient to the primary objective) increase integration of additional resource aims but usually in small increments (e.g., thinning young stands in riparian buffers or late-successional reserves or leaving snags in harvested areas). More complete integration is achieved when multiple objectives are given more equal standing and can be met simultaneously on the same area or in sequence through time. The type of integration is also important. Moving from a narrow focus on Trust revenue and environment constraints to ecosystem wellbeing increases the number of objectives that can be better integrated. Moving to larger landscapes or watersheds ideally reduces conflicts in multiple-resource integration, but there is limited knowledge of how key components may respond to larger-scale integrated management designs.

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[7] Integration of Trust revenue and environmental purposes (set through constraints) has been a primary goal of DNR for decades. The OESF Plan is itself an alternative means of integration relative to management on other DNR lands (and on the National Forests part of the Northwest Forest Plan). These other areas use a fixed reserve, or zoning, approach while OESF adopted an approach that creates a shifting mosaic of stand structures. The various fixed reserves are set to achieve a single or at least primary purpose, usually assigning harvesting for revenue to areas left over. Achieving multiple purposes on the same stands or riparian areas is constrained by this approach.

Table 1. The stand and reach prescriptions constituting the four broad management-strategy treatments in the T3 Watershed Experiment; acronyms are defined in the Glossary, at the end of the document

Alternative-1 inspired integration strategy (**Alt-1);** Z watersheds in Fig. 6)

Prescriptions applied within the watershed are designed to actively increase ecosystem wellbeing (Table 2) by better integrating community and environment wellbeing over **Control** and **Standard** by applying the latest environmental science in what is often called active restoration. On uplands, it explores (a) improving early-seral conditions by managing structures and species after VRH and (b) tries new thinning/gap methods to increase both diversity and net revenue more than standard thinning practice on some operable portions of the watershed. Inside some of the riparian buffers, it seeks to increase aquatic productivity (foodchains and habitat) with (c) small canopy gaps, thinning, and wood placement in streams while adding some net revenue. Upland harvest area will be similar to **Standard** (13%); riparian area managed is uncertain but is expected to add less than 5% of the watershed. This strategy may have minor reductions in Marbled Murrelet buffers along a few streams.

Alternative-2 inspired integration strategy (**Alt-2)**; A watersheds in Fig. 6)

Prescriptions applied within the watershed are designed to actively increase ecosystem wellbeing (Table 2) by better integrating community and environment wellbeing, seeking inspiration and innovation through social-science-based engagement with stakeholders and elevated concerns for rural livelihoods. On uplands, standard VRH treatments on about 13% of the watershed. Two alternative silviculture prescriptions will be applied at an operational scale on operable portions of the watershed following VRH: (a) an ethnoforestry/variable-density planting prescription that creates heterogeneity with clumps of conifers and interstitial spaces of different sizes that extend the occupation of non-conifer plants, including elk forage, culturally valued, and other early-seral species—reverting to standard conifer culture after crown closure, and (b) a cedar-alder mixture that allows access to the riparian alder /wide-thinning treatment directly downhill (see below). The upland prescriptions may be modified before they are permanently set in May 2021. There are also two different prescriptions inside the 30.5-m riparian buffers: (c) a wide thinning to <74 conifers ha^{-1}; <30 tpa) with multiple rotations of planted red alder in between residuals; and (d) VRH that extends in specific places into the 30.5-m buffer ("variable width" as described in the FLP). Area managed in the riparian buffer are uncertain but might achieve 5% of the watershed. This strategy may have minor reductions in Murrelet buffers. The very limited entry into 100-year-old "21-Blow" stands as described in the Study Proposal (Bormann and Minkova 2016) may have been precluded with the Murrelet addition to the HCP.

Standard OESF Management strategy (**Standard)**; P watersheds in Fig. 6)

Prescriptions applied within the watershed to represent how DNR will likely manage the majority of the OESF over the next 10 years. **Standard** focuses on implementing the trust beneficiary and habitat conservation plan mandates in the OESF forest land plan (FLP), the sustainable harvest calculation, and the long-term Marbled Murrelet conservation strategy. On uplands, a first wave of standard VRH and VDT treatments will occupy about 13% of the watershed (the estimated average rate of harvest under the current management pathways described in FLP and sustainable harvest calculation). Although limited riparian entry in the fixed 30.5-m buffers on T3 and T4 streams is planned in the OESF, it is excluded here to provide contrasts with other treatments. Objectives appear in FLP and meet habitat commitments of the HCP (NSO, MM, riparian, multispecies) without riparian entry.

No-action Control strategy (**Control);** C watersheds in Fig. 6)

A prescription of no-action is applied throughout the watershed for first 10 years so we can observe background natural disturbance such as windthrow and provide for the desires of some stakeholders. A key management objective is to maximize carbon sequestration for a decade by avoiding any tree harvesting. Carbon (C) standing crop and net primary production will be measured by remote sensing on all watersheds (in Uplands study plan) and stream C losses by sampling (Riparian study plan).

Comparing **Standard** management against strategies and prescriptions with different degrees and types of integration serves a central purpose of this study—to evaluate current practice through what is commonly referred to as effectiveness monitoring. Comparing the degree of integration planned against that achieved is much easier when you have contrasting evidence from real-time alternatives. A no-action control establishes what appears to be the lowest level of integration by precluding objectives that might be achieved by active management. The lack of revenue from harvest precludes DNR from considering this under their current mandate to supply revenue to their trusts (which is why this treatment is limited to 10 years).

Many studies with experimental designs are focused on questions developed by scientists to reduce uncertainties that they are most concerned about. In our case, we hope to apply the power of the scientific design to better inform key management decisions and increase the extent and quality of stakeholder input and engagement in a collaborative process that inform decisions. To this end, all of the management strategies included as experimental treatments were designed to connect to individual groups or constituencies, so groups could relate to at least one strategy. Our discussions with stakeholders uncovered that even the no-action control can be considered a desirable strategy by a few stakeholders, specifically those interested in carbon sequestration and carbon markets. The purpose of connecting strategies to groups is to encourage more in-depth and long-term stakeholder participation to elevate the quality of the debate and buy in to future decisions.

Statistical Design

Analysis of the entire-watershed treatments will use a randomized block design, with four treatments and four blocks, where treatments were assigned randomly within block[8]. Analysis of differences between sub-watershed riparian and upland silvicultural prescriptions will follow a series of specific contrasts. The simplest description of the design is to compare watershed responses from the 4 different strategies, each containing a different set of upland and riparian prescriptions (affecting < 20%) and unmanaged areas (> 80%) of the watershed). Nesting of upland and riparian stand and reach-scale prescriptions allows for comparison of various responses among them. Timber-sale logistics limit alternative upland treatments to two operational-scale (30 acres each) treatments in the Alt-1 and Alternative-2 inspired integration

[8] The DNR decided to switch treatments between two watersheds in different blocks, which compromises random allocation for part of the experiment. This event is described in the Uplands study plan. [move to here?]

watersheds. Standard VRH will be applied to other portions of these watersheds to achieve the 15-20% needed to equalize among watersheds. See riparian and upland study plans for greater detail.

Study Area and Layout

The choice of four management strategies also reflects the scale of the watersheds provided (Fig. 6; Table 1) and various operational, biophysical, and financial constraints (see Appendix 2 for changes since the initial ideas presented in the 2016 Study Proposal). The space to create a large-scale watershed experiment was provided when the DNR allocated 16 watersheds with a total area of 8000 ha (20,000 acres) in the Clearwater and Hoh River drainages from a large pool of possible Type-3 watersheds. The similarity analysis used to select watersheds is described in the riparian study plan. This decision, virtually unprecedented for a state agency, was made possible because of the OESF learning objectives, its mission for applied research informing management decisions, and its support by current leadership.

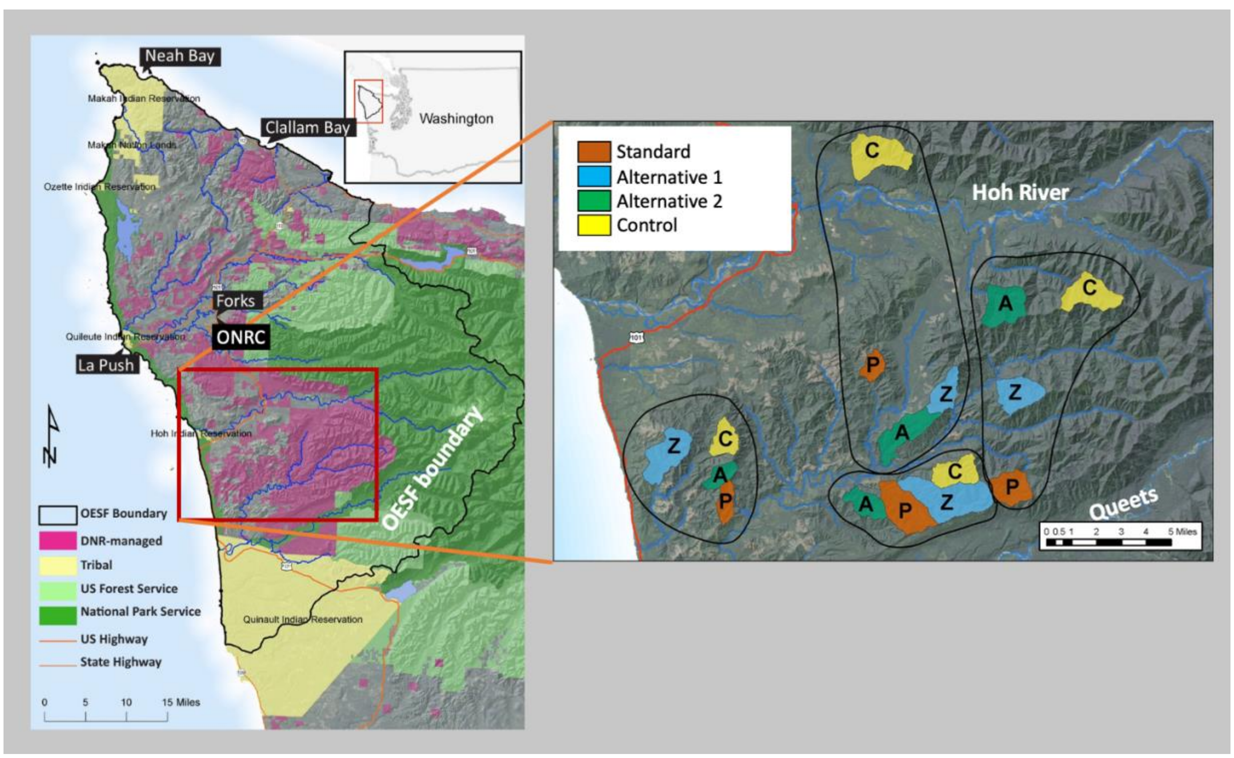

Figure 6. Map of the Olympic Experimental State Forest (OESF) and 16 experimental watersheds grouped into four blocks with randomly assigned treatments.

Initial Broad Measures of Success

Specific measures of success are being developed in the T3 riparian and upland study plans and WREST plans. Initial broad measures are presented here (Table 2) and lay the groundwork for development in future study modules, for example economic questions and decision tools.

Table 2. Initial core targets for ecosystem wellbeing and associated measures of success, where strategy effects at the watershed scale are extrapolated to entire-OESF scale, and likely benefits to environment and community wellbeing (*subject to addition/change*)

Target is to maintain or improve (sustain):	Measures of ecosystem wellbeing at watershed scale, change in:	Environ-ment	Com-munity
Management practices and efficiencies and economics • Revenue to beneficiaries;	Logging, roading, and administrative costs as they affect net revenues and management capacity	✓	✓
Riparian and aquatic habitat, water quality, and fish populations	OESF T3 50-basin monitoring measures (Appendix 1), modified to include additional measures identified in Rautu (2019) and fish abundance	✓	✓
Terrestrial animal habitat and abundance: • Late-seral habitat • Birds	• Plan based forest structure percentages; • Bird abundance as measured by acoustic monitoring (EarthWatch; Appendix 1)	✓	✓
Community wellbeing: • Local employment and associated tax base; • Quality of life and cultural vitality; • Number of people with outdoor lifestyles	Social welfare and perception • Field trips, surveys, interviews, including underserved communities. • Actual/promised volume & payments; • County and community jobs (by types, especially year-round, family wage); • Jobs in woods, recreation, other outdoor practices;	✓	✓
Environment wellbeing: • Atmospheric carbon capture, retention; • Disturbed/undisturbed portions of the landscape • "Healthy" conifer stands; • Cedar abundance	Entire watershed land cover, function • Aboveground net primary production and C stores w/ lidar, satellite models (uplands plan); • Tree cover, wind disturbance, landslides, soil disturbance (uplands plan); • Conifer stand density by age class via DNR lidar-based inventory (uplands plan); • Multi-spectral satellite model compared to historical data; (uplands plan).	✓	✓

Expected Outcomes

At the entire-watershed scale, treatment differences are expected that directly relate to the sum of applied prescriptions, extrapolated revenue and job numbers, and loss of tree cover (Table 3). As seen in other studies, hydrological effects recorded at the watershed pour point are possible but they may be considerably diluted because at most 20% of land in Alt-2 watersheds will be managed (see Riparian study plan). The outer Peninsula streams, however, have a unique combination of geology, soils, and climate so effects might be of a different magnitude and type. Larger effects are expected in the treated riparian and upland silviculture areas where monitoring will be conducted at smaller spatial scales (see riparian and upland study plans). Some change in fish populations seems plausible, and this will be a major interest, especially relative to Alt-1 and Alt-2 strategies which might lead to initial water quality reductions followed by an improvement of the aquatic foodchain. The implications of negative or positive effect on fish is quite important given the general belief that harvesting especially near streams has been responsible for salmon declines regionally (see the Riparian module study plan for details).

Table 3. Initial relative expectations for the different strategies to be evaluated in this entire-watershed or by other means

	Ecosystem wellbeing elements (examples)	**Expectations**
Environment	Stream "health" (various sets of indicators)	Alt-1 > Alt-2 > Standard = Control
	Viable salmonid populations	Alt-1 = Alt-2 > Standard = Control
	Near-term late-seral bird habitat (owls, Murrelets)	Control > Standard = Alt-1 = Alt-2
	Long-term late-seral bird habitat (owls, Murrelets)	Alt-1 > Alt-2 > Standard> Control
	Early-seral neo-tropical bird habitat	Alt-2 > Alt-1 > Standard> Control
	Ungulate habitat	Alt-2 > Alt-1 > Standard >> Control
	CO_2 sequestration (in forest and built environment)	Control > Standard > Alt-1 > Alt-2
	Soil productivity (indicators and actual growth responses)	Alt-2 > Alt-1 > Standard= Control
Community	Revenue to beneficiaries	Alt-2 > Alt-1 = Standard >> Control
	Local jobs	Alt-2 > Alt-1 > Standard >> Control
	Local salaries gross/net	Alt-2 > Alt-1 > Standard >> Control
	Road access to the forest (e.g., recreation, hunting)	Standard = Alt-1 = Alt-2 >> Control
	Poverty level	Alt-2 > Alt-1 > Standard > Control
	High school students wanting to stay	Alt-1 = Alt-2 > Standard > Control
Both	Solar energy capture (for all foodchains & wood production)	Alt-1 > Alt-2 > Standard > Control
	People-land connectedness	Alt-2 > Alt-1 > Standard > Control

Glossary

Community wellbeing. The welfare of communities of people (residents and other affected stakeholders) that are associated with an ecosystem defined as the focus of study. Wellbeing is a concept that can be both generally defined (e.g., Breslow et al. 2016) and locally specified through collaboration and analysis into issues like access, stewardship, aesthetics, cultural identity, job quality, recreation, education, governance, economy, and equity.

Ecosystem sustainability. This management framework is based on the Millennium Ecosystem Assessment and academic scholarship (Burch et al 2017; Olson et al. 2017) that include people as a fundamental part of the ecosystems that we want to study, by identifying how community and environment wellbeing interact in interdependent ways to produce an overarching ecosystem wellbeing. Determining local metrics and including learning are identified as requirements to maintain or improve ecosystem wellbeing through time. This framework requires more and different stakeholder involvement than traditional planning frameworks. The science of ecosystem sustainability is focused on the processes of achieving it including learning-based and other forms of collaboration, engagement steps needed to develop ecosystem wellbeing metrics, and the study of interactions between community and environment and tradeoffs and symmetries.

Ecosystem wellbeing. A total ecosystem representation of community and environment wellbeing for a geographically defined ecosystem. It can be different than the sum of community and environment wellbeing because it also includes both synergies and tradeoffs between them. These measures need to be locally defined by people with knowledge of local environment and community conditions.

Environment wellbeing. The welfare of the environment within an ecosystem defined as the focus of study. The condition of the environment and how well it is functioning has been studied by environmental scientists who use a diverse array of measures such as successional stage distribution, energy and nutrient flow, biodiversity, and disturbance regime to draw conclusions. Managers and the people who depend on the ecosystem can have more experiential knowledge than the scientists that is valuable and often not adequately accounted for. Tribal knowledge is particularly valuable as it represents a time-tested vision of community-environment integration.

FLP; Forest land plan. The land plan guiding management of the OESF adopted in 2016 (WADNR 2016).

HCP; Habitat conservation plan. The habitat conservation plan adopted in 1997 guiding habitat conservation for NSO, MM, and riparian species in the OESF (WADNR 1997).

Learning-based collaboration. This is a form of collaboration focused around groups of diverse stakeholders who choose to search for innovative solutions together using various forms of social learning (Wals 2007) and adaptive management (Bormann et al. 2017). For rural ecosystem sustainability, it's a group process that uses scientific insights into managing dynamic change and social and economic concerns of communities to develop a dynamic, adaptive, and collaborative forest management (see Fig. 3).

MM; Marbled Murrelet. A small N. Pacific seabird (*Brachyramphus marmoratus*) that nests on large limbs of coastal forest conifers, and currently subject of a controversial revision of the HCP.

NSO; Northern Spotted Owl. A small owl (*Strix occidentalis* Caurina) that nests in late-successional forests, declining sharply in Washington in part through displacement by Barred Owls (*Strix varia*).

T3; Type 3. A stream delineation referring to the smallest stream segment with resident fish. A T3 watershed, it follows is the smallest watershed with a T3 stream segment at its base.

VDT; variable density thinning. A type of commercial thinning in which a mixture of small openings (gaps), un-thinned patches (skips), and varying stand densities are created to achieve specific objectives, such as accelerating development of complex stand structure. Typically, these harvests produce less than half the net revenue compared to VRH.

VRH; variable retention harvest. These are the standardized DNR regeneration harvests that encourage growth of new trees and that leave around 20 trees ha^{-1} (8 tpa) of live "residual" trees standing to serve as legacies to the previous stand for habitat and other purposes. Residual trees may develop into snags or fall over, which are not considered a negative outcome as they provide for other kinds of habitat.

WREST; Washington rural ecosystem sustainability team. The ONRC, with faculty and students in the University of Washington School of Environment and Forest Science created this group that integrates social and biophysical sciences to develop and explore a new framework for managing natural resources.

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Appendix 1. Affiliated studies

We can draw on some existing DNR and UW programs and independent, grant-funded studies to support, complement, and extend the sustainability science, riparian, and upland modules of the T3 study (Fig. 6). These affiliated studies and their links to T3 are described briefly below.

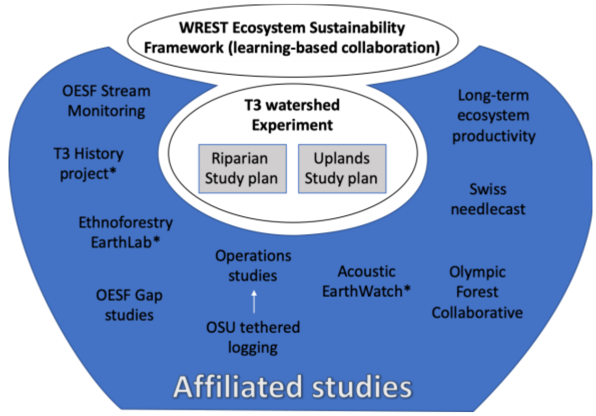

Figure 6. The current suite of studies supporting the T3 study on the Olympic Peninsula *indicates outside grant funding.

Existing programs

The DNR long-term status and trends monitoring program. This program was initiated in 2013 a 20% subsample of all type-3 watersheds in the OESF (Minkova and Foster 2017). This effort seeks to interpret the effect of DNR management on stream and riparian health using unmanaged watersheds on the Olympic National Park and Olympic National Forest as controls. This effort is especially valuable to this T3 experiment by developing baseline understanding of spatial and temporal variance of the stream habitat attributes and fish populations across the OESF, and developing and applying workable monitoring protocols, and providing temporal and spatial context across the OESF.

The long-term ecosystem productivity study (LTEP). The ONRC is overseeing a regional experiment with relevance to the T3 experiment. The LTEP site on the Olympic Peninsula is just north of Forks, WA and compares previously managed stands (now as controls), late-seral focused thinning, standard Douglas-fir plantations, and plantations emphasizing the inclusion of early seral species like red alder on soils and productivity. This study has provided a long-term perspective on upland stand growth and development possibilities also. The LTEP site near Hebo, OR included a wide thinning with a sub-plantation of red alder to be grown on a repeated short-rotation basis. Results from this treatment are informing riparian silviculture in one of the T3 strategies and providing plots for remote sensing models.

The Washington needlecast working group. The legislative funding for T3 included support for outreach and monitoring of Swiss needlecast on coastal Douglas-fir plantations. Needlecast has been greatly affecting young Douglas-fir plantations, mainly on forest industry land from coastal Oregon to British Columbia.[9] The T3 watersheds are likely to be affected, and monitoring of Douglas-fir here will benefit both T3 and needlecast efforts alike. T3 ground plots can provide truthing for Needlecast surveys and remote sensing.

Opportunities based on outside funding

T3 History project. This effort was funded by the Pacific Northwest Research Station, which helps establish the PNW Research Station as a key scientific collaborator in the project. ONRC and DNR scientists seek specific information on the natural and anthropogenic disturbances in

[9] This group is working closely Oregon State University, Swiss Needle Cast Cooperative (http://sncc.forestry.oregonstate.edu)

the T3 watersheds included in the experiment, with the primary goal of better designing study operational treatments to minimize the lag effects of past disturbance events such as road building, logging operations, slashburning, and windthrow. The idea is to better identify and include areas with similar initial conditions driven by historical happenstance. Historical timber and vegetation surveys, maps, aerial photos, Landsat images, NAIP photography, timber sale documents, fisheries and other records, and interviews have been compiled. This project is hoped to grow into a historical reconstruction of practices and effects during the 1940 to 1990 period.

Ethnoforestry trials. ONRC has a program affiliated with the T3 watershed study, on "ethnoforestry" led by PhD Student Courtney Bobsin and funded mainly by UW's EarthLab grant and Campus Sustainability Fund. Ethnoforestry is defined as a people-oriented forestry model, that seeks to better incorporate needs and desires of local Native American tribes and local residents that use the forests into current practices. The basic idea is to explore whether a range of species important to tribes and others can be integrated into DNR management without greatly affecting revenue and environmental targets, thereby increasing ecosystem wellbeing. This study will begin summer 2020 and include greenhouse and small field studies mostly addressing practical issues in implementing these practices. The initial small-scale trials are on DNR lands near La Push. What is learned there will be applied to the four community-inspired integration watersheds and then compared to other upland treatments at the stand scale. Scientific plans for this sub-study will be evaluated independently of this T3 entire-watersheds study plan.

Harvest operations using tethered logging systems. In an operations workshop our group held in 2016, questions about road maintenance, road standards, and logging systems were raised. These questions are relevant to T3 because net revenue and environmental impacts are often heavily influenced by these practices. DNR and UW are collaborating with Oregon State University and industry collaborators in an affiliated study that examines the environmental effects, operational efficiency, and safety of tethered logging systems. This study will not occur on a study watershed, but on a nearby area. Poor access to steeper slopes and deeper ravines increases logging costs, making some projects uneconomical. Many people believe that cable-assisted (tethered) systems allow for a mechanical harvester and forwarders to travel safely up and down steeper slopes, without harming soils. This idea will be tested on the steep Olympic slopes. Success might lead to use of this equipment in applying study treatments.

Avian acoustics study. A grant from EarthWatch Institute will bring highly motivated non-academic volunteers to aid in monitoring bird calls on the upland areas of T3 watersheds. Acoustic recording units are placed in four forest age strata in each experimental watershed. The total number of monitoring stations across the 16 watersheds is about 200. The vocalizations of 10 indicator species song birds are identified from the audio files at each monitoring station. The presence/absence data will be used to build occupancy models, which in turns will be used to evaluate the habitat quality and function of the forest age strata and the pre- /post-effects of stand-scale treatments (refer to the Uplands study plan). Avian species signatures will be extracted from continuous recordings to quantify species abundances. This program has been affected by the Covid-19 virus but is currently being implemented by DNR staff, using T3 funding.

Appendix 2. Evolution of the Research Program

The overview of the T3 Watershed Experiment presented here is an evolution of the initial study proposal (Bormann and Minkova 2016). This initial proposal was evaluated by UW and DNR collaborators and two groups of stakeholders, and then adopted by DNR in 2017. Implementation of this watershed study was subsequently delayed until sufficient funds were obtained from the Washington Legislature in 2019. In the intervening period, study leaders have been working on fine-tuning concepts, questions, management strategies, and information contributing to environmental reviews and timber sales. These changes (Table 4) are reviewed here.

Table 4. The four management strategies (experimental treatments) originally identified in the 2017 T3 Study proposal (top) and as proposed now (bottom).

Original strategies	Original strategy concepts
The OESF land-management **Plan**	Representing DNR management across OESF landscape planning units, basically a largely reserve-free, balanced distribution of successional stages that shift through time, and variable rather than fixed riparian buffers.
Fixed reserves or **Zoned**	Management concepts as applied on both DNR lands outside the OESF and by the National Forests under the NW Forest Plan.
Accelerated integration	Untested new approaches with fewer restrictions that might better integrate environment and community wellbeing.
No-action **Control**	A hands-off approach to represent background changes that may interact with treatments, and as advocated by some environmental groups. This is not considered a viable management strategy by DNR under current law.
New strategies	**New strategy concepts (see Table 1 for more details)**
Alternative-1 inspired integration (**Science**; modified from Zoned or Z watersheds)	Also managed under OESF plan guidelines, altered to seek an increase in ecosystem wellbeing by more fully integrating community and environment wellbeing. Harvest area will be slightly higher on the entire watershed than **Standard** mainly to add stream wood and riparian gaps and thinning. Uplands will examine complex early-seral silviculture and more accelerated thinning. This strategy may have minor reductions in Murrelet buffers along a few streams.
Alternative-2 inspired integration (**Alt-2**; formerly Accelerated or A watersheds)	This strategy will not necessarily fully comply with the OESF land or Murrelet plan to push the integration envelope further—as driven by views of some community stakeholders. Harvest area will be highest on the entire watershed. This strategy features short-rotation alders in riparian areas to increase fish food supply and increase the land-base for management supporting ecosystem wellbeing, as well as variable-width riparian buffers innovative upland practices, including alder-cedar mixtures and ethnoforestry. This strategy may have minor reductions in Murrelet buffers along a few streams.
Standard OESF Management (**Standard**; formerly Plan or P watersheds)	Represents management likely to unfold on the OESF at large over the next 10 years. This strategy focuses on how the trust beneficiary and habitat conservation plan mandates in the OESF land plan, the sustainable harvest calculation, and the Murrelet plan are actually being applied in this working forest. Fixed riparian buffers will not be entered to provide contrast to the other integration alternatives.
No-action Control (**Control;** Control or C watersheds)	No-action control for first 10 years to observe background disturbance and provide for the desires of some stakeholders, especially to maximize carbon sequestration. This is not considered a viable management strategy by DNR under current law.

The initial plan proposal assumed that the Olympic Region would be fully implementing the riparian direction in the 2016 OESF Forest Land Plan as directed during the previous decade. The Marbled Murrelet had been accommodated in the habitat conservation plan (WADNR 1997) on an interim basis. A detailed analysis and decision by the Board of Natural Resources (Board) came forward in late 2019 that added restrictions (although this may change after lawsuits from opposing sides). A settlement agreement with environmental groups (during the interim before the final Murrelet decision) also dictated that the Olympic Region apply thinning and VRH in a 1:1 ratio on the OESF, and this agreement is no longer in place. Incentives for thinning have greatly declined as no-harvest reserves increase, and because thinning generates far less net revenue, is administratively less efficient, and grows larger logs than some current mill infrastructure can handle.

In December 2019, the Board released a new sustainable harvest calculation (SHC) that does not include harvest in riparian areas in the metrics used to evaluate the Region's harvest program, which largely determines its funding level. Although this decision does not prohibit management in riparian areas, it may minimize it, given the need to meet harvest goals[10]. Further, when we looked at layout of the Zoned strategy, it became clear that light thinning in wider no-harvest riparian buffers differed little from the Control, especially for likely riparian responses. Together these were the reasons we decided to revise the strategies (table 5, bottom). There is a chance that the OESF will be managed more like the Alt-1 strategy than the Standard strategy. If this is the case, then the Standard watersheds will provide evidence of a more conservative management approach.

The revised set of strategies create a better series of questions and contrasts than the initial proposal, and better link to stakeholder perspectives. For example, those who think that any entry into riparian buffers is a concern, they have two strategies without riparian entry (**Control** and **Standard**) to compare to two others that have different kinds of entry (**Alt-1** and **Alt-2**). To those that are interested in increasing the land base for active management by extending active management into riparian buffers, they have the same contrast to look at. This general, +/- riparian entry contrast has significant statistical power (8 watersheds with/without riparian entry; df = 14). For those interested in alternatives to standard VRH or VDT upland silviculture, there are contrasts each with 4 replicates: (a) 4 stands (one in each of in 4 watersheds) with standard VRH and VDT (in **Standard**); (b) 4 stands in 4 watersheds without entry that would have been treated (in **Control**); (c) 4 stands in 4 watersheds with alternatives to VDT (in **Alt-1**); and (d) 12 stands in 4 watersheds with alternatives to standard VRH (one in **Alt-1** and two in **Alt-2**).

We recognize that seeking integration beyond **Control** and **Standard** strategies may be concerning to some stakeholders. We added **Alt-1** to the design to try to connect to this point of view. This strategy emerged largely from ideas being considered by natural resource specialists (who sometimes are in sync with the environmental community) and who are often focused on improving environment conditions as much as possible. For example, the deep shade in second-growth conifers along headwater streams, although keeping summer temperature low, appears to strongly limit stream food supply (low light, poor detrital and insect inputs). Slow rates of mortality and small size of wood entering from unmanaged riparian second growth provides only

[10] If harvest volumes are not achieved, then state law designated an "arrearage" volume that has to be added to the next decadal harvest goal.

temporary wood structures to alter pools and riffles. Active management can begin to address this (speeding growth through thinning and adding wood directly), and may be able to at least pay for itself if some harvest takes place.

We also recognize that the levels of integration included in **Alt-1** and **Alt-2** may be insufficient to others particularly concerned about the economic and social condition in rural communities that have watched a steady erosion of the active-management land base since 1990. Between 45 and 55% of Trustlands are in a reserve status (different stakeholders use different numbers). The initial study proposal included limited entry into older 80- to 100-year-old forests in one strategy. The idea was that these, mainly 1921-blow origin stands (not high-quality old growth, which is excluded) could tolerate some limited tree removals that would generate some net revenue. These removals would be designed to have limited environmental benefit such as reducing competition to specific high-quality habitat trees and reducing losses to windthrow and disease. We have not decided to remove this element from the study at this point, although it would be inconsistent with the new Marbled Murrelet long-term conservation strategy (WADNR 2019). Rather, we have delayed its consideration for the next 5 years.

Appendix 3. Implementation plan

This management experiment is a complex series of decisions, plans, and studies carried out by a variety of institutions and individuals over a significant amount of time that would be difficult by a single entity. Planning and coordination are therefore crucial. Here, we review funding (Table 5) and initial timeline for steps (Fig. 7).

Table 5. Funding needs for activities part of the T3 study (most affiliated studies not listed)

Funding available (green) Funding NOT available (orange)

#	Activity	Amount ($)	Duration	Staff	Funding Source	Funding Oversight
1	Plan timber sales	54,000	July 2019 - June 2021	Kevin Alexander	State Legislature proviso and normal DNR Olympic Region	Teddy and Bill as subcommittee of PI team (Theresa/Drew monthly meeting)
2	Coordinate TS layout and research designs		July 2021 - June 2022			
3	Peer-reviews of study plans	6,000	March 2020 - April 2020	All authors	Proviso	T3 PI team
4	Engage stakeholders	40,000	July 2019 - June 2021	Frank and Chelsea Midgett	Proviso	Bernard and Marc as subcommittee of PI team
6	Science oversight board	?	April 2020 - continuous	Maybe all PIs	?	Bernard and Marc as subcommittee of PI team
7	Acoustic monitoring – pre-treatment data collection	100,000 (grant)	April 2020 - August 2021	Dan, Teddy, Lauren, Bernard + volunteers	Earthwatch Institute	Teddy
8	Acoustic monitoring – post-treatment data collection	40,000 (grant)	April 2022 - August 2022	Dan, Teddy, Lauren, Bernard + volunteers	Earthwatch Institute	Teddy

Table 5 cont'd.

#	Activity	Amount ($)	Duration	Staff	Funding Source	Funding Oversight
9	Riparian experiments - pre-treatment data collection	Tier1-113,296 Tier2-147,115 Tier3-213,689	July 2020 – October 2021	Kyle, Kim Clark, DNR field techs, UW interns	Proviso, DNR, ONRC funds	Kyle and Kim,
10	Riparian experiments - post-treatment data collection	TBD	July 2022 – October2026	Kyle, Kim Clark, DNR field techs, UW interns	?	Kyle and Kim
11	Stream macroinvertebrates pre-treatment data collection	27,000	?	Stephen Bollens, WSU grad student, Kim Clark?	PNW Research Station + proviso	Bernard and Steve
12	Stream macroinvertebrates post-treatment data collection	?	?	Stephen Bollens, WSU grad student, Kim Clark?	?	Bernard and Steve
13	Upland experiments - pre-treatment data collection	5,000	June 2021	Warren, DNR field techs, UW interns	DNR monitoring funds, ONRC funds	Warren and Bernard
14	Upland experiments - post-treatment data collection	TBD	April 2022-December2026	Warren, DNR field techs, UW interns	?	Warren and Bernard
15	Disturbance history analysis	20,000	June 2019 – May 2020	Roxana, Keven Bennett, Warren	PNW Research Station	Bernard and Warren
16	Data analyses, reports, publications	TBD	?	UW grad student	?	PI team

Activity details

1. Refer to the table with Kevin's tasks and deliverables (Word document dated 01/22/2019)
2. Refer to the table with Kevin's tasks and deliverables (Word document dated 01/22/2019)
3. Two peer reviews are desirable for each of the 3 study plans: riparian, upland and acoustic monitoring. Up to 2 of them can be paid with estimated $3,000 per review
4. Includes the following activities:
    - Feedback from ONRC advisory board
    - Develop list of all interested stakeholders and have 1x1 or caucus contact to resume/start communication
    - Engagement in the development of the study plan via meetings and emails
    - Stakeholders' comments on the study plan
    - Stakeholders' comments on the field protocols
    - Field tours
5. Includes the following activities:
    - Stakeholders' input on study implementation
    - Stakeholders' comments on results, project reports and management recommendations
    - Field tours
    - Possible stakeholder work with openly provided monitoring data
6. Annual meetings of the ONRC board, Sci. oversight should be all co-PIs and ex office participation by university and agency administrators.
7. Six field teams per year with volunteer crew recruited by the funding organization EarthWatch Institute, led by DNR and ONRC researchers
8. Six field teams per year with volunteer crew recruited by the funding organization EarthWatch Institute, led by DNR and ONRC researchers
9. The 3 tiers of funding represent the minimum, medium and optimal sampling intensity. Includes stream and riparian habitat sampling and fish sampling (see riparian study plan for the list of monitoring indicators)
10. The 3 tiers of funding represent the minimum, medium and optimal sampling intensity. Includes stream and riparian habitat sampling and fish sampling (see riparian study plan for the list of monitoring indicators)
11. Includes only the field component of the study. The laboratory work for species identification and the analyses are sponsored by the WSU, Stephen Bollens lab.
12. Includes only the field component of the study. The laboratory work for species identification and the analyses are sponsored by the WSU, Stephen Bollens lab.
13. Vegetation sampling (see upland silviculture study plan for the list of monitoring indicators)
14. Vegetation sampling (see upland silviculture study plan for the list of monitoring indicators)
15. Includes summary and analysis satellite, LiDAR, photo and operational data with two goals: 1) Inform TS units layout and 2) retrospective analysis of anthropogenic and natural disturbances and the vegetation response
16. Potentially: economic analyses, trade-off analyses, modeling of future ecological conditions and economic returns, scaling up the findings to the entire OESF, …

Figure 7. Estimated timeline.

T3 Management Experiment Implementation Timeline for 2016 - December 2021

Coordination/communciation | Research/monitoring | Operations

Activity	2016-2017	2018	2019	2020												2021											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Study proposal																											
Informing DNR managers	proposal	proposal	fudning																								
Input from stakeholders	proposal					study plans				final treatments		monitoring field tour				first-year monitoring data		timber sales with research design						monitoring field tour			
Presentations at OESF conference	Bernard	Teddy					study plans												implementation								
Designation of experimental watersheds		by DNR+ONRC																									
Research workshops	all fields	silviculture, riparian, operations																									
UW social science meetings		Mark Miller, Bernard, grad students																									
Acoustic monitoring (grant with Earthwatch Institute)			agreement and trainings	study plan	peer review		field data collection	field data collection	field data collection	field data collection	field data collection	data processing	data processing	data processing	data processing	data analysis	data analysis	field data collection	field data collection	field data collection	field data collection	field data collection	field data collection	data processing	data processing	data processing	data processing
Riparian experimetnation		first draft - Bernard		study plan draft - Kyle	internal review	peer review	develop field protocols	develop field protocols	operational modifications	field data collection	field data collection	field data collection	field data collection	data processing	data processing	data analysis	data analysis					field data collection	field data collection	field data collection	field data collection	data processing	data processing
Upland (silviculture) experimentation					study plan draft - Warren	internal review	study plan -peer review	operational modifications	operational modifications										field data collection	field data collection						post harvest data collection	post harvest data collection
Infroming USFWS + NOAA Fisheries						study plans			variances needed							first-year monitoring data											
Infroming Forest Practices (WDFW)						study plans			variances needed																		
Implementation of treatments (Kevin Alexander)			planning	planning	target harvest acres and volume	TS units-GIS review	TS units - field checks	TS units - field checks	FY 2022 harvest action plan	RM permission for large units	FY 2022 timber sales layout	FY 2022 timber sales layout	FY 2022 timber sales layout	FY 2022 timber sales layout	FY 2022 timber sales layout	FY 2022 timber sales layout	FY 2022 timber sales layout	TS packets with research design	outreach to purchasers	TS packets with research design	TS packets with research design	first TS auction	first TS contracts	additional TS auction and TS contratcs	first FY 2022 harvests	first FY 2022 harvests	first FY 2022 harvests
Disturbance history analysis			data sources, summaries	data sources, summaries	data analysis	data analysis	final report																				
Stream macroinvertebrates research (WA State University)			planning Steve Bollens				develop study plan	develop field protocols	field data collection	field data collection	field data collection	field data collection	lab work	data processing	data processing	data analysis	data analysis	field data collection	field data collection	field data collection	field data collection	field data collection	field data collection	lab work	data processing	data processing	data processing

Appendix 4. Research and Implementation Team

OESF/DNR Principal and co-principal investigators and staff

- Teodora Minkova, Ph.D, is a natural resource scientist in DNR's Forest Resources Division and an affiliate assistant professor at the University of Washington's School of Environmental and Forest Sciences. She manages the OESF research and monitoring program and is a principal investigator on this study.
- Bill Wells, is Olympic Region Coast District Manager, and is a principal investigator on the overall T3 study.
- Warren Devine, Ph.D., is a natural resource scientist in DNR's Forest Resources Division, and is a PI on the T3 uplands study.
- Kyle Martens, M.S., is a fish biologist in DNR's Forest Resources Division, and is a PI on the T3 riparian study.
- Dan Donato, Ph.D., Forest Ecologist, DNR is a PI on the T3 uplands study.
- Drew Rosanbalm is Olympic Region State Lands Assistant Director.
- Kevin Alexander is planning silviculturist Coast District Olympic Region.

ONRC/UW Principal and co-principal investigators, students and staff

- Bernard Bormann, Ph.D, is a professor at the School of Environmental and Forest Sciences (SEFS), College of Environment, University of Washington and Director of the ONRC, and is a principal investigator on this study.
- Marc Miller, Ph.D, is a professor of School of Marine and Environmental Affairs at the University of Washington is a principal investigator on this study.
- David Butman, PhD, professor of biogeochemistry at SEFS, is a PI on the riparian study.
- Sandor Toth, Ph.D, professor of operations research at SEFS and leads ONRC needlecast efforts.
- Kim Clark, M.S. aquatic/marine specialist for ONRC.
- Rich Osborne, Ph.D., is aquatic/marine coordinator for ONRC.
- Frank Hanson, is outreach lead for ONRC.
- Keven Bennett, GIS specialist for ONRC.
- Courtney Bobsin, Ph.D. candidate, and is ethnoforestry lead for ONRC.
- Bryan Pelach, Ph.D. candidate.
- Chelsea Midgett, Ph.D. candidate.

Other co-principal investigators

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- Stephen Bollens, Ph.D., Aquatic ecologist, Washington State University, Vancouver is a PI on the riparian study.
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- J. Ryan Bellmore, Ph.D., Riparian ecologist, Pacific Northwest Research Station is a PI on the riparian study.
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- Elsa Toskey, M.S. student at WSU.