Forest Restoration in the Tongass

Why, How and Where

The Wilderness Society &
Southeast Alaska Wilderness Exploration, Analysis and Discovery

Written by: Bob Christensen

2012

Cover Photo: Gap Treatment Site

TABLE OF CONTENTS

LIST OF FIGURES

PREFACE

"I have read many definitions of what is a conservationist, and have written not a few myself, but I suspect that the best one is written not with a pen but with an axe." - Aldo Leopold 1949

In 2005 I began work on the "Tongass Ground-truthing Project" with my good friends Richard Carstensen and Kenyon Fields. For three years we assessed the impacts of past and proposed logging on the Tongass National Forest with a blend of GIS analysis and field surveys. We explored much of the Tongass and published reports that looked at the long-term effects of old-growth logging. Many of the findings were validations of what environmentalists had feared in watersheds "hammered" by the timber industry. As important as I believe this kind of monitoring was (and continues to be), the most profound things we learned pointed unexpectedly in another direction.

This is best illustrated by our observations while walking streams and riparian forests heavily logged in the 1950s'-70s'; forests that had essentially been tilled and compacted by the tracks of skidders and the butts of giant logs. Much to our surprise, what we found in the watersheds we ended up calling the "hammered gems" were vibrant and clearly valuable riparian habitats that continue to serve a globally significant abundance of salmon, bears, eagles, etc. Certainly to the eyes of forensic foresters and aquatic biologists there was evidence of the long-term costs of industrial logging (esp. impacts to large wood recruitment for fish habitat), but there were also clear signs of nature's capacity to adapt to catastrophic disturbance and rapidly regenerate the diversity and complexity of life. The inherent resilience of floodplain forests blew my mind, and in a sense, served to restore my inner landscape in such a way that I became very motivated to find out where I could plug in to this good work.

Contrasting riparian (L) and upland (R) second-growth.

While regenerating riparian forests in the hammered gems provided inspirational examples of nature's incredible resilience, conditions in the upland forests of these watersheds were another story. We found that upland stands, usually including most of a hammered gem's near-shore, south-facing and well drained habitats, often regenerated into dense thickets of young conifers that essentially shaded out most other life. These highly simplified stands are often described as "biological deserts", and provide very little habitat value. Even stands that had been thinned by the Forest Service quickly returned to a stem exclusion phase that without active management will remain very poor habitat for at least a hundred years. These stands beg for restoration action!

The vast majority of the work done in the process of ecological restoration is carried out by Nature herself, and in doing so, she is our most powerful teacher and ally in this endeavor. Through ecological restoration we can learn about what it takes to re-create the diversity and abundance of biological life (no doubt we have a responsibility to do so), and with axe in hand, we can actively participate in restoring humanity's connection to the land. In this way restoration is a path to, as William Jordan has said, a "full citizenship in nature". As citizens of nature I have no doubt we can serve our common good by contributing to nature's recovery through ecological restoration, but the most important way we can do this may be by allowing the experience of ecological restoration to assist us with reinventing the sacred nature of our connection to the earth, and in so doing, work on the root cause of environmental degradation.

Walk the flood-plain forests of Southeast Alaska and experience nature's restorative power, and like me, you may be compelled to participate in ecological restoration.

- Bob Christensen, 2012

GRATITUDE

First, I want to thank the Wilderness Society for giving me the opportunity to work on what I believe is one the most valuable things a citizen can be thinking about today - ecological restoration. I appreciate their staff's patience, especially Evan Hjerpe, with my slow and intensely heuristic approach to these kinds of projects.

Although my occupation is as an environmental consultant, I consider myself first and foremost a student of nature. Since coming to Southeast Alaska in 1991 I have been dedicated to learning as much as I can and have been engaged in a rigorous field studies program that has provided opportunities to let my curiosity run wild in forests, beaches and waterways of Southeast Alaska. I owe the deepest gratitude to the nature of Southeast.

Along the way, I have worked with and befriended many "teachers" that I owe much of my understanding too. There are too many to mention here, but I do wish to acknowledge one in particular - John Coauette. John was a brilliant statistician who worked for the Forest Service and who successfully ushered us beyond the timber volume paradigm to seriously consider the role of structural complexity in the stewardship of forested habitats. John was also a wonderful person- as playful as a child, as thoughtful as a great philosopher and as earnest as a human being can be. You could always count on John to help you see things clearer, or raise important questions in a way that was rigorous, open-minded, systematic, insightful, and above all, profoundly enthusiastic and supportive. I think his world-view is a particularly suitable blend of attitudes for developing a restoration program for the Tongass and I have taken great pleasure in imagining what John would say many times while writing this report. Thanks John, you are sorely missed.

Finally, I want to thank all the folks that provided feedback as this document took shape, especially Dominick DelaSalla and Andrew Larson who provided a thorough peer review.

John Coauette

BRIEF SUMMARY

This report is meant to be an approachable reference on ecological restoration of Southeast Alaskan forests. Our intended audiences are resource managers, community and tribal leaders, conservationists, contractors and others interested in forest restoration. For this effort we have conducted an exhaustive literature review, interviewed experts in the field, conducted GIS analysis and drawn from ground-truthing experiences throughout the region.

KEY FINDINGS

- Habitats that serve critical ecological and social functions (salmon forests) and are sensitive to logging (karst forests) have been disproportionately impacted by past logging in Southeast.
- Numerous Tongass watersheds and landscapes that are uniquely productive for species like salmon and deer have been highly degraded by past logging.
- The effectiveness of the Tongass Land Management Plan's conservation strategy is limited by having been designed in an already degraded forest.
- The scientific literature documents several silvicultural tools proven effective for restoring structural complexity, biodiversity and ecological function.
- Initial stem density reductions (e.g., pre-commercial thinning) in second-growth forests provide a critical step in ecological restoration by greatly increasing future silvicultural options for wildlife habitat enhancement.
- There is compelling evidence that variable density thinning with skips and gaps is the most effective approach for restoring old-growth characteristics.
- Strategic planning that prioritizes and integrates restoration actions across multiple scales enhances the effectiveness of restoration efforts.
- There is wide ranging support for the watershed as a particularly useful scale for orienting and planning on the ground restoration activities, especially where salmon are a species of interest.
- There is broad support within the scientific community for acknowledging and dealing with uncertainty by employing effectiveness monitoring and adaptive management practices.
- The benefits of employing a collaborative approach to ecological restoration are rapidly coming to light through a number of real world examples.

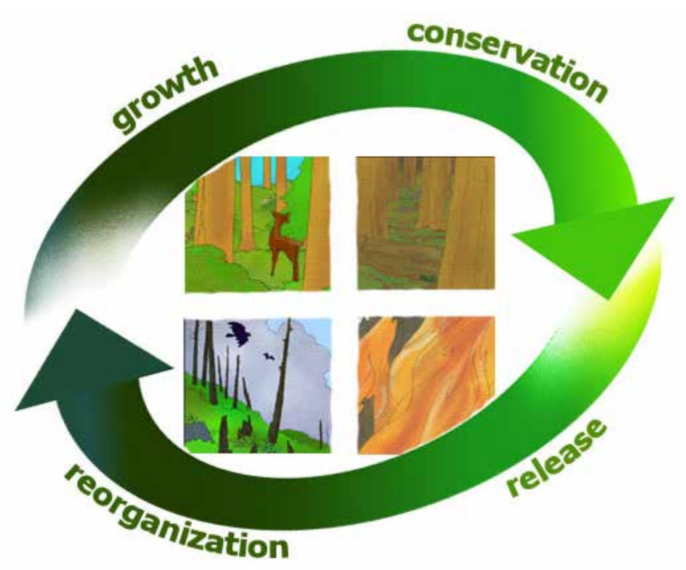
The Cobble landscape on Prince of Wales Island is an example of an area where the majority of prime salmon and deer habitats have been logged and where restoration can accelerate the recovery of these ecological attributes.

INTRODUCTION

THE PURPOSE OF THIS DOCUMENT

We are at a turning point in Southeast Alaska. We need only look south to the forests of Washington and Oregon to glimpse the future of Tongass forest management. True, our own reality will be a customized version of what we see in this crystal ball, tailored by the challenges and opportunities that are peculiar to this region, but the gist is plain for those willing to see - the future of forest management lies primarily in the lands that have already been logged, and what we do there will likely be influenced by contemporary pressures to manage these lands for more than timber production.

The reasons for this transition are numerous and debatable: a boom and bust cycle that has run its course, a change in the public's priorities for how federal forest lands should be managed (manifest in various environmental laws), the perturbations of a globalized wood-products market, etc., but the question is largely moot. The transition has, for all practical purposes, already happened (Beier et al. 2009).



Holling's adaptive cycle (1986) was used in the Beier article cited above to describe the history of Tongass timber system and to address the connection between social and ecological resilience. In the Beier paper the system of forest management is described as having recently gone through a boom and bust cycle that finds both environment and society in the reorganization and growth phase. This phase is critical to orienting the trajectories of recovery in the direction of ecological and social resilience.

The concept of "resilience" is used throughout this report. What do we mean by resilience?

Resilience is an indicator of the range of disturbance that ecosystems, economies, cultures, communities, etc. are capable of experiencing without losing their essential character (Gunderson & Holling 2002).

There is a growing body of work that applies the concept of resilience to integrated social-ecological systems because people are integral parts of ecosystems and changes in our world are demanding proactive, rather than reactive approaches to adaptation. Resilience in this context comes from:

- **promoting biological, institutional and cultural diversity;**
- **embracing change and learning from history and experimentation;**
- **thinking long-term about slow variables & anticipating the future. (Chapin et al. 2004)**

It is likely that much of the future forest work on the Tongass will focus on, or include aspects of, ecological restoration. In fact, for a large portion of logged forests in the Tongass (areas that are now mandated to be conservation lands) some form of restoration is required for responsible land stewardship. However, there are many unanswered questions about how to use ecological restoration to balance improved ecological integrity with the social values provided by forest ecosystem services.

Fundamentally, this report is an effort to provide useful perspective and technical information on employing ecological forest restoration to improve social prosperity and ecological integrity. The broad goals of this report include: defining what restoration is, highlighting what it is good for and discussing how to prioritize, plan and implement it on the ground using practical and effective silvicultural tools. Toward that end, we have synthesized a broad spectrum of scientific literature on forest restoration and integrated key findings with local issues.

WHAT IS ECOLOGICAL RESTORATION?

The dictionary defines restoration as a *return to a prior state* through replacement or repair but there is considerable debate on what the term means, or should mean, in an ecological context. As one writer put it, when you are restoring an old car it is a straight-forward affair to acquire the engineering diagrams and parts necessary to return the vehicle to its prior, "original" condition.

But nature is far more complex and dynamic than an old car. In ecological restoration we rarely have anything that approaches a complete parts list, we certainly do not have engineering diagrams and we are further hampered by an incomplete understanding of how it all originally worked (Halvorsen in Hobbs et al. 2004). Add in the dynamic and ever-changing nature of nature and the challenge of defining ecological restoration begins to take shape.

One of the primary authorities in defining ecological restoration is the Society for Ecological Restoration (SER). SER defines ecological restoration as an "intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability". - SER 2008

Thoughtful arguments have been made that the SER definition is too loose and leads to "false advertising" in the field of restoration. Strong cases have also been made that the definition is too specific and does not allow for pragmatism or "future-proofing" restoration efforts (Choi 2007). The debate pivots on questions like: Recovery to what? What are ecosystem health and integrity? What is sustainability? (Elliot 1982, Light & Higgs 1993, Bradshaw 2002, Katz 2003, Hobbs et al. 2004, Throop & Purdom 2005)

The details of defining ecological restoration are important to pursue as part of every ecological restoration effort, but they will never be absolute. Like Higgs (1994), Parker & Picket (1997) and Bradshaw (2002), we believe "context should influence what we understand restoration is".

There are approximately 430,000 acres of regenerating clearcut forest on the Tongass National Forest (plus ~ 340,000 acres on state and private lands). There is room for a broad spectrum of ecological restoration approaches that range from very strict adherence to pre-logging ecological fidelity (e.g., in congressional and administratively designated non-development lands) to balancing social values with functional ecological integrity (e.g., roaded areas, especially near rural communities).

"The definition of good restoration will vary from site to site, but will always be rooted by ecological fidelity: the combination of structural replication, functional success, and durability." - Higgs 1997

The US Forest Service has adopted the SER definition of ecological restoration in their Interim Directive on Ecological Restoration and Resilience (USFS 2010). In addition to identifying ecosystem recovery as a primary goal, this document emphasizes the role social values play in defining restoration and targets ecological resilience. In doing so the USFS identifies broad social and ecological contexts as being important to defining ecological restoration. This broader scope is supported by some of the leaders in the field (Jordan 1993, Cairns 1995, Hayles 1995, Higgs 2005, Hobbs et al. 2006).

Ecological restoration has been practiced in an ad hoc style on the Tongass in the past but given the minimal scale and limited monitoring of past actions it is clearly still in its formative stages. We are poised to make ecological restoration a much more central part of Tongass forest management.

This shift in forest management priorities will likely involve an unprecedented degree of collaboration with rural communities. This dynamic social context will surely shape the details of what can and will be defined as ecological restoration. It is a broader conversation that is only just beginning in Southeast Alaska and our hope here is to provide food for thought. In that light we offer some local perspective on what restoration *is not*.

WHAT RESTORATION IS NOT

To assert that activities only qualify as ecological restoration if they result in a carbon copy of the pre-disturbance ecological conditions is unwise (Hilderbrand et al. 2005). Change is integral to nature and any snap-shot in time provides only part of what is actually a moving picture. It may be impossible to achieve strict historical fidelity in the outcomes of ecological restoration and it would be unfortunate if scientists, managers, practitioners and citizens were to become high-centered on this issue. However, it is equally unwise to muddy the definition of ecological restoration so much that there is no clear link between the activity and its contribution to long-term ecosystem recovery. A purely relativistic interpretation of what constitutes restoration undermines credibility on all fronts.

The most obvious cases of muddying the waters of restoration occur in mitigation. Mitigation seeks to offset proposed ecological damage through the repair or creation of habitats with similar values. This is common practice in land development activities where habitats are completely destroyed to make room for mines, highways, housing developments, etc. Typically mitigation strives for a "no net-loss" outcome. Though there is considerable overlap in the techniques used in mitigation and those used in restoration, the relationship with ongoing degradation and "no net loss" sets mitigation apart and runs counter to the first principle of ecological restoration; restoration seeks to *stop and reverse degradation* (National Research Council 1996) where mitigation seeks to o*ffset ongoing degradation*.

Mitigation can play a role in ecosystem recovery but confusing it with restoration is like confusing the bailing of a sinking boat with fixing the leak. - Carstensen & Christensen 2008

A key aspect of identifying what is and what is not restoration is the *primary intent* of the activity. A good local example of what we mean here is pre-commercial thinning or "PCT". The primary intent of PCT is to increase the future economic value of a stand by reducing tree density to concentrate growth in desirable trees (TLMP 2008). Although this activity results in a stand with healthier individual trees and can provide an important interim step in ecological restoration, the initial result is still a highly simplified and homogenous forest whose fate is likely a relatively rapid return to clearcut. Where diversity exists in pre-commercially thinned stands it is more often due to variation in site productivity or natural disturbance than to intentional promotion of long-term biocomplexity.

This area was clearcut in 1964 and pre-commercially thinned in 1982. The ecological benefits of PCT here have largely been erased at this point in time with only trace elements of understory vegetation remaining.

Silviculturists are well aware of the need to provide ecological values within timber stands and are correct in pointing out the benefits of PCT (short-term understory productivity, increased wind firmness and <u>stem density reductions that greatly enhance future silvicultural options</u>). However, the primary intent of PCT in most of the treated stands in the Tongass has been to optimize wood production. PCT prescriptions can contribute to improved ecological integrity by setting a stand up for additional treatments that provide longer-term ecological values, but if additional treatments are not part of the plan and the primary intent is a return to a large-scale clearcut it is unreasonable to call these efforts ecological restoration.

The discussion of what is and what is not restoration will continue for some time. We consider this a good thing as it is a sign of active learning and an open exchange of ideas. Lacking an absolute definition, perhaps an equally relevant question at this time is: why do ecological restoration?

WHY DO ECOLOGICAL RESTORATION?

> **"Here is the means to end the great extinction spasm. The next century will, I believe, be the era of restoration in ecology". - E.O. Wilson 1992**

The reasons for doing ecological restoration are numerous and the list continually grows in proportion to our expanding ecological and social awareness. Clewell and Aronson (2006) have published a very useful paper on the subject called Motivations for the Restoration of Ecosystems where they describe five rationales: technocratic, biotic, heuristic, idealistic, and pragmatic.

- Technocratic motivations stem from a governmental responsibility for maintaining the basic environmental conditions for survival including clean air, clean water, and preventing species extinction.
- Biotic motivations stem from broad-based support for biodiversity conservation, including species, biotic communities, ecotypes and landscapes.
- Heuristic motivations emphasize the opportunity to better understand ecological systems presented by their intentional restoration or re-creation (Bradshaw 1983), what Walters and Holling referred to as "learning by doing" (1990).
- Idealistic motivations for restoration reflect the connection between people and nature and often drive local stakeholder involvement where diverse groups engage in balancing environmental, economic and social values. Idealistic motivations also emphasize the power of restoration to provide a medium to heal the environmental despair experienced in society while counteracting the root causes that lead to this despair.
- Pragmatic motivations for restoration emphasize the material consequences to humans of doing, or not doing ecological restoration. These motivations are wide-ranging and include things like maintaining access to air, water, food, jobs, scenic beauty and recreation opportunities as well as larger scale issues like climate stability.

Ecological restoration in Southeast Alaska can draw upon each of the above rationales:

- Governmental agencies are responsible to fully account for the early, unfettered logging practices it facilitated in the 1960s - 1980s;
- There is growing awareness of the importance to conserve rare and important habitats and species, including endemics;
- Southeast provides a globally unique research opportunity in doing ecological restoration near pristine reference conditions and in a landscape that still retains all of its parts;
- Both indigenous and settlement populations have suffered from the social ills that follow a boom and bust economic phase, as well as deeper historical injuries that can both be aided through bio-cultural restoration efforts; and,
- The interdependence of social and ecological resilience is readily apparent in Southeast and provides a rare opportunity to strike a balance between local prosperity, productivity and ecological resilience that is recognized as globally significant.

Clewell and Aronson make a strong case for unifying these five rationales as a means of improving the effectiveness and relevance of restoration efforts, especially with regard to gaining much needed public support by emphasizing social benefits. The melding of idealistic and pragmatic motivations is particularly compelling because of the potential for realizing both material and non-material social benefits, both of which are intimately connected to the way in which people treat the natural world.

> **"Restoration work is not fixing beautiful machinery, replacing stolen parts, adding fresh lubricants, cobbling and welding and rewiring. It is accepting an abandoned responsibility. It is a humble and often joyful mending of biological ties, with a hope clearly recognized, that working from this foundation we might, too, begin to mend human society." - Barry Lopez 1991**

THE SETTING

SOUTHEAST ALASKA

Southeast Alaska is a wild and dynamic panhandle of land that is sandwiched between the Pacific Ocean and the Coastal Mountains that run along the border of Canada (Figure 1). Plate tectonics have resulted in one of the most complex geologies on earth. Repeated glaciations have carved the bedrock into an island archipelago of rugged mountains and deep fjords that includes thousands of miles of coastline and hundreds of mapped islands. The "shavings" of this glacial carving have been left in a variety of deposits on the ridges, slopes and valley bottoms. These glacial deposits have been reworked by mass-wasting and riverine processes of an intensity that can only be achieved when mixing persistent and often heavy precipitation and steep topography, resulting in a mind-boggling complexity of landforms, each with their own inclinations towards the kinds of living communities they host.

Figure 1. Google Earth view of Southeast Alaska.

Since the last major glaciation, most plants and animals migrated in by air, water, foot or as a passenger aboard another form of life. There are species who can trace their colonial path back to the west and the Bering land bridge, the north and east via the trans-boundary river systems that cut through the coast range, from the south along the inside passage and quite possibly from glacial refugia along the outer coast (Heaton 2003).

Satellite image of the Glacier Bay area helps to imagine how glaciers shaped Southeast's topography.

Current scientific research indicates the region has been inhabited by indigenous peoples for at least 13,000 thousand years. These early human inhabitants probably made their way here along ancient coastlines from the northwest and more recently via the same trans-boundary rivers systems that even today are still acting as colonizing corridors for new forms of life.

A highly dynamic geological and glacial history, isolation, heavy precipitation and a distinctive disturbance regime of high-frequency, small-scale natural disturbances such as wind-throw, landslides and endemic tree disease have produced a forest that is relatively simple in tree and shrub species composition but is highly complex in age, structure, productivity and plant community patchiness (Deal et al. 1991, Kramer et al. 2001, Hennon & McClellan 2003).

Old-growth, muskeg, uplift forest and estuarine beach meadow complex of Hoonah Sound.

THE TONGASS NATIONAL FOREST

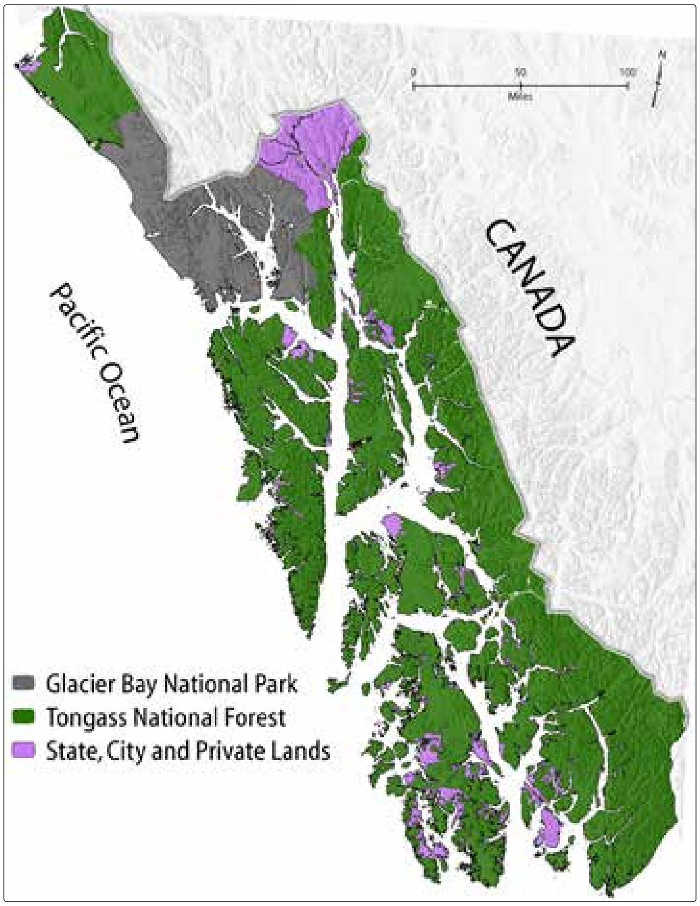


Figure 2. The Tongass National Forest

Theodore Roosevelt established the Alexander Archipelago Forest Reserve in 1902 by presidential proclamation. In 1907, Roosevelt passed a second proclamation that created the Tongass National Forest.

In 1908 the two forests were joined into a single national forest, with the combined forest area encompassing most of southeast Alaska. Further presidential proclamations in 1909 (in the last months of the Roosevelt administration) and in 1925 (by Calvin Coolidge) expanded the National Forest to its present area. Today, the Tongass National Forest (Tongass) encompasses 17 million acres of public land (Figure 2). It is the largest National Forest in the US.

Although the information presented in this report is relevant to all forested areas in Southeast Alaska, and there are many non-national forest areas in Southeast Alaska that could benefit from ecological restoration, the focus here in this report is on the Tongass.

LOGGING HISTORY

Individual tree selection and small-scale logging has occurred on the Tongass since the first peoples settled here. Early uses included shelter, boxes, canoes and various tools by indigenous peoples, buildings, shipwright work, charcoal and some experimental export by Russian colonizers, lumber, pilings and large logs for mining operations, herring reduction plants, salmon canneries and fish traps in the years leading up to statehood (Mackovjak, 2010).

Early logging was conducted by "hand-loggers" who high-graded the largest and best trees one at a time from the near-shore coastal and riverine areas. Beginning in the 1930's, A-frame logging of the coastal fringe created a scattering of small clearcuts. In both cases impacts to wildlife habitat were generally low (a few exceptions like eagle nesting trees).

"This form of logging, or beach combing, [hand- and A-frame logging] has been practiced for years, and in almost any bay or good booming and rafting grounds we find that most of the handy spruce has been removed." - N.J. Frost, Southeast Alaska timber cruiser, 1928

The severest impacts and most obvious restoration needs come from the first few decades of industrial logging. This era began in the 1950s when long-term contracts between the USFS and timber companies were signed that guaranteed an industrial scale supply of old-growth to pulp mills in Ketchikan and Sitka. At the time, there were few regulations to direct logging and it is no surprise that the industry targeted the easiest to access and highest volume stands as a matter of course. This resulted in a pattern where beach, riparian, and the most productive and accessible upland forests were logged first.

Although this pattern of industrial logging was driven largely by economics, strong ties between economics and forest productivity resulted in degradation of some of the most important fish and wildlife habitat in the region. Like in many other forested landscapes (Lindenmeyer & Franklin 2002), this resulted in an under representation of intact forms of these habitats within designated conservation areas in the Tongass.

KEY CONTEXTUAL ELEMENTS

Restorationists can find themselves walking in the shoes of the historian, detective, soothsayer, scientist, and inventor in rapid succession in their efforts to identify the goals and objectives of restoration work and the methods for generating desirable outcomes. An understanding of a few of the working parts, basic processes and forest types in Southeast Alaska's dynamic and complex setting can be very helpful in these endeavors.

We include in this section a brief description of some key contextual elements and encourage the reader to consider how these variables might interact and evolve at a variety of spatial and temporal scales for each site, watershed and landscape you find yourself working in.

Key Concepts

Biodiversity - is the variety of life and its processes, including the variety in genes, species, ecosystems, and the ecological processes that connect everything in ecosystems.

Productivity - is the rate of production and total carrying capacity associated with a specific species, or habitat type in a given area.

Habitat - is an area with the combination of resources (e.g., food and cover) and environmental conditions (e.g., temperature and competitors) that promotes occupancy by individuals of a given species (or population) and allows those individuals to survive and reproduce.

Connectivity - is a measure of landscape "permeability" that derives from the costs associated with meeting a species' habitat requirements as it moves through space and time. Connectivity is important for population viability and genetic diversity and is a common goal of restoration.

Succession - is the process by which plant and animal communities successively give way to another. Southeast forests typically progress from stand initiation to stem exclusion, understory re-initiation and old-growth forest. Restorationists can shape the trajectory of secondary succession following catastrophic disturbance from logging.

Field-work in Southeast is a good way to get a handle on how wet the climate. Shown here, the author at right along with mentor and trusty field companion Richard Carstensen - Koziusko Island Rainforest.

Climate

The climate of Southeast is maritime with cool, wet weather predominating throughout most of the year. Annual precipitation varies from less than 30 inches to more than 250 inches per year but the vast majority of the region can simply be described as very wet. It is so wet in fact that one of the primary factors affecting plant community dynamics is how well-drained the site is (Harris and Farr 1974, Cullen 1987).

The climate is also quite cool, even during the brief summer period, and plant growth tends to be concentrated in just a few months per year. The northern most extent of several relevant plant species occurs in southeast (e.g., Western Redcedar, Salal, Sword Fern) likely due to insufficient growing degree days.

Elevation amplifies the cool and wet conditions of the region and greatly increases snowpack accumulations. Growth rates above 1,000 feet can be so slow that trees may only add a few inches of girth in 100 years.

Bedrock Geology

Bedrock geology in Southeast is highly complex. There are 9 geologic terrains sandwiched in the 70 mile width of our region! The many subtle variations in rock types that make up these terrains erode in different ways and serve as distinctive types parent material for drainage patterns, aquatic habitat and soil development.

Repeated glaciations further complicate the situation through mechanical weathering and mixing the deposition of various types of glacial till that can make it difficult to precisely discern how geology may be influencing ecological processes. However, there are a few generalizations that can be made that can provide a basic orientation for the restoration planner and practitioner.

For example, granitic rock-types tend to underlay lower productivity forests because they often lead to poor drainage patterns and weather to produce nutrient poor soils that can even be a bit toxic to plants. In contrast, some sedimentary, metamorphic and volcanic rock-types more frequently underlay productive forest types because they are more friable and lead to better drainage and soil development (Carstensen & Connor 2011).

Limestone bedrock is a very special case that underlays some of the most productive forests in the region. As early as 1930 it was known that the best timber in Southeast grew on limestone bedrock (Mackovjack 2010).

This large tree is growing directly on an epikarst feature.

"Karst lands add a vertical, underground dimension to planning. A few characteristics of this ecological unit include mature, well-developed spruce and hemlock forests along valley floors and lower slopes, increased productivity for plant and animal communities, extremely productive aquatic communities, well-developed subsurface drainage, and the underlying unique cave resources." - (TLMP 2008)

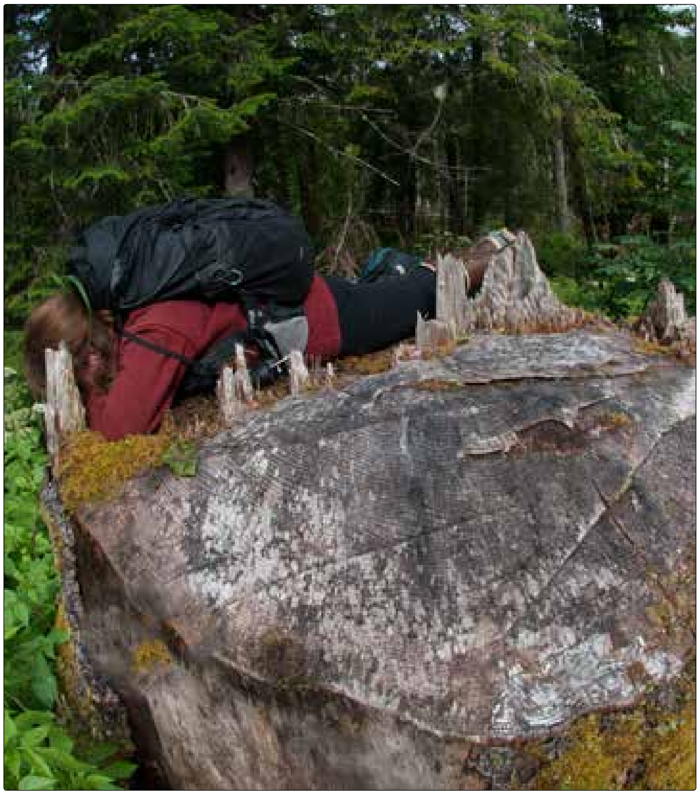
Our region's heavy rainfall and acidic soils erode limestone into surficial features (karst) and subterranean cave systems, both of which provide beneficial drainage. Limestone bedrock also leads to productive soils by buffering PH and preventing soil compaction, though oftentimes this soil layer can be quite thin.

Karst forest represents only 6% of productive forest in the Tongass, about 45% of which has been logged (Figure 3). The vast majority of karst *large-tree forest* was logged by 1975. Ongoing emphasis on rapid rotation timber harvest of karst forests could lead to major soil loss and damage to sensitive epikarst and cave systems as it has in other areas of the world (Harding and Ford 1993, Baichtal and Swanston 1995). Special attention should be given to karst forests during restoration planning and caution should be taken when operating in these areas.

Landforms

Landforms are classified at a variety of scales depending on the subject. Geological scale landforms in Southeast include features such as mountain ranges, island groups and watersheds and find their origin and current condition in tectonic and glacial processes.

For the purposes of this report we are interested in finer-scale 'surficial landforms' that derive from recent glacial, marine, fluvial and hillslope process. These type of landforms are one of the most influential factors in a shaping a site's biodiversity, productivity and structural complexity due to the influence these features can have on drainage, disturbance regime and soil development (Cullen 1987). Knowing what landforms occur in a restoration area is critical to predicting the trajectory of succession fol-



This 5 foot diameter spruce was just over 100 years old when it was cut - a testament to the remarkable productivity of alluvial surfaces. .

lowing treatments and for effectively planning at watershed and landscape scales.

Some of the most well-drained and productive landforms in Southeast Alaska are alluvial surfaces (sediments deposited by water) and colluvial surfaces (sediments deposited by gravity). Forests that grow on these landforms are often especially productive because they are both well-drained and nutrient rich. Plant and animal diversity can also be high (Hanley & Hoel 1996) in part because these surfaces experience micro-scale shuffling of successional ages following relatively frequent disturbance events.

> **"The most structurally and biologically diverse stream habitats of Southeast are found on the lowland flood-plains. Southeast's largest salmon spawning runs are in flood-plain channels. Rearing values for all 5 Pacific salmon species as well as Dolly Varden char and steelhead are higher on flood-plain streams than in any other channel process group." - Carstensen 2007**

Alluvial forests that occupy valley bottom flood plains and tributary alluvial fans provide a backbone of watershed habitat productivity and connectivity for a variety of plant and animal species. These areas are even more critical if they host salmon streams (salmon forest) because of the added boon of marine derived nutrients that enter the food web in these locations (Reimchen 2001, Chaloner et al. 2002, Gende et al. 2003, Naiman et al. 2010).

Salmon forest accounts for only 6% of productive forest types in Southeast Alaska. *Nearly 50 watersheds in the Tongass have seen over 75% of their salmon forests logged* (Figure 3).

Like karst, well-drained surficial landforms are rare and productive features in Southeast. Strategic planning of restoration efforts should take into account the roles productive landforms play at watershed and landscape scales.

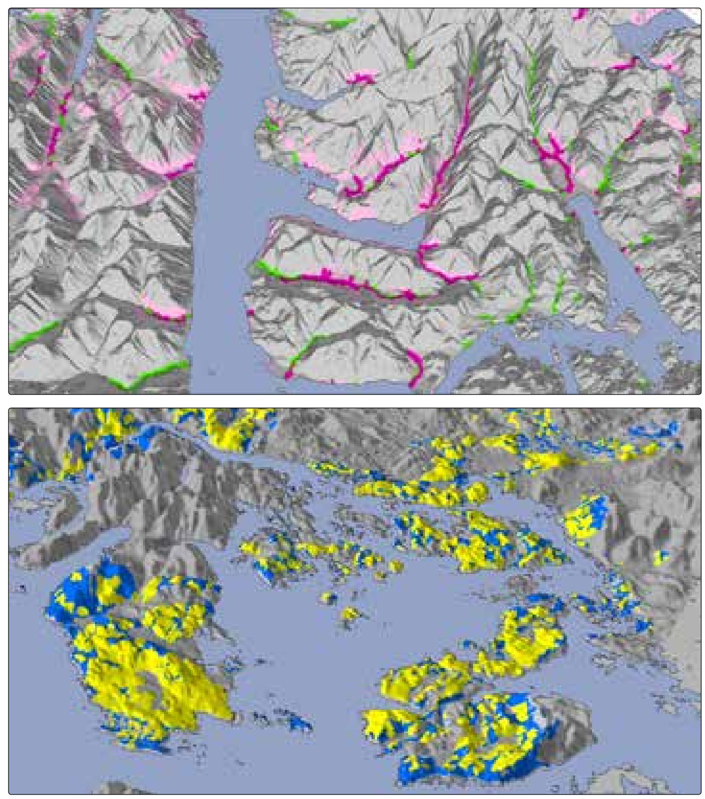


Figure 3. Landscape scale impacts to highly productive forest types. Top map shows northern Baranof and Southern Chichagof islands where the majority of anadromous flood-plain forest (or salmon forest), and alluvial fan forest, have been logged (pink = logged, green = intact). The second map focuses on the Sea Otter Sound area of Prince of Wales island where the majority of karst large-tree forest types were logged by 1975 (yellow = logged, blue = intact).

Habitat Fragmentation

Habitat fragmentation is an important but somewhat difficult to understand concept. Habitat fragmentation can be both a state (e.g., associated with an island archipelago) and a process (e.g., associated with natural and anthropogenic disturbance) and depending on the species of interest, the same process that increases fragmentation for one species may result in a decrease in fragmentation for another. To further confuse things, at finer-scales some degree of fragmentation is characteristic of specific types of habitat. For example, fragmentation in canopy closure is a distinguishing feature of gap-phase old-growth forest.

> **"Taken together the island structure and the dendritic pattern of much of the forest means that the Tongass National Forest has a natural level of fragmentation unsurpassed by any other National Forest. This base level of fragmentation must be clearly understood before the effects of management-induced fragmentation can be properly evaluated." - Keister & Echardt, 1996**

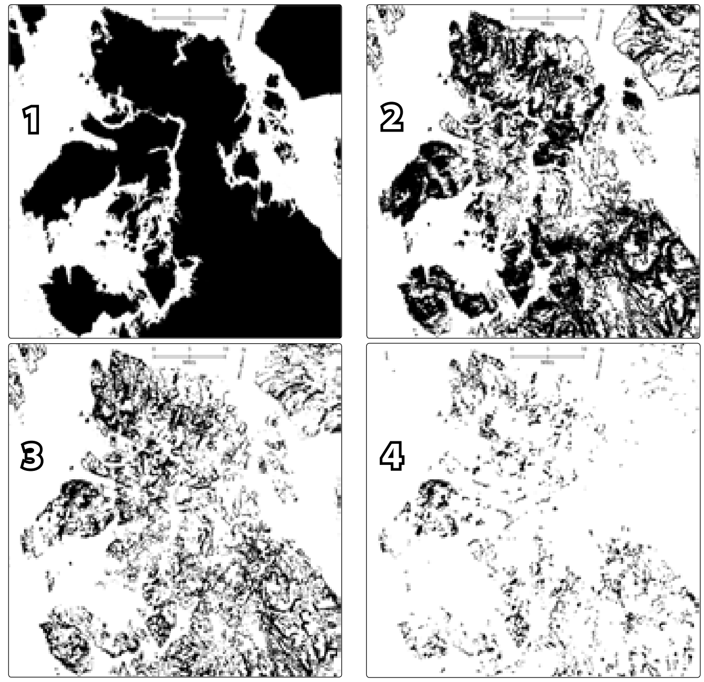


Figure 4. Fragmentation on Northern Prince of Wales Island. 1) Land fragmented by Island Biogeography; 2) productive forest land before logging; 3) productive forest land after logging; 4) productive large-tree forest after logging (Size-Density Classes 6 & 7).

There are many ways that habitat fragmentation can stress populations: habitat loss, core area loss, increased edge density, increased patch density, reduced average patch size, etc., each of which is worthy of a dissertation or two. For those who are interested, we highly recommend Lindenmayer 2006, and for the spatially inclined, McCarigal 2012 (FRAGSTATS 4.0).

A good way to think about habitat fragmentation within the context of the ecological restoration of logged forests in Southeast is to consider the ecological process known as "neighborhood effects" (Dunning et al. 1992). Neighborhood effects refers to the ability of an organism to move from one habitat patch to another and is influenced by the distance between habitat patches and the "permeability" of the space between (Frelich & Reich 1995).

Landscape permeability is determined by the degree to which the space between optimal habitat patches is hostile or hospitable (Singleton et al. 2002). Permeability between patches is also referred to as "connectivity" (Baudry & Merriam 1988). One of the most obvious impacts of logging on landscape permeability is habitat fragmentation leading to reduced connectivity (Lyndenmeyer & Fisher 2006). This can be risky in landscapes with high degrees of natural fragmentation and associated endemism.

Past logging has dramatically added to natural habitat fragmentation and reduced the amount of effective habitat for wildlife species that depend on old-growth in many watersheds throughout Southeast (Figure 4). This has occurred in the form of decreased overall old-growth acres, decrease core old-growth acres, decreased core/edge ratio, decreases in the average size of individual blocks of old growth and increased distance between these blocks (Shephard et al. 1999), among others.

Reducing habitat fragmentation (and increasing connectivity) through ecological restoration will depend upon our ability to design restoration prescriptions and plans that increase the size of small patches of remnant old-growth habitat and increase landscape permeability between these patches and the larger blocks that occur in riparian management areas, beach buffers and old-growth reserves.

Natural Disturbance

The biodiversity, productivity and complexity of forest ecosystems we hope to assist restoring in Southeast would typically be shaped by the natural disturbance agents of wind, mass-wasting, flooding, snow-loading, insects, disease, fungus, etc. (Harris & Farr 1974). Wind is the most significant disturbance agent in terms of total acres on the Tongass. Both lower-frequency large-scale stand replacing events and higher-frequency small-scale gap creation events are common (Deal et al. 1991, Nowacki & Kramer 1998, Ott & Juday 2002).

Disturbance that exposes mineral soils favor spruce and alder regeneration (e.g., flooding, landslides, wind disturbance that uproots trees), while disturbance that leaves the soil layer intact favors hemlock regeneration (i.e. single tree mortality from insects, disease, fungus and wind that break the tree at the bole).

Natural disturbance in Southeast Alaska generally leaves the biomass and structure of the trees on-site while logging and restoration prescriptions that remove wood result in a loss of legacy structures (Tappeiner et al. 1997, Lindenmeyer & Franklin 2002). This is one of the key differences between natural disturbance and timber management. Removal of wood as part of restoration should be done in moderation and with consideration for how the loss of the material might impact the short-term values and long-term trajectory of the site.

"Wind disturbance plays a fundamental role in shaping forest dynamics in southeast Alaska. Recent studies have increased our appreciation for the effects of wind at large and small scales. Current thinking is that wind disturbance characteristics change over a continuum dependent on landscape features (e.g., exposure, landscape position, topography). Data modeling has revealed distinct wind disturbance regimes, grading from exposed landscapes where recurrent, large-scale wind events prevail to wind-protected landscapes where small-scale canopy gaps predominate. Emulating natural disturbances offers a way to design future management plans and silvicultural prescriptions consistent with prevailing ecological conditions." - Nowacki & Kramer 1998

Google Earth image looking north over the west end of Lemesurier Island and into Glacier Bay National Park. Two patches of blowdown are outlined in the foreground, each of which is between 3 and 5 acres. These stands were blown down 10 years ago by Northerly gales from a strong winter high pressure system and facilitated by proximity to the Glacier Bay fjords - probably a much more common event in the little ice age.

Example of single tree mortality creating canopy gap and associated understory growth response (+ blueberry and bunchberry response). In this case the stem of the tree was "snapped-off" and left the soil layer intact.

The dominant coniferous tree species in Southeast Alaska are Western Hemlock, Sitka Spruce, Western Redcedar, Alaskan Yellow-cedar and Mountain Hemlock. We include below a brief description of each tree that is relevant to forest restoration in Southeast Alaska.

Western Hemlock (Tsuga heterophylla) - Western Hemlock is the largest of the worlds Hemlock trees and can grow to heights over 190′ with diameters exceeding 9′ recorded. Western Hemlock is long-lived (> 1,200 years) and highly shade-tolerant. They grow slowly in the understory until a gap provides an opportunity for more rapid growth. Western Hemlock will often become stand dominants in disturbance refugia and their propensity to deformity and heart-rot make them valuable wildlife trees.

Sitka Spruce (Picea sitchensis) - Sitka Spruce is the largest of the worlds spruce trees and can grow to heights over 200′ with diameters exceeding 15′ recorded. Sitka spruce is long-lived (> 800 years). The root system is generally shallow except on deep well-drained soils and karst. Sitka Spruce is fairly shade-intolerant and does well as a pioneer or climax species, especially on mineral soils. Germination and seedling survival are enhanced by sprouting on nurse logs, especially on semi-active flood plains.

Western Redcedar (Thuja plicata) - Western Redcedar is a large cypress tree capable of heights > 150′ and diameters exceeding 20′ recorded. Western Redcedar is a very long-lived tree species(> 1,400 years) that is highly shade-tolerant. Western Redcedar is found most often with hemlock and/or spruce on moister soils in Southern Southeast Alaska and like hemlock can provide excellent wildlife habitat to cavity nesters and species that can utilize forked tops. Its northern distribution is limited to about midway up the panhandle.

Alaskan Yellow-cedar (Chamaecyparis nootkatensis) - Alaskan Yellow-cedar is a moderate sized cypress tree capable of heights > 150′ and diameters exceeding 20′ recorded. Yellow-cedar is very long-lived (> 1,400 years) and is considered shade-tolerant in most of its range, though probably less so locally. Yellow-cedar are highly rot resistant and provide long-standing snags throughout its range. These snags are especially abundant in areas where Yellow-cedar die-back is occurring. Yellow-cedar is found growing most often with hemlock on moist to wet soils and is distributed sporadically throughout the region (somewhat tied to a latitudinal/elevational gradient).

Red Alder (Alnus Rubra) - Red Alder is the most common deciduous tree outside of the transboundary river systems and can be found on alluvial fans and in locations of recent mineral soil exposure such as landslide areas and where ground disturbing logging techniques were used. Red Alder is a nitrogen fixing pioneer that is also highly regarded as enhancing a variety of wildlife habitats (e.g., salmon, birds, small mammals).

Read more in Silvics of North America (Burns & Honkala 1990).

Forest Types

Of the 17 million acres in the Tongass National Forest only about one third hosts productive forest lands. Productive forests in Southeast have some of the greatest biomass accumulation of any ecosystem on earth (Leighty et al. 2006) making the Tongass a globally significant carbon sink (DelaSalla et al. 2011).

This biomass accumulates in a wide variety of forms. For example, within what qualifies as productive old-growth or "POG", there are significant differences in wood volumes per acre (from < 10,000 to > 200,000 board feet per acre), plant diversity, structural complexity and wildlife habitat qualities. The type and extent of specific types of old-growth habitat loss are critical to understanding what and where to conduct ecological restoration. Examples of a few POG forest types are included on this page.

Low-volume-high-complexity wetland forest.

Low-volume-high-complexity poorly drained forest.

Very-high-volume-low-complexity "wind forest".

High-volume-very-high-complexity karst forest.

High-volume-very-high-complexity riparian forest.

The mixing and weighting of the components of forest ecology listed in the previous few pages (as well as others) result in a spectrum of forest types that range from wetlands with only a few trees per acre to well drained and wind prone sites that may at times have several thousand trees per acre. A variety of forest classification systems have been developed to provide resource specialists additional detail beyond the simplistic classification of POG/not POG. For an excellent summary of relevant forest classification systems please see Chapter 5 of <u>The Coastal Forests and Mountains Ecoregion of Southeastern Alaska and the Tongass National Forest</u> (Schoen & Dovichin eds. 2007).

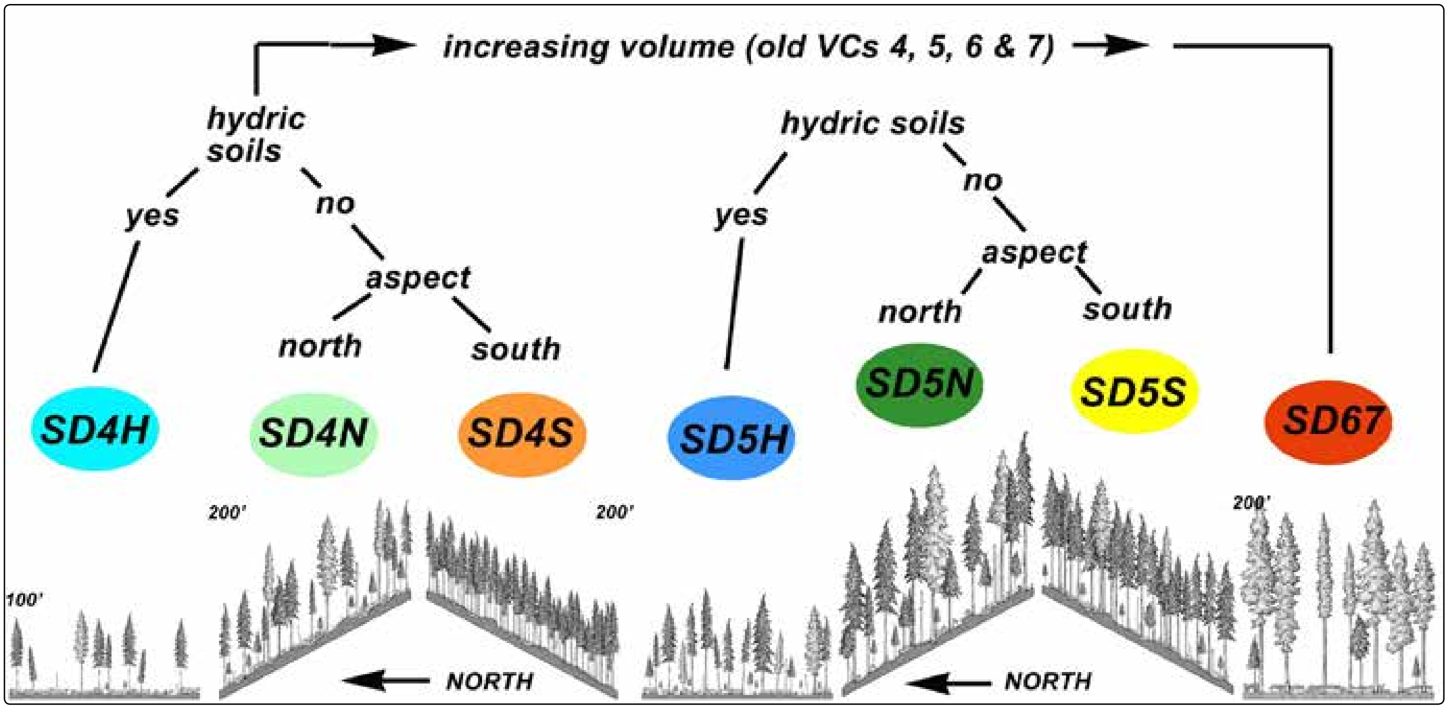


Figure 5. Visual key to the Size-Density model data by Richard Carstensen.

The most recent effort at forest classification for the Tongass, and probably the most relevant for ecological restoration work at present, was produced by John Caouette and Gene Degayner in 2005. This classification models tree size and density based on volume class, aspect and soil characteristics (Figure 5). This model provides a much better indicator of the structural character of forests than was provided by the pure volume-based approaches of the past and is considerably more relevant to wildlife habitat considerations.

Unfortunately this data does not currently provide much detail on the site characteristics of logged stands but this could be overcome somewhat by simply identifying whether the second-growth stand is hydric (has wet soils) or is well drained, and whether the stand is wind-prone or protected. As it is, the size/density model can be instructive for planning restoration projects within the context of existing old-growth forest conditions at watershed and landscape scales.

Given the complexity of Southeast Alaskan forested habitats, the many variables that influence their development and the incomplete data we have to work with at present, we believe that ground-truthing stand conditions is critical to the success of restoration at stand, watershed and landscape scale. Please see the section on Watershed Restoration Plans for more information on important field questions.

Conservation and the Tongass Land Management Plan

Not all the of the key contextual elements for restoration in Southeast are biogeographic in nature. There are key social elements to consider as well.

Conservation in the Tongass has been influenced by the legacies of past management actions on a variety of levels (psychological, cultural, economic, political, etc.). For the purposes of this report, there are two key points we wish to highlight from this historical roller-coaster that are key to identifying restoration priorities:

- Most regulations for protecting fish and wildlife habitat in non-Wilderness areas of the Tongass were not established until 40 years of industrial-scale logging had already taken place.
- Almost half of the areas logged *would have been* protected by the present conservation strategy and past logging has impaired their ecological function.

Because of the necessity to use old-growth forest as the primary component in laying out conservation lands, larger biological reserves were excluded from the watersheds that were most heavily logged. In effect, past management activities forced the resource specialists and scientists who designed the Tongass conservation strategy to play hand they were dealt.

Because of standards and guidelines in recent Tongass land management plans, including some second-growth forest in the conservation strategy was unavoidable. This is particularly true for riparian management areas, but also occurs in beach buffer and old-growth reserve areas (Figure 6).

To date, there has been little planning dedicated to the question of how active management of second-growth can serve to increase the functional capacity and overall resilience of the Tongass conservation strategy. The net effect of this problem is a less than ideal system of conservation lands that include under-utilized opportunities for active management and very limited budget to do something about it.

Ecological restoration of second-growth forests within and in close proximity of Tongass conservation strategy lands represents an important opportunity to increase the resilience of ecosystems throughout the region. In particular, restoration in riparian management areas, beach buffers and old-growth reserves will enhance productivity and connectivity at multiple scales and can serve to overcome the problem of "playing the hand that was dealt" by the unfettered early days of logging. Moreover, conservation strategy lands are generally off-limits to logging and provide an opportunity for low-conflict collaboration where there is clear direction to actively manage second-growth stands for the restoration of old-growth attributes.

It should be noted that in general reserves cannot be large enough to preserve regional biodiversity; we also need managed forests to function to conserve biodiversity. (Perry 1998, Carey 2001, Lindenmeyer and Franklin 2002). Restoration in conservation strategy lands is an important part of maintaining ecological integrity but it is critical that lands between reserves (the matrix) also do a much better job of providing biodiversity, structural complexity, heterogeneity and ecological function.

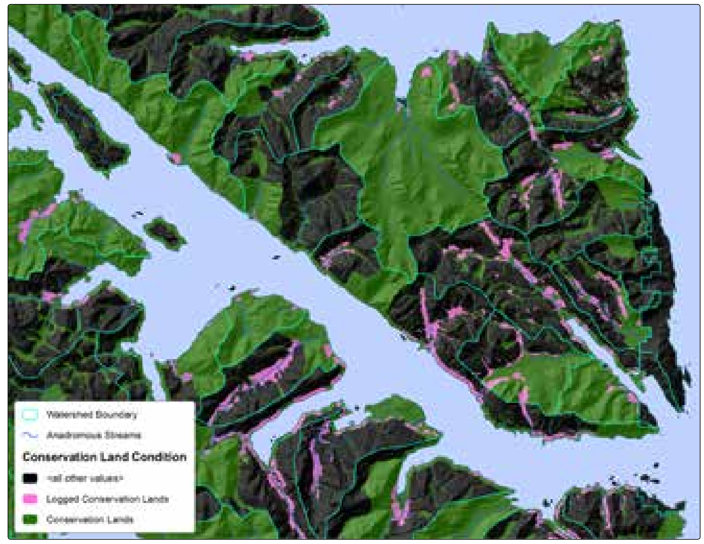


Figure 6. Logged conservation lands. The 2008 TLMP conservation strategy is intended to protect old-growth forests, key habitats and ecological functions from future logging. Unfortunately, these protections came too late for some watersheds and landscapes and habitat loss (e.g., riparian and beach buffers) and impaired ecological function (e.g., connectivity) had already occurred prior to the establishment of these standards and guidelines (pink areas on map). The case for restoration of these areas is strong.

The list of key contextual elements included in this section of our report highlights a few biogeographical features that are key to understanding how to do ecological restoration in Southeast Alaska. This report also includes an extensive bibliography that provides more detail on these and other topics that are relevant reading for restoration practitioners in Southeast Alaska.

For readers who are interested in learning more about the biogeographic setting of Southeast Alaska we highly recommend three of Richard Carstensen's works: <u>Reading Southeast Alaska's Landscape (2011);</u> the "Terrestrial Habitats" section (chapter 5) of <u>The Coastal Forests and Mountains Ecoregion of Southeastern Alaska and the Tongass National Forest</u> (Schoen & Dovichin eds. 2007); and for residents and visitors to Juneau who would like to see-in-person some specific examples of these important biogeographical features we highly recommend the <u>Natural History of Juneau Trails</u> (2011).

TECHNIQUES FOR TONGASS RESTORATION

GOALS AND OBJECTIVES

This report touches on a broad range of social and ecological benefits that can be created through restoration work, but the core of this document is the description of *specific techniques for facilitating the ecological restoration of old-growth forest attributes*.

Timber management has simplified forest ecosystems (Alaback 1982; Franklin 1993; Carey et al. 1999), enabled invasion by exotic species (Hobbs & Humphries 1995; Halpern et al. 1999; Thysell & Carey 2001; Howell et al. 2004), imbalanced biotic communities (Aubry 2000; Carey 2000; Haveri & Carey 2000; Wilson & Carey 2000; Carey & Harrington 2001), reduced prey biomass (Carey et al. 1992; DeSanto & Willson 2001; Smith and Nichols 2004), impaired food web function (Carey et al. 1996, 1999, 2002; Colgan et al. 1999; Tiegs et al. 2008); increased habitat fragmentation (Lehmkuhl & Ruggiero 1991; Farmer et al. 2006; Macdonald & Cook 2007) and resulted in an under representation of productive forest types in conservation reserves (Lindenmeyer and Franklin 2002).

The goals that we believe are essential to guiding this effort center on expediting the return of biodiversity, old-growth structures and ecosystem functions. This will require the use of appropriate reference conditions and measurable objectives that are well-suited to informing the adaptive management process.

Ecosystem function objectives:

- Nutrient cycling
- Habitat connectivity
- Stream bank stabilization
- Hydrological regulation
- Thermal regulation
- Seed dispersal

Biodiversity and structure objectives:

- Presence of large trees
- High stand volume and/or biomass
- Large number of live and dead snags
- Large amount of downed wood
- Wide decay class distribution
- Several canopy layers (vertical structure), including shade tolerant trees, shrubs and herbs
- High variation in tree sizes and age
- High spatial heterogeneity (irregular tree species and size distribution)
- Presence of canopy gaps
- Thick forest floor
- Pit and mound relief
- Presence of epiphytes
- Presence of cavity-trees
- High variation in crown structure
- Presence of advance regeneration

One of the primary objectives of forest restoration is to expedite the succession of low biocomplexity even-aged stands (above left) to provide the composition, structure and functions of high biocomplexity old-growth (above).

THE SILVICULTURAL TOOLBOX

The Society of American Foresters (SAF) defines silviculture as "the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis" (SAF 1994).

Silviculture has been employed in one form or another for hundreds of years to meet "the diverse needs and values of landowners and society". Although the field of silviculture is diverse and includes many examples where a broad range of social and ecological values are targeted, the vast majority of practices have been focused on timber production goals.

In a recent book titled "A Critique of Silviculture: Managing for Complexity" (Puettman et al., 2010) the authors present a convincing description of the art and science of silviculture as often being narrowly focused on:

- trees to the near exclusion of other forest organisms;
- on the concept of uniform stands;
- on an agricultural research model;
- on a scale-independent view; and,
- on predictability of outcomes.

Silvicultural activities are implemented through a variety of practices (e.g., site preparation, promoting natural regeneration, planting, fertilizing, thinning and final harvest). Practices in Southeast Alaska have largely been limited to promoting natural regeneration through clearcut logging and thinning the regenerating trees to maximize wood fiber production.

"Currently, the only intermediate treatment commonly used on the Tongass is precommercial thinning." - USFS in their TLMP, 2008

Collaboration between silviculturists and ecologists is critical to the success of forest restoration. Silviculture brings well-established tools for guiding natural processes to meet stand-level objectives while restoration ecology is tuned to identify habitat needs, integrate multiple-scales and test methods in restoring productivity and biodiversity (Franklin et al. 2007).

"The most characteristic aspect of [post logging] succession is an extended period of species impoverished, understory vegetation following the establishment of a dense overstory canopy layer. Less than 1% of the understory biomass of old-growth forests are maintained in these younger forests for 100 years or more". - Alaback 1982, 1984, 2010.

Example of "the problem" - clearcut regenerated second -growth forest in stem exclusion phase of secondary succession. Depauperate understory in these types of stands provides very poor wildlife habitat.

Changes in stand-level management practices of second growth can support significantly increased biodiversity. The key to restoring a diversity of species and processes is to develop more diverse and complex stand structures (Franklin and Spies 1991, Carey 2001, Harrington and Nicholas 2007, Keeton 2006, Alaback 2010) with techniques that mimic the results of natural disturbance (Hobbs 1987, Reeves 1995, Franklin et al. 2002, Perera et.al. 2004, Drever et al. 2000) within a scientifically credible adaptive management framework.

"Skillful practice itself is a continuing and informal kind of research in which new ideas are constantly applied and old ideas tested for validity. The observant and inquiring forester will find many of his questions about silviculture answered by the results of accidents of nature and earlier treatments of the forest." - from <u>The Practice of Silvicuture</u> (Smith & Hawley 1962).

CONVENTIONAL THINNING

Forest thinning is an important silvicultural tool available to foresters and restorationists, especially where natural regeneration results in very high stem densities (trees per acre). Self-thinning eventually reduces stem density (Oliver & Larson 1990, Franklin et al. 2002), however, as trees compete for resources their growth slows, the canopy closes, small crowns and weak roots systems develop, and the understory becomes devoid of vegetation; conditions that can remain for >150 years, in productive, wind protected disturbance refugia (Alaback 1982, Nowacki & Kramer 1998).

Conventional thinning is a space-based approach to reallocating stand resources (light, space, water, nutrients) to increase growth in residual vegetation. Conventional thinning typically targets the reallocation of stand resources to improve the commercial value of "crop trees" and results in expediting wood volume accumulation, large tree presence and suitable crown ratios.

Example of recent precommercial thinning.

Precommercial Thinning

Precommercial thinning (PCT) is a form of space-based thinning that takes place early in the life of a clearcut regenerated stand (<25 years). It is described as precommercial because the small trees that are cut have no commercial value. PCT has been a common practice in Southeast Alaska since the 1980s because natural regeneration in clearcut stands often results in very dense conifer colonization, especially on sites with little soil disturbance (Hanley 2005).

This stand did not receive a traditional PCT treatment. Thinning at 40 years of age exposed weakly rooted trees to wind and most of the stand blew down.

Initial stem densities on productive sites in our region can be several thousand trees per acre (Demars 2000), which completely shade-out the vast majority of understory plants in 15-20 years (Alaback 1982) and result in very poor wildlife habitat values (Walmo & Schoen 1980, Hanley 1993, DelaSalla et al. 1996). Closed canopy second-growth is aptly described by an ADF&G wildlife biologist as exhibiting "succession debt" (Person et al. 2003) or more commonly as a "biological desert". Although high-density regeneration from blow-down occurs in Southeast Alaska, logging has pushed the abundance of this forest type far outside the natural range of variation (McClellan 2005).

Early forms of PCT in Southeast Alaska targeted a residual tree spacing of 8-14 ft and favored spruce over hemlock. Many of these stands have already returned to a stem exclusion phase but some improved stand characteristics (larger more well rooted trees with healthier crowns) have set them up well for targeting long-term structural and biological diversity with a second treatment. More recent PCT has used spacings of 16-20 ft., less uniformity and been more variable in species retention (Ben Case Pers. comm.), but these stands will also require additional treatments for ecological restoration, especially on sites with high productivity.

PCT can be an important step in managing second growth for ecological values. PCT results in faster growing, more firmly rooted trees and sets the stage for future silvicultural options. Even in areas where PCT is a misnomer (i.e. unsuitable second growth) some form of early spaced thinning is an essential step in ecological restoration of old-growth attributes.

Commercial Thinning

Commercial thinning is only just beginning to become a relevant topic in Southeast. The most common commercial thinning techniques that are suited to local second-growth forests are thinning from below, thinning from above and strip thinning. Each of these prescriptions targets a different set of canopy classes and can be applied at varying levels of intensity (i.e. light, moderate and heavy thinning) depending on the desired future stand density and commercial product goals (Figures 7 & 8).

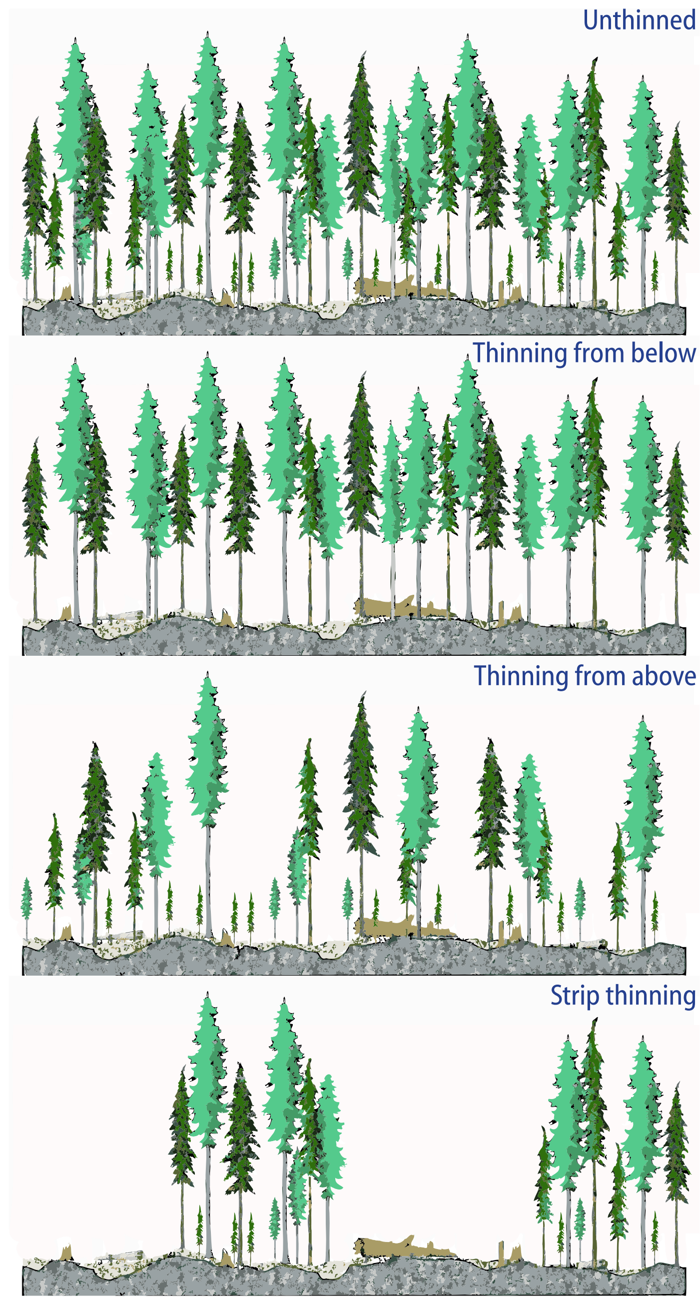
Thinning-from-below

Thinning from below (also called low thinning) removes the smaller and less economically desirable trees, usually in a fairly consistent spacing, to maximize growth and yield of the trees left standing (Figure 8). This technique reduces competition between trees for limited resources (light, water, space and nutrients) by removing the trees that are growing below the dominants (i.e. the intermediate and suppressed).

With adequate intensity (i.e. spacing), this approach removes the trees that are believed will likely die before they are commercially valuable and so is said to "capture mortality". Historically, this approach also commonly removed defective or damaged trees and favored 1 or 2 particular species for future harvest.

> **"Spacing-based thinning prescriptions typcially eliminate pairs and groups of closely spaced overstory trees, components of natural forest structure that are not quickly replaced via stand development processes." - Larson 2008**

Figure 8. Some common thinning prescriptions.



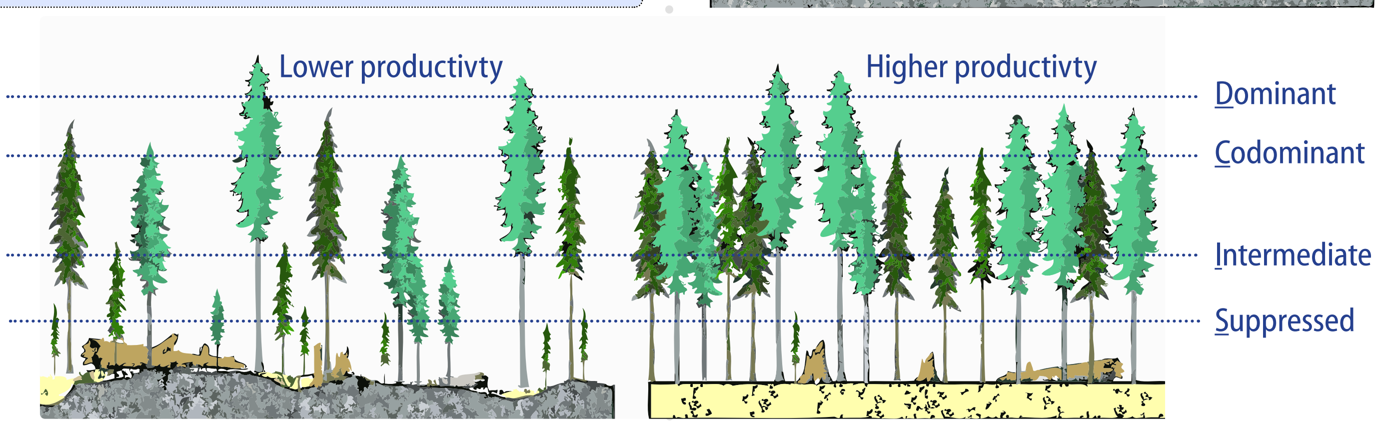


Figure 7. Productivity and tree canopy classes. The different tree heights in a stand are referred to by four canopy classes: Dominant, Codominant, Intermediate and Suppressed. On productive sites regeneration is composed primarily of dominant and co-dominant classes because new tree growth is so vigorous it shades out small trees. On lower productivity sites there is more variability in canopy classes.

Thinning from Above
Thinning from above (also called crown thinning), reduces canopy closure by removing dominant and codominant trees to favor residual trees in these same classes, while also promoting growth in subordinate classes (Figure 8).

Thinning from above is the least "space-based" approach to conventional thinning described here and can serve to retain vertical structure while prompting more vigorous responses from understory herbs, shrubs and suppressed trees - all of which can improve wildlife habitat. Thinning from above has had limited application in Southeast but it may become more common as commercial thinning becomes a viable practice.

Example of strip thinning implemented as a PCT with limited success in improving tree growth rate or understory abundance.

Strip Thinning
Strip thinning removes all or most trees from a fairly uniform corridor through a stand (Figure 8). Strip thinning implemented at the precommercial age class in Southeast has been experimented with in a few locations with little success.

Locally, strip thinning has only recently been seriously considered for commercial size classes and this technique has not been seriously tested in our region. This approach can be more economical when cable yarding is necessitated by operability constraints. There is some potential for improving wildlife habitat using strip thinning in commercial size class second-growth, however, the designs will need to be sensitive to avoiding edge unravelling from wind disturbance and exacerbating predation on deer in valley bottoms (Dave Persons pers. comm.)

Thinning from below applied as a PCT has resulted in a biologically low value stand with nothing but the "bones" of understory left behind. Following PCT it is common for the canopy to re-close and kill off the understory within 10 or 20 years. Structural complexity and heterogeneity end up low also. Although PCT on productive sites is often better for long-term ecological values than not doing initial thinning, habitat values are limited until the stand is re-thinned for wildlife.

"As a by-product, [conventional] thinning can stimulate understory vegetation at first, since sunlight and nutrients become more available immediately after treatment. Soon, generally not more than 15 years, crop trees expand their branches and create a dense overstory canopy which shades out understory forage plants once again. While more intense thinning treatments (wider average tree spacing) may lengthen this process to a certain extent, data available to date suggests that on productive sites thinnings even up to a spacing of 20' will still produce only short-term benefits to wildlife habitat." - Paul Alaback 2010

ECOLOGICAL RESTORATION TECHNIQUES

Restoration of forest habitats can be partially achieved by the conventional thinning techniques described above, but there are significant ecological shortcomings with most of these approaches as they are typically implemented.

For example, the benefits of conventional thinning to the restoration of understory plant communities is typically very short-lived (Alaback 2010, Cole et al. 2010). It is not uncommon that heavy slash loading from precommercial thinning buries the forest floor so deeply that understory plant regeneration is made functionally inaccessible to key species (e.g., deer) until sufficient decomposition occurs, and unfortunately, timing of slash decomposition often coincides with the re-closure of the tree canopy and a return of bare understory. PCT also generally results in the removal of "defect" and a fairly uniform space and age structure, all of which lead to a biologically simplified stand.

Commercial thinning has only recently been applied in the Tongass. Although it is likely that commercial thinning will generate some ecological boons for wildlife, it remains to be seen how diverse and durable these habitat enhancements will be. It is likely that commercial thinning on productive sites may experience similar pitfalls to PCT with the habitat benefits being very short-lived and narrow in scope unless a variably-spaced, uneven-aged approach to residuals is facilitated and additional techniques for enhancing biodiversity and structural complexity are also employed. We consider commercial thinning benefits to wildlife habitat an important area of study for Southeast forests.

Much of the research cited in this report comes from work done in the forests of the Pacific Northwest. There are many similarities between these forests and those of Southeast. For example, it takes about 250 years for both forests to reach the old-growth stage of succession. However, there are also significant differences, especially with regard to the absence of a fire ecology in Southeast Alaska and the more significant role that our old-growth forests play in winter survival for species like the Sitka Black-tailed deer (O'Clair et al. 1992).

"Management for diversity calls for diversity in of management. This is critical because suitable connectivity, stand complexity, landscape heterogeneity, and aquatic ecosystem integrity will be defined on a species-specific basis and can vary markedly between species. Since defining these variables for a large set of species is essentially impossible, creating a range of conditions is a practical response to this problem." - Lindenmayer & Franklin 2002

There are several prominent foresters and ecologists who strongly believe in the need for managing matrix timber lands for wood production and a broad range of ecological values, several of which suggest that such efforts are of paramount importance to the conservation of forest biodiversity (e.g., Franklin, Carey, Harrington, Tappeiner, Deal, Hanley, McCllelan, etc.). For the interested reader, please see these literature review documents on the subject: Louks et al. 1996, Moores et al. 2004, Zobrist & Hinckley 2005, Heiken 2007 and Swanson 2009.

Although the blending of ecological values and timber production is an important and promising subject, and there is a great deal of overlap in the tools that might be used, our primary orientation here is:

- a review of individual techniques that emphasize ecological restoration; and,
- describing a method for blending these techniques in a prescription that expedites development of the diversity, structure and function that is characteristic of southeast Alaskan old-growth forest.

Coupled with a socially and ecologically prioritized strategy that emphasizes whole watershed functions, we believe that these techniques can provide immediate and long-term benefits to residents of southeast Alaska (human and otherwise).

The keys to success will be a willingness to collaborate and "mix it up" (Harrington 2007) in experimenting with what works, monitoring the outcomes and feeding new information back to the collaborative group to improve the process (adaptive management).

Slash Treatments

Thinning prescriptions that include the felling of trees can generate an abundance of slash. Thinning slash can be considered as both a positive or negative contribution to ecological restoration depending on site environmental conditions and the desired future conditions.

In situations where restorationists would like to protect understory plant regeneration from browsing pressure (e.g., when high deer densities exist) slash from thinning can help herbs and shrubs get a foothold in reoccupying the site by protecting it from grazers for 10-15 years while the slash naturally biodegrades (Nyberg et al. 1989, Parker et al. 1984, Doyle 2006). Slash also protects small mammals from predation, which may in turn enhance understory plant seed dispersal by frugivorous mammals (Willson 1991, 1993 & 2000).

On Haida Gwai, sitka black-tailed deer are an introduced species considered by many a "pest". Studies have documented the toll deer have had on the maintenance and recovery of species ranging from cedar trees to goshawks (Allombert & others). This may seem ironic to Southeast residents where maintaining deer populations to meet hunter demand is a priority, but it would be foolish to ignore the results of this research and its utility to understanding how to restore the broadest possible array of biological diversity. Take home message: slash can be used as a tool for reducing the impacts of overabundant deer.

In situations where restorationists are eager for understory regeneration to immediately become available to grazers, or when the thinned stand is an important piece in the habitat connectivity puzzle, slash can be problematic because it reduces habitat permeability, i.e. slash increases the "cost" that some wildlife have to pay to move around their home range by reducing food availability and making travel difficult.

Slash can be mulched or bucked to expedite decomposition and understory growth. It can be cleared to create travel corridors. This can be especially useful if corridors are located in

Imagine walking through this example of heavy slash loading from a fairly standard PCT treatment on Kupreanof Island. This slash reduces landscape permeability by impeding movement and making understory plants functionally inaccessible for species like deer.

existing high traffic areas (ideally these trails would be mapped with a GPS prior to the thinning so that they can be relocated for slash treatment afterward). These corridors could also provide social benefits by making access to clearcuts easier for people who use these locations for hunting and gathering.

Slash treatment is a good example of a technique that is not simply good or bad. As with many restoration treatments, site-specific conditions and multiple scale considerations are important to predicting and assessing the effectiveness of slash treatment. Given the imbalance between the resources available for ecological restoration and the abundance of acres where slash could be treated on an annual basis in the Tongass, it is particularly important to be strategic with this technique.

Girdling

Girdling (also called ring barking) is a technique used to kill a tree but leave it standing (Figure 9). The key is to injure the phloem (sapwood) sufficiently to stop sugar transport from the leaves to the roots. This is typically done by using a chain saw to cut a complete circle around the tree just deep enough to sever the sapwood but not so deep into the heartwood that the stem is overly weakened.

Girdling can be implemented to meet the goals for a variety of spaced thinning approaches with the primary difference from conventional approaches being that the trees are not felled.

The benefits of girdling to wildlife habitat enhancement include those provided by conventional thinning (increased or maintained growth rate in residuals, increased light to forest floor for understory plant development) but also provide the benefit of avoiding the often very heavy slash that results from felling thinned trees, creation of snags and metered contributions of dead wood to the forest floor (Bull et al. 1997, Doyle 2006).

The caveats of girdling are that it can be an inconsistent method for killing targeted trees, it is generally more work than felling trees (not accounting for other goals such as slash management) and it results in reduced commercial value from a stand.

Chain saw girdling has killed this spruce, increasing light penetration and ground cover plant growth.

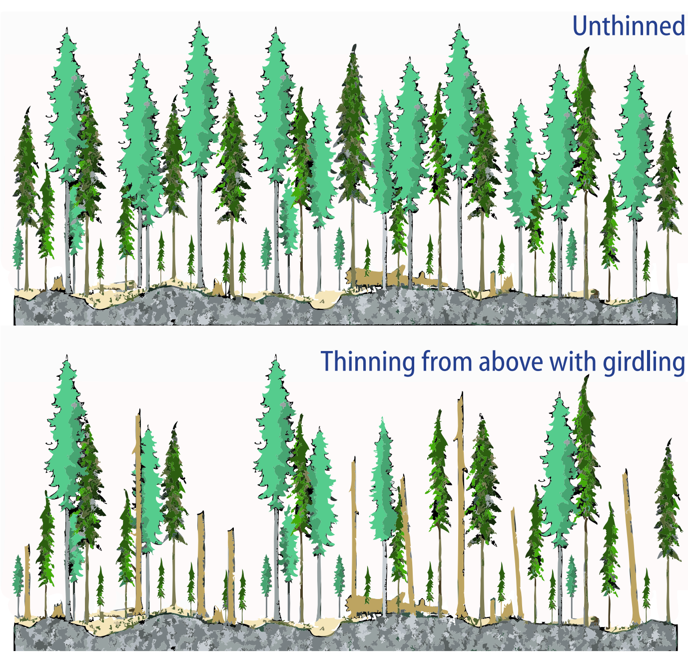


Figure 9. Girdling for snag creation.

This is a photo of a pruned stand near Thomas Bay in Southeast Alaska. Understory response to pruning here has been promising so far.

Pruning

Pruning for silviculture in Southeast Alaska has not been thoroughly studied. Initial studies have suggested that pruning spruce trees to expedite "clear wood" production may be foiled by epicormic branching responses (Petruncio 1994, Deal et al. 2003). Hemlock appears to be more reluctant to form epicormic branches after pruning (Montigny & Stearns-Smith 2001).

Much of forest restoration in southeast Alaska is about increasing light penetration to the forest floor, the trick is how to maintain it over time. Anecdotal evidence suggests pruning can be effective at extending understory abundance in space and time (B. Case Pers. comm.).

Pruning may be especially effective in edge locations where side lighting affects can improve habitat values at the margins of openings by allowing for understory plant development to expand its footprint into the neighboring closed canopy forests (Doerr et al. 2005). Expanding understory vegetation regeneration into neighboring closed canopy forests could provide a nice balance of food and cover in regenerating second-growth for winter grazers like deer.

The epicormic branching that is considered a negative for timber management objectives can be a positive for wildlife. Epicormic branching provides structural complexity to the stand that can be used as roosting platforms for birds and small mammals (Harrington & Nicholas 2007) and potential nesting foundations for Goshawks (Lewis 2001) and other raptors.

Fertilizers

Fertilizers have been successfully used to improve the health and vigor of trees in PNW state Douglas-fir plantations for decades (Hanley et al. 2006). Red Cedar have also shown positive growth responses to fertilizers (Harrington & Devine 2011). Nitrogen is typically applied aerially in the form of urea granules to stands with pole-size or larger trees (Bengston 1979). Sewage biosolids have also proved effective. Results for western hemlock have been variable and experiments with sitka spruce, though having promising results, have not been tested thoroughly enough to result in a clear prescription (Hanley et al. 2006).

Fertilizers can encourage a stand to develop characteristics of old-growth such as fewer, larger trees with fuller crowns (Miller & Fight 1979), but in areas where understory is part of the focus it is important to account for increased tree leaf area and employ wider spacings (Omule et al. 2011).

Southeast Alaska is well suited to experimenting with fertilizers in enhancing understory growth, as well as increasing the nutritional value of understory plants to grazers. It may be possible, for example, to create a "seed-bomb" of fish waste and berry seeds used to increase the rate of understory plant initiation and growth in second-growth forests.

Fertilizers might also be used in a single tree selection approach where promising large-tree candidates are identified for enhanced root development and height and girth boosts that lead to canopy structural diversification.

Helicopter used to spread N fertilizer in Douglas-fir forest (image from Reforestation Services, Inc. web site).

Fire

Historically, prescribed fire has been used by foresters in the lower 48 to encourage forest regeneration after clearcutting. More recently prescribed fire has been used in combination with thinning as a tool to restore fire adapted forest ecosystems that have developed heavy fuel loads after many years of fire suppression.

Prescribed fire was applied after this Prince of Wales Island stand was clearcut in 1975. Normally we would expect a stand like this to be well into the stem exclusion phase but conifer regeneration has been very slow, which is unfortunate at this scale, but could work well for situations where deterring tree growth at finer-scales (i.e. when understory persistence is key) could provide more durable ecological benefits.

Because southeast Alaska is too wet to experience much fire, and prescribed fire has seen little use, there is not much that is known about the utility of prescribed fire for shaping the successional trajectory of Southeastern second growth forests. Theoretically, some of the same benefits that have been documented in other areas (pseudo-scarification, nutrient release) could prove useful in Southeast as well.

For example, openings in second-growth that experience hemlock flush (a sudden very high density regeneration of hemlock trees that precludes all other understory plants) may respond well to a burning. Burning of thinning slash piles (jackpot burning), combined with scarification could introduce complexity by diversifying soil conditions and vegetation regeneration.

Using fire to create and maintain desirable wildlife habitat attributes is untested and should be experimented with conservatively at this point.

Interplanting and underplanting

In some cases it will be desirable to increase plant diversity to an extent that exceeds what would occur through natural secondary succession. Under these circumstances interplanting and underplanting can be used.

Interplanting is the planting or seeding of vegetation amongst natural regeneration, typically at stand initiation. Underplanting is the planting or seeding of vegetation below the dominant canopy crown class. In terms of ecological restoration, these techniques are used to stabilize slopes, enhance soil productivity, increase structural complexity and promote biodiversity. Efforts on the Tongass have focused on experimental work with red alder and yellow-cedar.

Interplanting of red alder is being experimented with on the Tongass because retrospective studies suggest that red alder adds considerable ecological value to early successional regeneration of conifer forests. Increases in soil development and nitrogen fixation (Tarrant & Trappe 1971, Berg & Doerksen 1975), structural complexity (Deal & Russel 2008), plant and animal biodiversity (Hanley & Barnard 1998) and aquatic invertebrate productivity (Piccolo & Wipfli 2002) have all been documented.

> **"Most evidence to date is that greater benefit for wildlife might be accomplished by including red alder when regenerating clearcuts at the time of logging than can be accomplished by silvicultural treatment once even-aged conifer stands are fully established." - Hanley et al. 2005**

Active experimentation exists as part of the Tongass Wide Young Growth Study (USFS 2008), but there is enough preliminary evidence to suggest that planting of red alder can be a powerful tool for restoration.

Underplanting of yellow-cedar has also been experimented with in Southeast. The motivation for these efforts have derived from a combination of the high cultural and economic value of yellow-cedar and the fact that it appears to be in significant decline due to climate change (Hennon et al. 1990). Underplanting of yellow-cedar has been tested with promising success (Hennon 2006). A conservation strategy has been published that includes restoration and facilitated migration methods that target consistently colder and well-drained sites for yellow-cedar planting because these areas are thought to better protect shallow roots from freezing (Hennon et al. 2008).

Field crew standing next to a 6 year old planted alder on Zarembo island (photo courtesy of Bob Deal).

In conjunction with techniques to reopen second-growth canopies, underplanting of herbs and shrubs can enhance the reestablishment of understory vegetation for select species (Ray Slayton Pers. comm.). This approach may be especially valuable in areas where large clearcuts have resulted in broad-scale, long-term depauperate understories; areas that may be difficult for some species to recolonize because their seeds do not remain viable during prolonged periods of stem excluded second growth or the primary method of dispersal is rhizomal (Tappeiner & Alaback 1989). Native herb and shrub underplanting also could also support the integration of traditional and cultural plant uses and non-timber forest products availability with increased forest diversity and wildlife productivity.

Ground Scarification

Areas that experienced mineral soil exposure from past logging processes (e.g., tractor skidding and downhill cable yarding) often regenerate into pure alder or mixed alder and conifer forests (Harris & Farr 1974). These areas have served as natural laboratories for studying the positive contributions of red alder to forest productivity and diversity with very encouraging results thus far.

Ground scarification can be used to emulate disturbance that encourages alder and herbaceous plant growth in second growth forests (Ruth & Harris 1979) and can be accomplished with equipment designed to efficiently provide the benefits of mineral soil exposure while controlling potential negative impacts such as soil loss, over-compaction, and destabilized slopes. Scarification has not been tested locally but evidence from other areas suggests it may work well (Groenier et al. 2008).

"Slash-buster" head mounted on a trackhoe. This machine is a highly versatile tool for ecological restoration as it can serve multiple purposes (mulch, scarify, artificial tip-up creation, slash management, tree-topping for snag creation, etc.

Scarification for Red Alder generation holds a great deal of promise for increasing forest resilience (Hanley 2005, Deal 2006, Almond et al. 2006) especially in areas with widespread logging history. It is important to pay attention to site-specific conditions when planning the use of red alder in reforestation projects. We refer the reader to Constance Harrington's "A field guide to predict site index for red alder" as a good starting point. For an excellent summary on relevant red alder information please see PNW-GTR-669, "Red Alder: A State of Knowledge" (Deal & Harrington eds. 2006).

Tractor logging of this stand in the 1960s exposed mineral soils and led to alder dominated regeneration. Spruce trees have come up below the alder canopy at a spacing that is consistent with the pre-logging forest; a testament to the ability of alder overstory to manage conifer density without thinning. Lush understory here provides high quality summer food (cow parsnip, lady fern and nightshade) and cover for a variety of wildlife..

Creating "Tip-ups"

Windthrow (also called blowdown) that results in "tipping up" the tree such that the root wad is pulled from the ground and the entire tree is laid on its side is an important natural disturbance agent that shapes forest development.

Tip-ups contribute to forest diversification and resilience by exposing mineral soils for pioneer plant colonization, increasing light penetration to the forest floor, diversifying stand structural complexity and providing coarse woody debris to the ground. Tip-ups can be actively facilitated through the use of heavy machinery (e.g., bulldozers and track hoes) or the use of explosives. Tip-ups can also be initiated more passively by creating canopy openings and forest edges in wind-prone locations, but caution should be taken to avoid extensive unravelling.

Tip-up blowdown on the edge of an experimental strip thin on Prince of Wales Island.

Free Thinning

Free thinning focuses on the release of individual trees while the remainder of the stand is left alone. This method is flexible and could be applied to any crown class, depending on the site conditions in the immediate vicinity of the release tree.

Free thinning has traditionally been implemented to promote the growth of trees that are thought to have particular economic value but the technique could easily be applied to facilitate the development of important biological or structural components of a stand. The approach lends itself to *targeted* implementation and is well suited to sites that are sensitive to disturbance or that would benefit from selective increases in individual tree growth rates.

Free thinning is particularly well-suited to riparian forest restoration in Southeast Alaska. Logged flood plain forests here initially regenerate into alder dominated stands with fairly widely-spaced spruce regeneration in the understory. While the spacing and growth rates of the spruce trees is generally acceptable in most situations, there may be specific cases where releasing individual spruce is worth the effort of free thinning. For example, release of spruce trees to expedite the presence of large trees that are capable of stabilizing banks or that can provide durable large wood for instream salmon habitat.

Free thinning is a highly flexible and promising tool for ecological restoration but to be effective ecological and technical training is critical.

This logged flood plain forest might be a good candidate for a free thinning approach designed to create large trees for bank stability and future fish habitat.

Restoring Woody Structures for Wildlife

Habitat diversity is directly related to tree form diversity (Brown 2002). Tree forms that are generally lost through clearcut timber management practices are: snags (both live and dead), large downed logs and various live tree deformities (e.g., forked tops).

Woody wildlife habitat structures - Top left: live snag with dead top serves as a roost for a Goshawk; Top right: dead snag with cavities; Middle: nurse logs and snap-off stumps are habitat for plants, mosses, lichens, fungi, bugs, amphibians, birds and mammals; Bottom: unusual spruce growth form with tremendous structural complexity provides numerous niches for wildlife.

Of all the structures mentioned above, snags may be the most critical disturbance "lifeboats" for biodiversity. The value of snags to both invertebrate and vertebrate wildlife is well documented (Spies et al. 1988, Spies & Franklin 1991, Ohmann et al. 1994, Tyrrell & Crow 1994, Carey & Johnson 1995, Mazurak & Zielinski 2004). Ideally, these habitat structures would be retained in areas that are logged because of how difficult they are to replace. Unfortunately, this has not been the case for most of the logging done on the Tongass.

Girdling can be used to create dead snags. Unfortunately, because of the weakened stem structure that results from girdling (especially in wet/heavy snow climates like Southeast), the life of snags created with this method can be short-term, especially with smaller diameter hemlock (Hennon & Loopstra 1991).

Injected herbicides have been used to create snags (Lautenschlager et al. 1995). A related method is the inoculation of live trees with heart-rot fungi. Introducing heart-rot fungi to trees targeted for snag creation is a particularly attractive approach for general increases in standing dead wood densities because second growth heart-rot fungi stocks can be low (Bull 1996), relatively low cost methods for injection (i.e. using a rifle) have been successfully tested (Manning 2003), active inoculation can result in fungal colonization faster than natural processes (Parks 1996), and heart-rot fungi play important roles in ecosystem function in addition to snag creation (i.e. nutrient cycling).

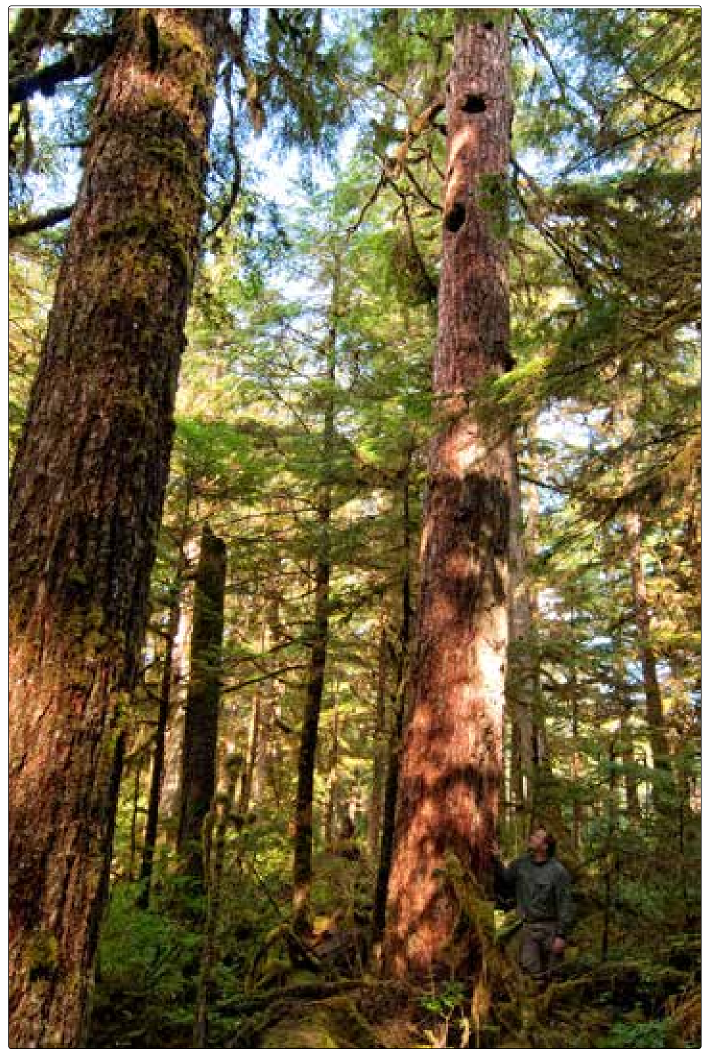
Both herbicide injection and fungi inoculation would likely produce snags that last longer than girdled trees but the results of these efforts are somewhat unpredictable.

Topping trees with a chain saw or small explosive may produce better immediate results because topped trees tend to develop internal wood decay the fastest, especially if the top is left jagged (more surface area for rot causing spore and water to accumulate). Tree-topping can be used to kill trees or to wound the tree enough to induce partial decay and create long lasting habitat features such as horizontal branch structure on which raptors can roost and build nests. This form of snag creation mimics the effects of wind and rot generated "snap-offs".

"Dead wood isn't dead." - Oregon Department of Fish and Wildlife 2006

A variety of wood habitat restoration approaches are described in Brown's 2002 article "Creating and Maintaining Wildlife, Insect, and Fish Habitat Structures in Dead Wood", including:

- depressions cut into the top of a tree to produce nest sites;
- artificial cavities and hollows cut into standing trees;
- slits and flanges cut into trees to create roosting habitat for bats.



This live hemlock snag is large enough to allow for excavation of black bear dens (note 2 large cavities 50' up the tree). That's right, black bears are cavity nesters too! The value of such features is hard to imagine until we consider how to restore them. Unfortunately, this kind of old-growth habitat feature is for all practical purposes impossible to restore in clearcut areas.

These techniques, and some of the others listed in this section, are probably too costly to be feasible for broad-scale applications, but in areas where ecological degradation has been particularly high, or at sites where social benefits would be especially valuable (e.g., for educational and research purposes), these more intensive approaches to restore and enhance habitat may be suitable.

Large spruce stump and cull log in a patch of 40 year old second growth. The habitat values of these structures can be expanded upon with creative planning.

Utilizing Legacy Features

The section above on restoring snags and other wildlife trees to second-growth forest is a sobering indicator of the costs of past clearcut logging. Even with considerable time, money and entrepreneurial ingenuity, there are many legacy features that simply can't be practically restored in the near-term (e.g., large snags). This fact emphasizes the value of retaining and maximizing the utility of those old-growth legacies that still remain in second growth forests.

Large stumps and cull logs, for example, are a common feature of second growth forests in the Tongass. These structures are precious legacies of the natural capital that is maintained in an old-growth forest and can be used as foundational material for ecological restoration. Stumps and culls can be modified to provide cavities for birds and small mammals. Large stumps occupy significant ground area and in many cases prevent young-growth regeneration in their immediate vicinity. This creates a natural gap in the canopy that can maintain understory plant cover after stem exclusion has resulted in barren understories throughout the rest of the stand.

The tops of stumps are especially adept at banking understory herbs and shrubs because not only do they see the most light in a stem excluded stand but these structures are used as perches and latrines for seed eating birds and small mammals; becoming natural gardens of blueberry, current, salmon berry, etc. that often reside out of the reach of deer browsing pressure. Centering ecological restoration treatments on large stumps can take advantage of this natural process of seed banking and plant cultivation and act as functional dispersal points for understory recolonization.

This stump has served to maintain a gap in what is otherwise closed canopy forest. It has also retained blueberry while the surrounding ground has only ferns, mosses, and a few annual herbs. This may be a good site to center an artificial gap because it retains legacy structure and biodiversity, and it would be less work to install (less trees to fall and more space to fall them).

Artificial Canopy Gaps

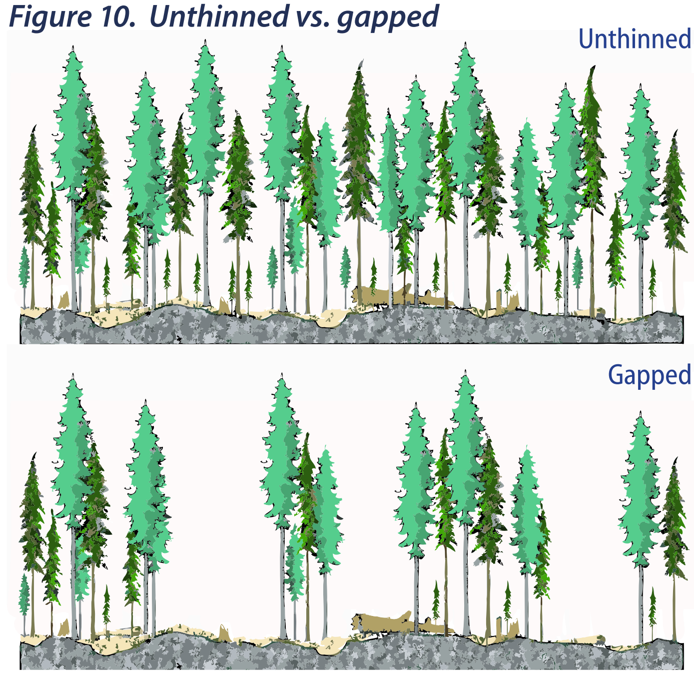
One of the most promising techniques for contributing to the ecological restoration of second growth forests is artificial canopy gap creation.

Natural canopy gaps play important roles in maintaining and promoting biocomplexity in old-growth forests (Lertzman et al. 1993, Fahey & Puettman 2008). In Southeast, natural gaps are caused by the disturbances of wind, snow-loading and individual tree mortality, are generally <1/2 acre, and typically occupy 5.8-12.7% of old-growth forest types (Ott & Juday 2002). Natural canopy gaps promote understory plant growth, create edge habitats, diversify microclimates and provide structural diversity.

Example of a natural canopy gap in a densely stocked wind forest. Note the coincidence of light penetration and understory vegetation response.

Like natural gaps, artificial canopy gaps (Figure 10) can be very effective in promoting structural and biological diversity in second growth (Demeo 1990). Preliminary results from a study by Paul Alaback (2010) suggest that creating canopy gaps can provide uniquely significant contributions to ecological restoration by increasing understory shrub and herb abundance *over the long-term* (20+ years with indications of longer term benefits likely). The gaps included in this study showed statistically significant increases in species diversity, understory cover, forb biomass, and shrub annual growth for gap plots as compared to either thinned or unthinned controls. So far, this has been achieved without the "hemlock flush" that can plague larger forms of canopy opening (e.g., clearcuts, strip thinning).

Figure 10. Unthinned vs. gapped



"Canopy gaps are an essential feature of the dynamics of dense forests since they often create a range of microclimates, structures and growing conditions that supports a diversity of plant and animal species". - Alaback 2010

This is a gap installed on Prince of Wales Island that utilizes a combination of girdling and the bucking and piling of downed wood to control slash. This approach has proved to be an effective technique for providing immediate and long-term benefits to wildlife that graze on understory herbs and shrubs as well as those that utilize small snags.

Old-growth canopy gap (shot from base of snag) with corresponding understory forest plant photo.

Mr. Alaback's research indicates that canopy gap treatments create habitats that are on average 4 times the deer carrying capacity of our thinned second growth stands in the summer or over 8 times the carrying capacity of thinned sites in the winter. He estimate as much as a four-fold increase in deer carrying capacity for winter habitats when up to 50% of a given stand has gap habitat and suggests that with just 5-10% gap habitat in clearcut units as much as a 50% increase in winter deer carrying capacity should result (Alaback 2010).

The installation of artificial canopy gaps is a relatively new and experimental technique. Although preliminary results are promising, there are no strict rules for their creation. Existing study gap sizes range from < 250m^2 – > 1,000m^2. Gaps have been created by felling trees in or out of the gap, or by the use of girdling. Downed logs have been left whole or bucked and piled. Most gaps in Southeast are patch clearcuts but a few include live trees.

Artificial canopy gap in second-growth with corresponding understory forest plant photo.

Additional research and experimentation will help to fully realize the potential of this prescription for ecological restoration, but there are some common sense guidelines for making the most of this technique in the short-term:

- Site gaps on legacy features such as snags, large stumps and remnant understory veg.
- Overall, adapt the gap size and shape to the site-specific conditions (e.g., slope, aspect, plant association, solar exposure).
- Consider pruning the trees along the edge of the gap to maximize side lighting into the surrounding forest.
- Consider adding tip-ups to artificial gaps. Pit and mound microtopography created by tip-ups associated with gap formation are particularly important to maintaining a diversity of habitats for forest understory plants (Ouden & Alaback 1988).
- Consider leaving at least one live (on north edge) and one girdled tree for improved cover and structural diversity.
- Scarify, fertilize and underplant target understory species where feasible.

Understory response in this gap was dominated by salmonberry, devil's club and currant. This plant association is to be expected on active alluvial fans where mineral soil exposure is common. Although a deer-centric restorationist might be disappointed with the understory response here because it lacks winter deer foods (cornus, coptis, rubus) it should be noted that this response benefits a plethora of other mammals, birds and bugs that feed on berries or feed on berry feeders.

Thickets comprised of unthinned second growth have far less value than those that have experienced an initial spaced thinning because the trees grow very slowly and weakly and it takes a much longer time for more than visual cover values to develop (e.g., snow capture).

No-thin Thickets and Corridors (a.k.a. "skips")

Choosing not to thin (skips) patches within a matrix of ecologically thinned second growth mimics patterns of natural disturbance (wind-forest regeneration), introduces structural and biological heterogeneity (Larson & Churchill 2008) and provides cover values while the matrix canopy matures enough to capture snow. Thickets, along with gaps and the surrounding matrix, provide a primary element of forest structural diversity that is key to restoration of old-growth attributes (Harrington 2005).

In Southeast, thickets are best sited in stands that have already had one spaced thinning.

Skips can be deployed in multiple ways. For example, watershed elevational connectivity can be enhanced by "skip-corridors" that extend from flood plain forests to higher elevation old-growth areas. This approach dovetails nicely with class 1 and 2 stream buffers. Skip-corridors can also be designed to connect remnant patches of old-growth or important seasonal habitats and serve to protect existing trail systems. Side-lighting sources (thinned matrix, alder patches and lower productivity stands) can improve the functional value of skip-corridors.

Skips can also be integrated as patches within the matrix. These "skip-thickets" can be used to protect snags (hazard trees), provide thermal and visual cover and increase edge density that can be used by a variety of wildlife. Restorationists must be careful to properly balance edge and core habitats in wolf country. Higher edge densities associated with islands of old-growth forest in second growth matrix have been shown to increase fawn mortality caused by wolves because their cover attracts deer and the wolves learn to use them as "killing fields" in the winter (D. Persons Pers. comm.).

This photo shows a contact between a thinned area and a skip-corridor. This prescription has left a nice balance of food and cover availability that could be further enhanced along the edge if pruning were also conducted.

VARIABLE DENSITY THINNING (VDT)

Variable density thinning (VDT) is emerging as a valuable tool for the silvicultural promotion of old-growth attributes in what is largely homogenous and high density conifer stands (Carey & Harrington 2001, Carey 2003, Keyes et al. 2010). VDT is a relatively new technique (large scale experiments began in the 1990s) but it already shows considerable promise for restoring old-growth attributes through a powerful framework that targets measurable objectives.

In essence, VDT is a free-thinning framework on steroids that targets spatial heterogeneity and structural complexity (Tappeiner et al. 2007.)

VDT is well suited to Southeast because it is designed to mimic natural processes such as tree death from competition, windthrow, lightning, disease, insects and other small-scale disturbances that combine to create the structural complexity and biological diversity observed in late-successional forests. (Carey et al. 1999, Carey 2003, Harrington et al. 2004, Aukema & Carey 2007, Wilson and Puettmann 2007, Ares et al. 2010). Toward this end, VDT typically retains a diversity of tree species and sizes, including suppressed and intermediate crown classes if available, and integrates structural complexity and spatial heterogeneity with variable spaced thinning that includes skips and gaps throughout the matrix (Figure 11).

There are a variety of VDT prescriptions being tested in the lower 48, including applications in long-term studies (see Case Studies section in conclusion). Common starting points when managers use VDT for ecological restoration are a variable spaced matrix, skips and gaps, but it should be clear that the prescription can be adapted to meet site-specific needs by tweaking the distribution and abundance of the primary components and adding techniques like those described on the previous pages for to enhance stand diversity.

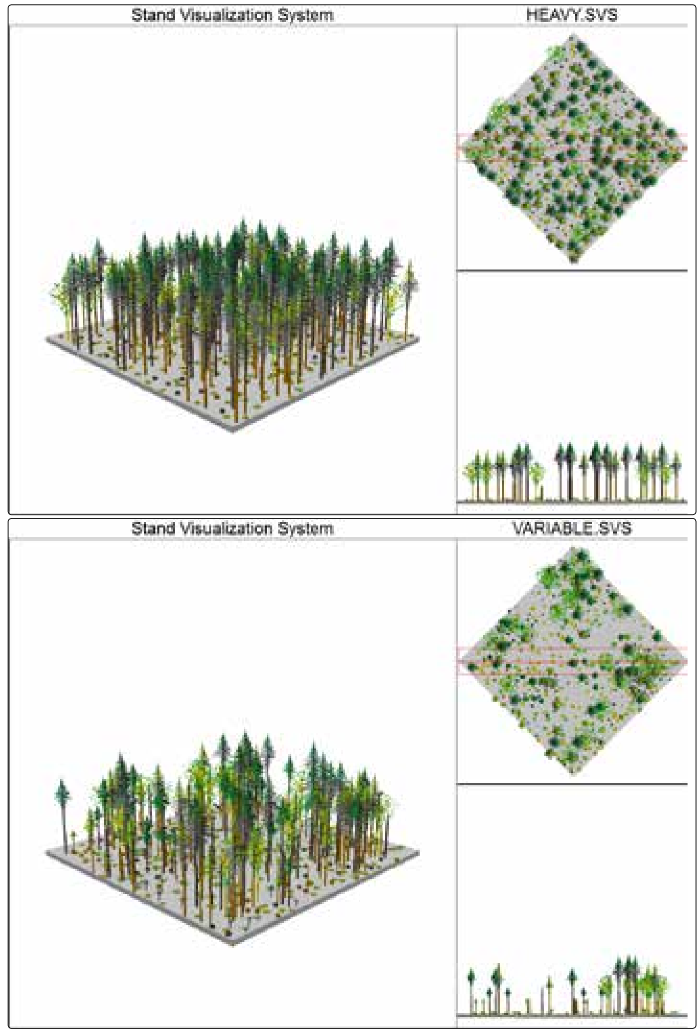


Figure 11. Comparison of spaced thinning to variable density thinning using a Stand Visualization Simulator. The Stand at the top represents a traditional spaced thin to 16 x 16' retention. The stand at the bottom is a simplistic VDT based on a 16-24 foot variable spaced matrix that includes skips and gaps.

This is an example of a VDT prescription installed on Chichagof Island. Stem density reduction was accomplished through a combination of cutting all trees below 7" in diameter and using girdling to achieve an average spacing of 18' for residuals. Elevational skip-corridors were left unthinned and gaps were installed for forage production.

Some suggestions for using VDT on the Tongass:

- Overall, the VDT stand should serve an integrated role in watershed scale productivity, diversity and connectivity.
- Include skip-corridors > 200' wide and 1/10 - 1/2 acre skip-thickets that together cover 10%-15% of treatment area.
- Center corridors on class 1 and 2 streams and obvious wildlife travel corridors (esp. between old-growth patches), treat 15-20% of skip-corridor with gaps and utilize side-lighting from alder patches, open canopy forest, roads or thinned matrix.
- Mix 2 densities of spaced thinning in the matrix (e.g., wider spacing near skips) with 25-50% variance allowed. Use girdling, injected herbicide or wood removal to reduce slash. Prune dominants and edges.
- Gap the skip-corridors, larger skip-thickets and the matrix to 10 - 20% of treatment area. Center gaps on a diversity of remnant understory (mineral & organic soils), and legacy features; prune gap edges, and create gap snags and tip-ups.
- Retain at least some suppressed trees as well as growth form "defects" (e.g. bent boles, epicormic branches, forked tops).
- Retain and interplant alder into younger second-growth, underplant alder, shrubs and forbs into gaps if necessary, rejuvenate alder where feasible along roadsides, etc.

"Restoration thinning treatments that release individual trees as well as multi-tree clusters promote characteristic late-successional tree spatial patterns at the within-patch scale. This formulation of restoration thinning explicitly incorporates conservation of existing small-scale spatial heterogeneity within the treatment area as a core element of the silvicultural design process. This approach extends current restoration thinning practices that emphasize introduction of patch-scale spatial heterogeneity with "skips", "gaps", and variable thinning densities throughout the stand. Restoration thinning prescriptions will be most effective at creating desired spatial patterns when they do not include minimum tree spacing guidelines, and when they contain clear, operationally meaningful descriptions of the desired spatial patterns." - Larson & Churchill 2008

Is VDT the holy grail of forest restoration thinning prescriptions? Maybe it is - but only insomuch that the prescription is implemented *strategically* by knowledgeable and skilled land stewards. To fully utilize the tools available in VDT it will take a team effort to see and understand both the trees and the forest, and to have the vision necessary to connect the dots from homogenous second growth to forests that are capable of filling the shoes of southeast Alaskan old-growth.

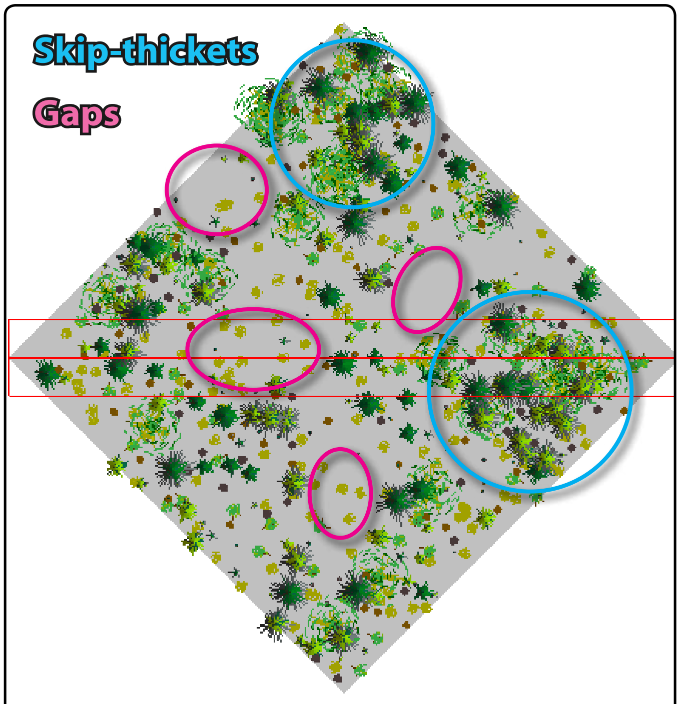
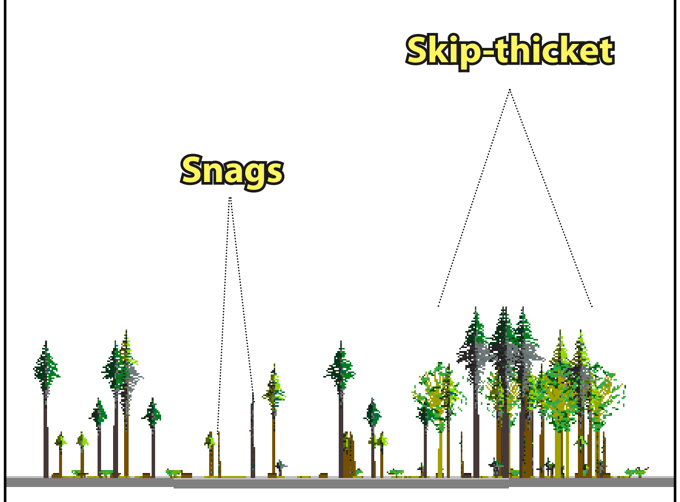


Figure 12. A closer look at the SVS represenation of a basic VDT prescription. Note the gray color in trees indicates die-off from girdling.



STRATEGIC PLANNING

"The cumulative response to restoration that is based on opportunistic, ad hoc selection of restoration sites and designs is likely to be additive at best; only strategic, spatially explicit restoration planning incorporating landscape scale processes is likely to create a cumulative response that is synergistic and complementary." – Simensted et al. 2006

A strategic plan is a road map for how to best achieve restoration goals and objectives, including how restoration fits into a broader plan for ecological and social resilience. In recent years we have learned that effective planning is often steered by community-based collaboratives and grounded in watershed scale analysis and landscape oriented planning. A functional strategic plan is a living process with informational and experiential feedback loops that foster creative adaptations to a changing world.

- *Collaboration Framework:* establish a participatory process to steer the strategic process, share the work-load and build trust between stake-holders.
- *Ecological Assessment:* conduct watershed-based assessments to identify restoration needs and guide the development of goals and objectives.
- *Prioritization Process:* select areas via a multi-scaled process that blends ecological need and social opportunity.
- *Watershed Restoration Designs:* assemble suite of projects that improve watershed and landscape integrity.
- *Action Plans*: Identify the who, what, where, when and how of the restoration project and conduct NEPA work.
- *Implementation:* Dovetail restoration projects with other resource project opportunities (e.g., IRMP), and use contractual tools to maximize local benefit, improve economics, streamline logistics and develop social capacity.
- *Adaptive Management:* blend research with a legitimate, multi-stakeholder monitoring program to validate and/or alter future restoration activities.

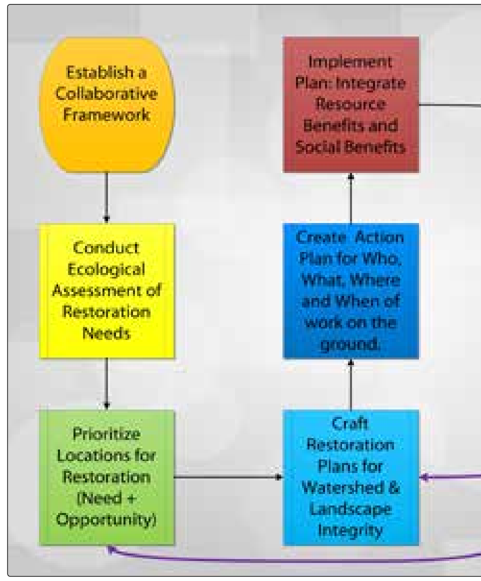


Figure 13. Strategic Plan.

COLLABORATION

Land stewardship conundrums cannot be separated from human values and social justice issues (Ludwig 2001). Science alone cannot solve such riddles because democratic society requires compromise that stems from a moral center that is outside the scope of science (Higgs 2005).

Forest restoration projects present an ideal opportunity for balancing science-based natural resource stewardship with community values through a collaborative process. Forest restoration requires the input of many experts, including wildlife biologists, planners and local contractors. It also affects many people and groups, from those who rely upon the project area for sustenance and economic opportunity to those with a strong interest in resource protection. Trade-offs must be made that involve balancing differing objectives, such as protecting wildlife and maintaining access.

Acknowledging the role of human values from the outset can lead to less adversarial local involvement and leadership support.

[Collaboration is] "A process through which parties who see different aspects of a problem can constructively explore their differences and search for solutions that go beyond what any one group could envision alone." - USFS 2005

"Those most affected by the degradation must have a vested interest in the system to ensure success and protection from further degradation." - Cairns 2000

The Tongass is inhabited by people who directly derive their sustenance and spirit from the landscapes in which they live. It behooves resource managers that are planning ecological restoration to provide opportunities for the people that are most likely to be affected by restoration activities to participate in creating a land stewardship vision, identifying restoration goals, and prioritizing areas for action.

Multi-stakeholder group conducting a site visit near Sitka, Alaska to discuss balancing ecological, economic and feasibility of second growth restoration efforts.

Contractors, resource specialists and local citizens conduct a site visit to learn from an example of forest restoration that seeks to increase wood utilization.

Community participation will legitimize the work of ecological restoration and bring to the table numerous resources, such as: local knowledge, workforce capacity (contractor and volunteer), funding support, and place-based roots that can lend a project long-term stability.

Collaborative stewardship can serve to create a "zone of agreement" for traditional adversaries and provide the social license to move beyond natural resource management gridlock and towards creating positive feedback loops between social and ecological health.

Collaborative restoration group visiting the site of a recent ecological thinning project. The value of field trips to building relationships and consensus around the issues of ecological restoration cannot be overstated.

ECOLOGICAL ASSESSMENT

The primary purpose of the ecological assessment used in the strategic planning process outlined here is to create a highly inclusive, watershed-based selection of potential ecological restoration sites in Southeast Alaska. It is driven by a variety of key ecological attributes (e.g., salmon, deer, endemics) and results in a pool of watersheds that can easily be modified by a local collaborative group to reflect their priorities.

A scientifically credible ecological assessment of restoration needs is a fundamental step in strategic planning. Ecological assessments provide an important touchstone to collaborative stewardship groups as they work on balancing conflicting values and understanding the interrelationship between complex ecological and social systems. Given its large size, remoteness and complicated biogeography, a comprehensive and scientifically sound starting point is especially important in Southeast Alaska.

A useful tool for establishing common ground understandings, prioritizing restoration actions and planning work is GIS (Poiani et al. 2000). Geographic Information Systems (GIS) provide multiple-scale perspectives on landscape condition and can help us see broad-scale patterns that are difficult to see from ground-level.

"The most effective way to approach complex ecological issues is to consider them at the watershed level, where the fundamental connection among all components of the landscape is the network of streams that defines the watershed." - USFS 2011

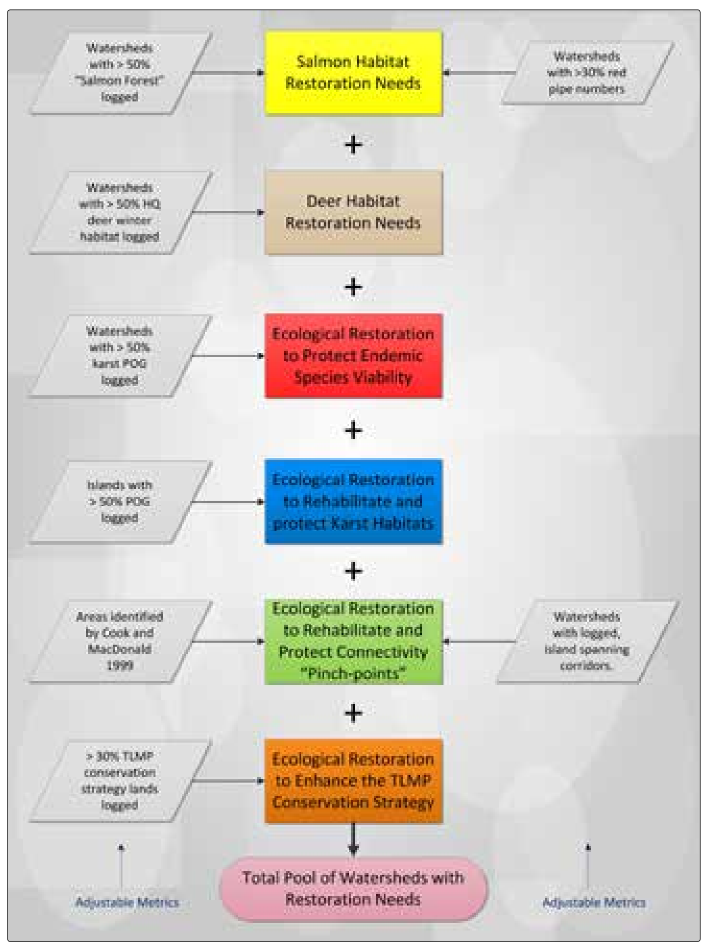
There is considerable science that supports a watershed-scale approach to resource planning (Soulé & Simberloff 1986; Stanford & Ward 1992; Reid et al. 1996; Naiman et al. 1997; Williams et al. 1997; National Research Council 1999; Sedell et al. 2000; Pringle 2001; Newbold 2002; Baron et al. 2002; Ogg & Keith 2002; Heller 2004; Smith et al. 2005; Lertzman & Mackinnon. in press).

The ecological assessment presented here is a GIS model based on watershed-scale analysis. The available data are fairly coarse and so the results of the model are best applied in regional reconnaissance efforts and would benefit from ground-truthing.

One of the goals we had in mind when assembling the restoration needs model was to make it useful to collaborative groups by basing it on popular resource interests, and balancing a simple framework with the ability to make local adjustments (Figure 14). This model is based on locally important species, habitats and processes, including:

- salmon habitat productivity;
- deer habitat productivity;
- karst forest integrity;
- endemic species extinction risk;
- landscape connectivity; and,
- structural weaknesses in the Tongass Land Management Plan conservation strategy.

Figure 14. Graphical representation of the GIS model used to generate the total pool of watersheds with potential restoration needs.



This model was assembled using common sense metrics that we believe are a good starting point, but are easily adjustable:

- For salmon habitat used the GIS to create a list of watersheds that had greater than 50% of their salmon forests logged and/or with greater than 30% of stream crossings classified as impassible by fish (red pipes).
- For deer habitat used the GIS to create a list of watersheds with greater than 50% of high quality deer winter habitat logged.
- For karst forest integrity used the GIS to create a list of watersheds where greater than 50% of karst old-growth forests had been logged.
- For endemic subspecies we used the GIS to create a list of islands where greater than 50% of their productive old-growth had been logged.
- We used the GIS to identify watersheds that had low-elevation, cross-island forested-corridors that had been severed by past logging.
- Lastly, we used the GIS to identify watersheds where more than 30% of the TLMP conservation strategy lands had been logged (reserves, riparian buffers, beach buffers and matrix lands considered unsuitable for logging).

We developed a simple scoring system so we could combine and compare restoration needs across the region. Each time a watershed was identified by one of the above mentioned metrics it received a "restoration need point". This provides us an adjustable, systematic and ecologically based ranking process. For example, if the goal of the restoration effort is to address watersheds with the greatest overall need, cumulative scores can be derived from the ecological attributes: salmon + deer + endemics + karst + pinch-points + conservation strategy = cumulative need (Figure 15). On the other hand, if the prioritization process needs to focus just on salmon or endemic species, watershed ranking can be based upon these variables alone. It can be up to the collaborative.

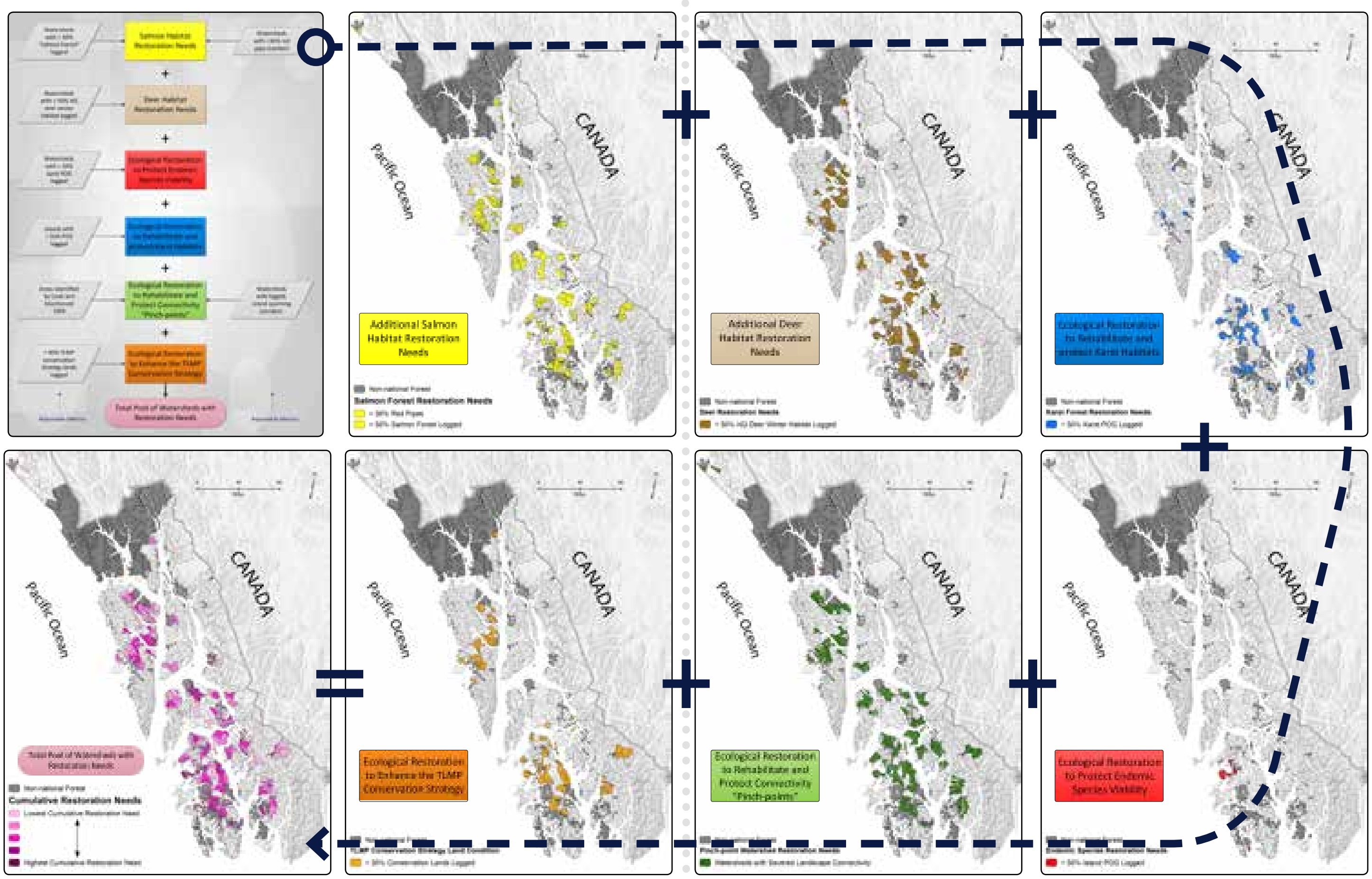


Figure 15. Watersheds identified by the restoration needs model, including a cumulative impacts map (left). Larger version on next page

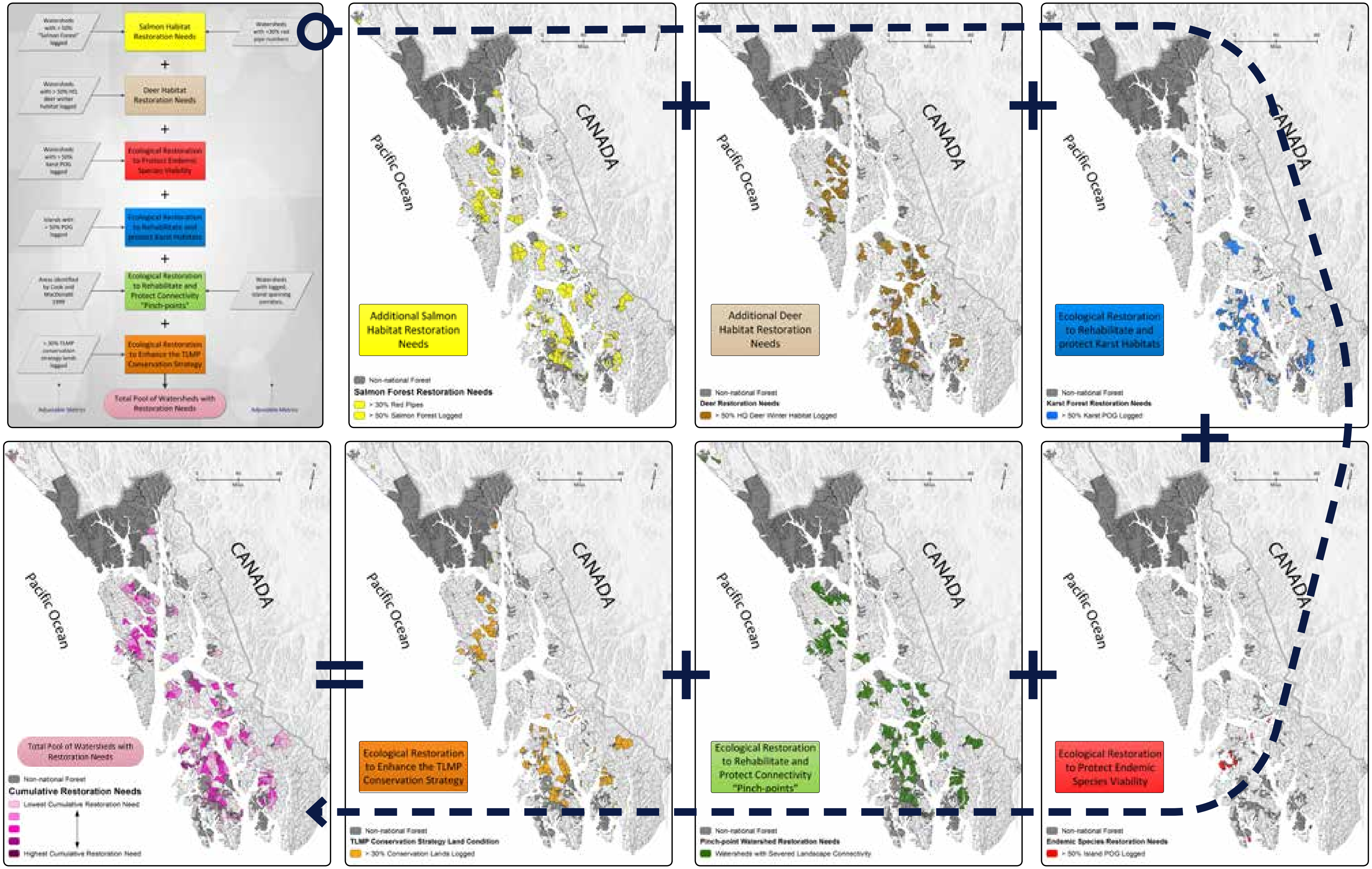


Figure 15. Watersheds identified by the restoration needs model, including a cumulative impacts map (left).

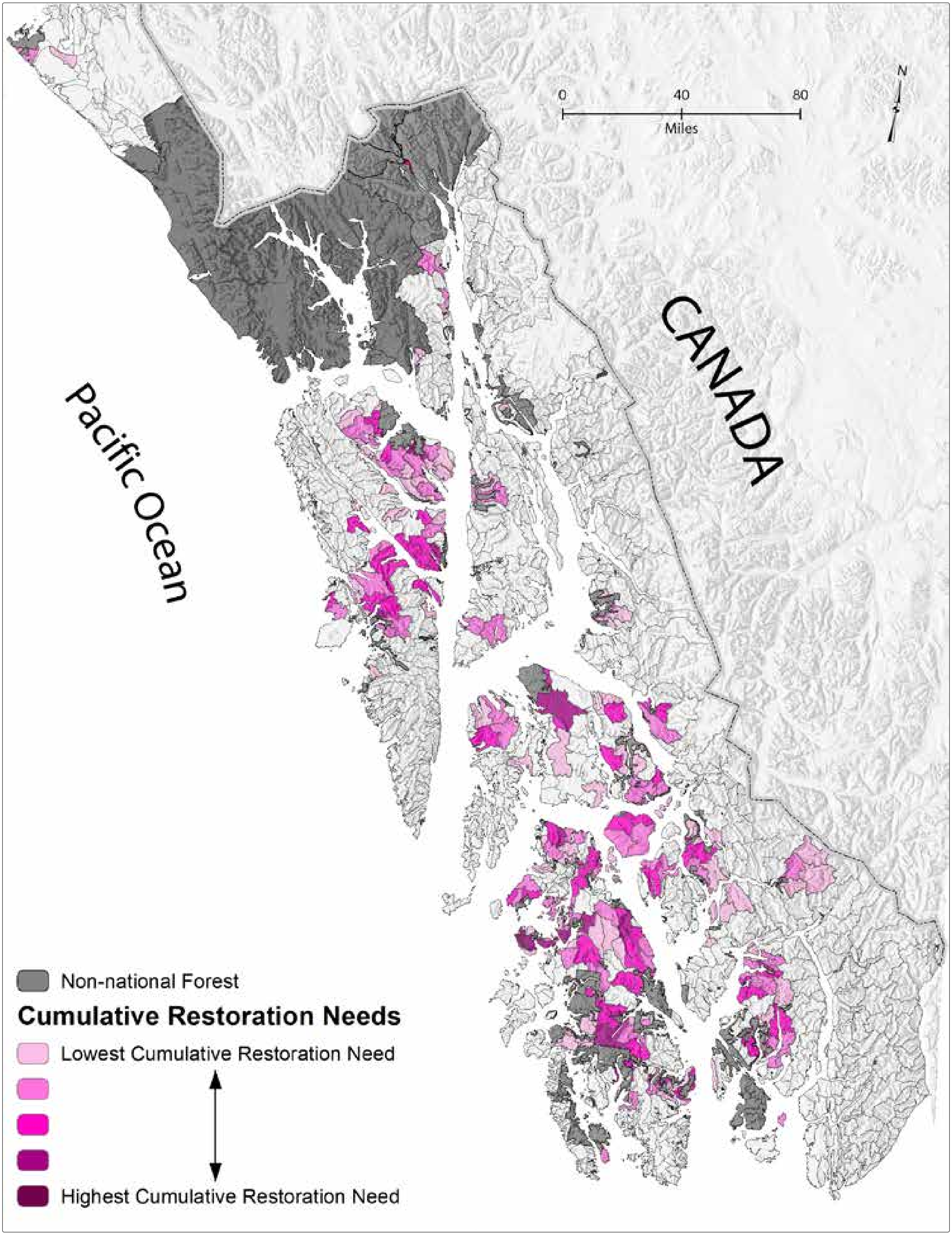


Figure 16. Watersheds' cumulative restoration needs for Southeast Alaska.

"All ecological restoration projects share a common suite of ecological goals that consist of recovering ecosystem integrity, health, and the potential for long-term sustainability." - SER international Guidelines 2005

PRIORITIZATION

Prioritizing serves to pare down the total pool of watersheds with restoration needs to a "short-list" based on a balance of ecological need and social opportunity. We developed a second GIS model to help with this process. Like our model for generating the pool of watersheds with restoration needs, the prioritization model presented here is just an example. We think it is a good example, but we want to emphasize that in an ideal situation we would be structuring our models with assistance from a collaborative group that is engaged in ground-truthing and multi-party effectiveness monitoring.

As with the restoration needs model, a primary goal of the prioritization model we present here was to make it something that would be useful to collaborative groups: a systematic and adjustable method of balancing ecological need with social value criteria. It can be, and in many cases should be, further tweaked by the collaborative. For example, recreation opportunity is hard to quantify at this point but may be an especially important social opportunity criteria in some communities.

Ecological Need

For our prioritization model we started with the watersheds identified as having the greatest cumulative need for ecological restoration (Figure 16) based on impacts to salmon habitat, deer habitat, karst habitat, potential endemics, landscape connectivity and the TLMP conservation strategy .

We only have 3 social criteria to add to the ecological need criteria but we want them to be weighted equally as a starting point. In order to do this we normalized the ecological needs scores to fit within a classification of have a value of 1, 2 or 3, where 3 indicates the highest need for ecological restoration. In the next step we will add our 3 social criteria. This will give us cumulative scores of 1 - 6, where 6 is the greatest cumulative ecological + social need.

Three additional methods of prioritizing restoration needs in the Tongass have been developed in recent years and are well worth investigating.

Audubon and The Nature Conservancy collaborated on a watershed-based regional assessment of conservation and restoration priorities (Schoen & Dovichin 2007). They used spatial optimization modeling software called MARXAN to identify priority watersheds for conservation and restoration. The restoration priority watersheds identified in the Audubon/TNC report represent some of the ripest "low-hanging fruit" of restoration opportunities in Southeast Alaska because they contain significant intact habitat patches that can be used as ecological anchors in watershed restoration planning (Lee et al. 1997, Gresswell 1999, McCarthy & Lindenmeyer 1999, Lindenmeyer & Franklin 2007).

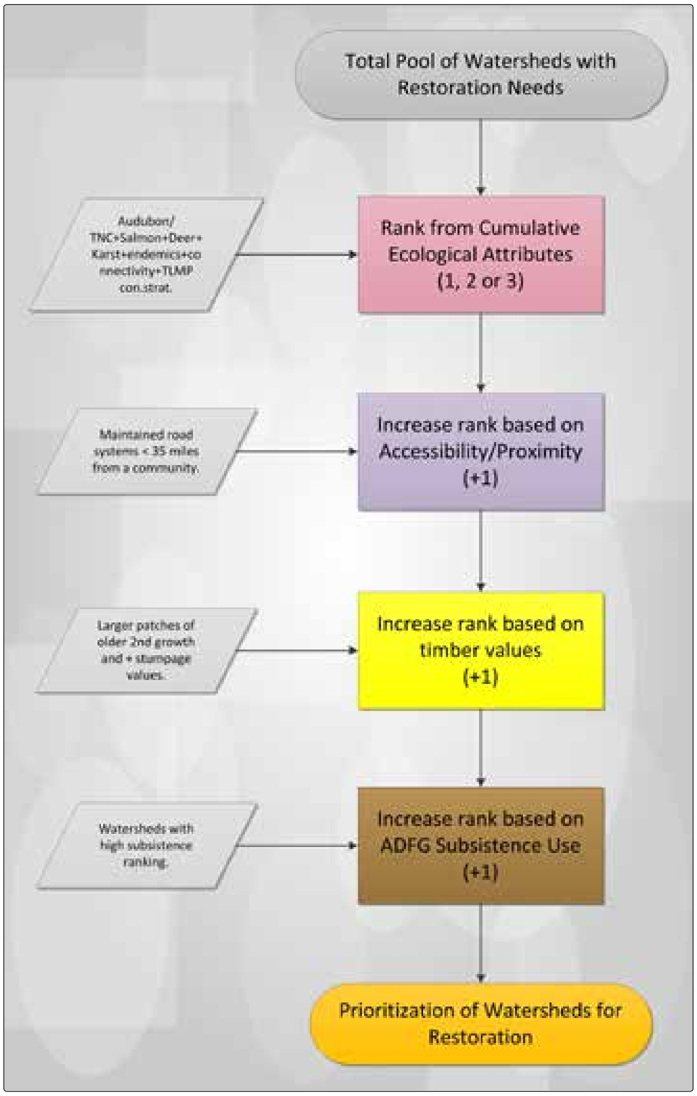
The USFS recently identified priority watersheds for restoration in the Tongass using its national Watershed Condition Framework (USFS 2011). This framework includes a strategic planning outline that is very similar to the one we developed for this report. It includes 6 key steps:

- **A. Classify Watershed Condition**
- **B. Prioritize Watersheds for Restoration**
- **C. Develop Watershed Restoration Action Plans**
- **D. Implement Integrated Suites of Projects**
- **E. Track Restoration Accomplishments**
- **F. Verify and Monitor Accomplishments**

Both of these methods represent excellent touchstones for strategic planning, but neither approach includes social variables in their prioritization models. A third approach was developed by The Nature Conservancy in collaboration with residents and agency representatives of Prince of Wales Island (Albert et al. 2008) This approach included social values through data on subsistence use and young growth economic opportunity.

The model we develop here draws from each of the approaches above and represents another iteration of balancing ecological and social values in prioritizing Tongass restoration locations.

Figure 17. Graphical representation of the GIS model used to prioritize watersheds.



Social Opportunity

The next three steps of our model serve to integrate social values that are primarily related to access, economics and current use.

- First we used the GIS to assign higher priority to those watersheds that had maintained road systems within 35 miles of a community.
- Next we used the GIS to assign higher priority to watersheds with the most economical timber.
- Finally, we used ADFG subsistence use data to identify watersheds that rank high based on the food resources they provide Southeast Alaskans.

For each of these ranking exercises the watersheds were given a point for coming up as high priority. The watersheds with the greatest number of points qualified for our short-list (Figures 17-19). Criteria could be added or modified depending on the perspective of the collaborative, but we believe this example is useful for demonstration while providing a solid, prioritized pool of restoration watersheds that could be used to engage the community in local knowledge-based corrections and localized priorities. This model has been designed with that in mind.

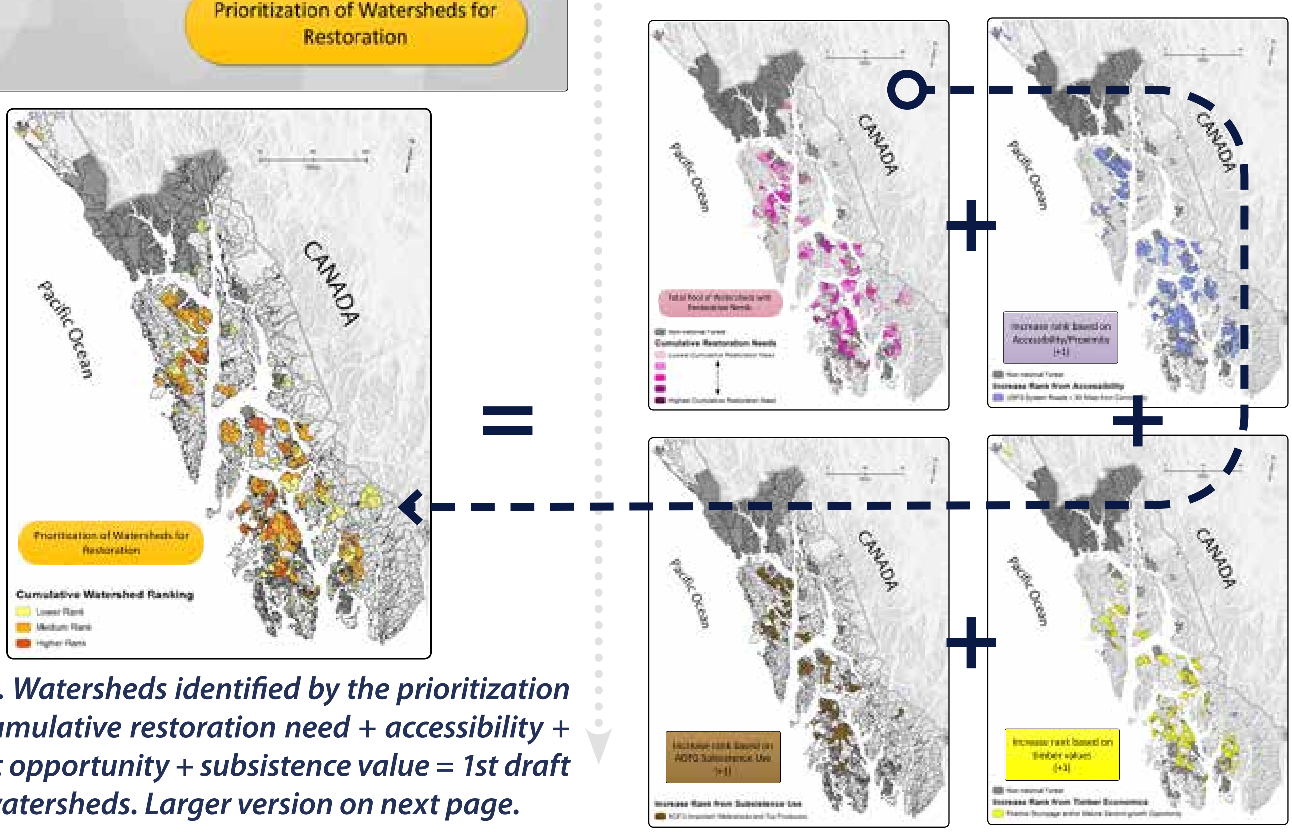


Figure 18. Watersheds identified by the prioritization model: cumulative restoration need + accessibility + economic opportunity + subsistence value = 1st draft priority watersheds. Larger version on next page.

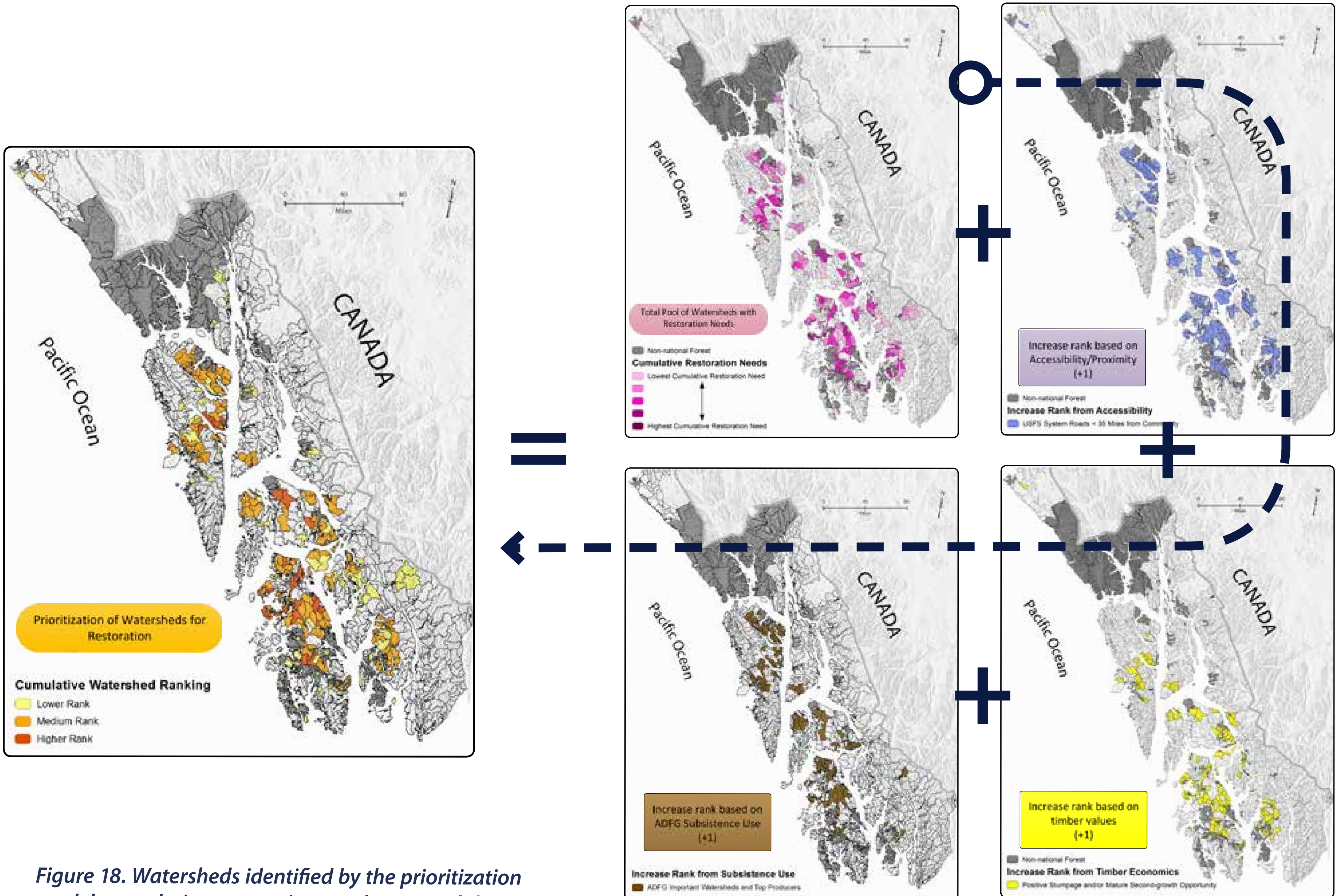


Figure 18. Watersheds identified by the prioritization model: cumulative restoration need + accessibility + economic opportunity + subsistence value = 1st draft priority watersheds.

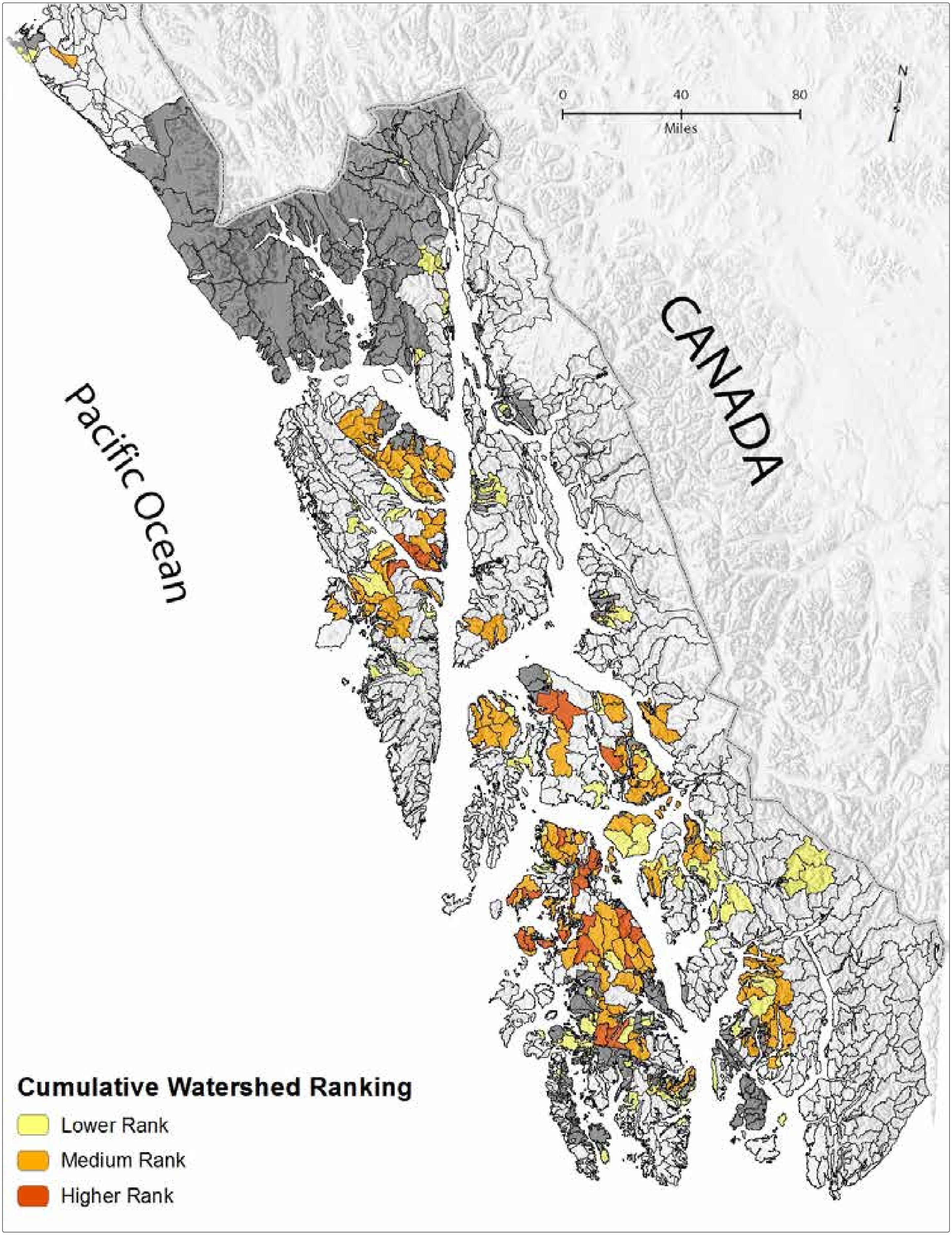


Figure 19. Prioritized restoration watersheds for Southeast Alaska

WATERSHED RESTORATION DESIGNS

> **"The most effective way to approach complex ecological issues is to consider them at the watershed level, where the fundamental connection among all components of the landscape is the network of streams that defines the watershed. Watersheds are easily identified on maps and on the ground, and their boundaries do not change much over time. Watersheds are also readily recognized by local communities and resonate with members of the public as a logical way to address resource management issues." - USFS 2011**

Watershed restoration designs are multi-scale plans that integrate stand level prescriptions into a holistic strategy to improve overall watershed condition. Watershed condition in Southeast Alaska is influenced by the state of hydrological processes, old-growth habitat structures and functions, productivity hot-spots and the degree to which each is tied together through elevational and landscape connectivity.

At fine scales, watershed restoration designs should include projects and prescriptions that address restoration needs within and between managed stands and remnant old-growth patches. At broader scales, designs should be attentive to the ways that key watershed features interrelate within and between watersheds as a functional landscape ecology.

Watershed restoration planning is a subject that is worthy of its own in-depth technical report but we want to include here some general observations that we hope can add to the development of a credible approach for the Tongass.

At the watershed scale, it is very important to balance GIS data with ground-truthing fieldwork, resource specialist input and local knowledge. This is true for all three primary components of a watershed restoration design:

- description of the watershed condition;
- comprehensive list of specific problems to be addressed; and,
- specific projects that are intended to address those problems.

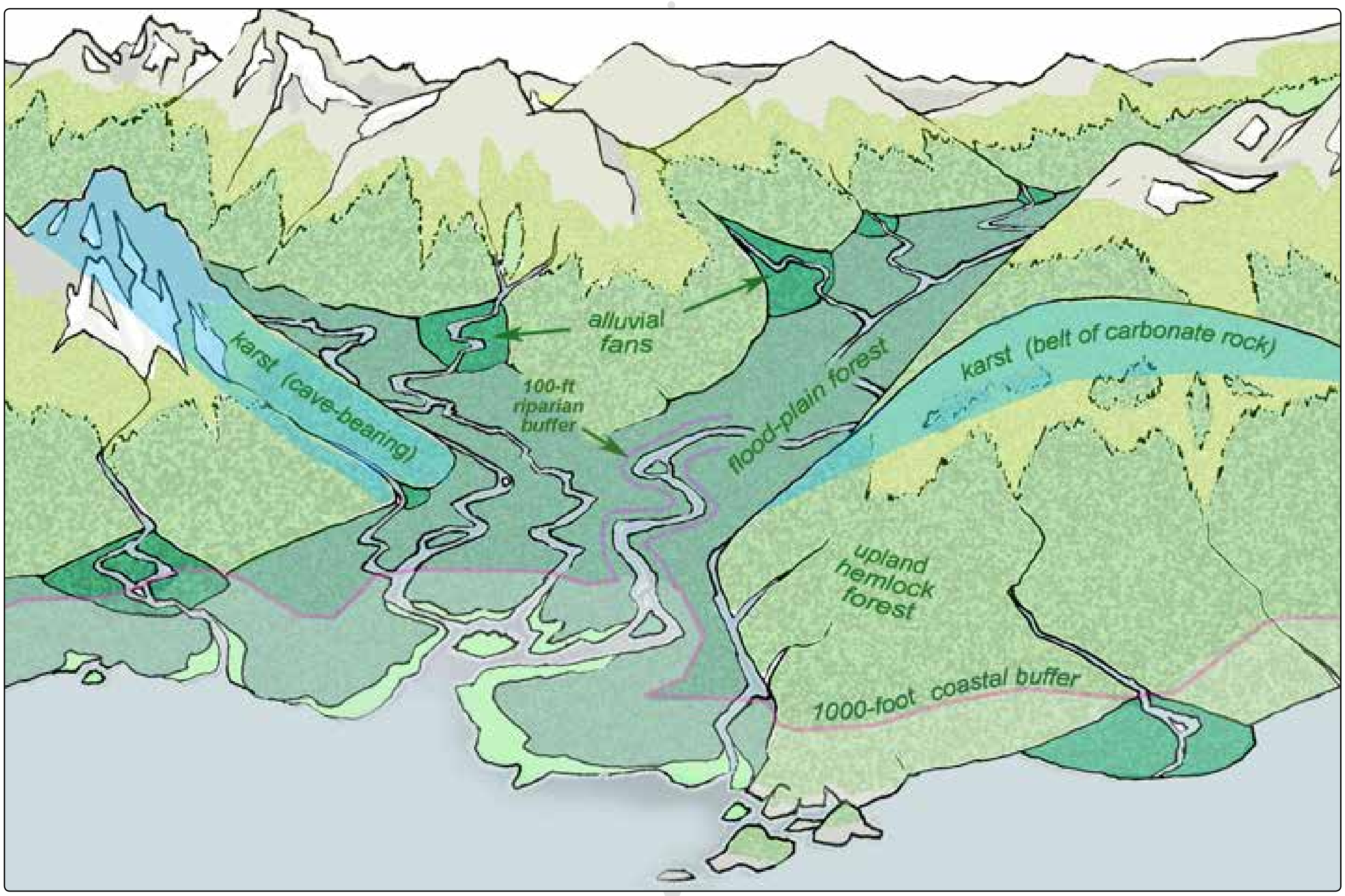


Figure 20. Key features of a watershed that are important to restoration planning: beach buffer, flood plain forest, alluvial fans and special habitats such as karst forest.

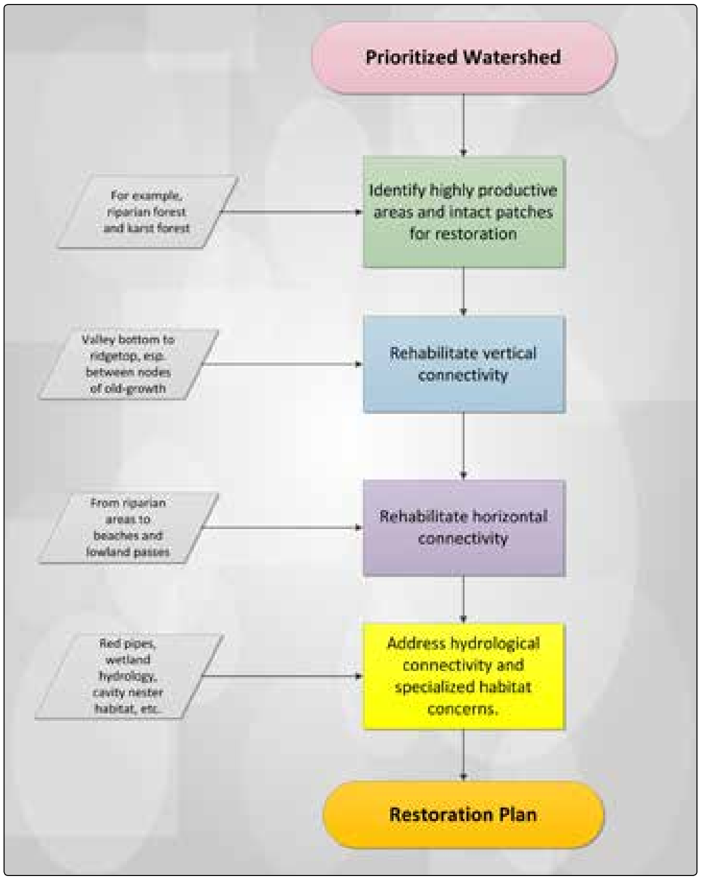


Figure 21. Graphical representation of the basics to cover in watershed restoration planning processes.

As we have noted in this report, the primary conditions that we will be addressing in watershed restoration in the Tongass stem from clearcut logging of old-growth forest. GIS data can provide a coarse before and after snapshot of ecological conditions that can be useful for structuring reconnaissance field work that targets identifying problems on the ground as well as appropriate reference sites in the nearby area.

The problems encountered in each watershed will also be somewhat similar. For example, many of the high priority restoration watersheds will have experienced flood plain logging of salmon streams, a high degree of low elevation old-growth habitat loss and fragmentation and reduced landscape and elevational connectivity. Impaired hydrological processes and invasive species colonization will likely have occurred in association with road construction.

The list of specific projects will vary from watershed to watershed but here too there will be similarities. It may be useful to think of this common suite of projects in terms of a basic recipe for watersheds restoration as follows:

"High-productivity sites should respond rapidly to restoration treatments, producing structurally complex forests in the shortest time. Hence, stands on high-productivity sites may take priority for treatment if the primary objective is restoration of complex structure on a portion of a large management area, for example to provide critical habitat for species of concern." - Larson et al. 2008

First, the top priority problems to address with restoration within many watersheds will be the condition of high productivity landforms. For example, flood plain forest restoration will almost always be a priority step because of their contribution to watershed productivity and landscape integrity. The restoration of flood plain forests should be geared toward the long-term recovery of these stands' ability to maintain abundant salmon populations, as well as performing their important roles as terrestrial hot-spots for diversity. Productive growing sites are also high priorities because they grow trees faster and will tend to need more aggressive and timely restoration interventions on the one hand, while providing the most rapid results on the other (Larson et al. 2008).

Second, landscape and elevational connectivity will also be a common concern. In high priority restoration watersheds it is likely that much of the low elevation old-growth around flood plain forests was logged, especially if the watershed includes a number of alluvial fans reaching down toward the valley bottom. This is critical in anadromous watersheds because of the importance of marine derived nutrients to terrestrial ecological resilience in our region and can be especially important if you are working in a watershed that is amongst the most productive in its landscape; a "source" that helps maintain diversity and abundance in lower productivity neighboring watersheds "sinks" (Pulliam 1988).

Within the watershed, the valley bottom provides a focal point for improving landscape connectivity while the class 1 and class 2 tributaries to the valley main-stem stream can guide efforts to work on elevational connectivity. The majority of these lands should already be classified as "Riparian Management Area" and are well suited to ecological restoration. Buffers on these features may need to be expanded a bit to provide a reasonable degree of wind-firmness. Identifying lower elevation passes and beach buffer areas that would benefit from restoration or that represent likely wildlife corridors are good starting points for increasing connectivity between watersheds.

Third, if habitat fragmentation is a problem we may wish to increase permeability between remnant patches of old-growth. If possible, projects can also be designed to expand the functional footprint of these patches. These anchor habitats can serve as "stepping stones" for resource propagation and serve to reestablish plant and animal diversity in neighboring restoration areas (Lindenmeyer & Franklin 2008).

Fourth, it is also important to respond to specific habitat type issues. For example, if a high percentage of karst forest within a watershed has been logged it may be worth including some of these areas in a high priority list of restoration sites. Another example is the near eradication of south-facing low elevation old-growth (prime winter deer habitat) in some areas.

Strategies for conserving both aquatic and terrestrial resources at multiple scales are based on similar principles: secure areas with high ecological integrity "anchor habitats", extend these areas, and connect them within watersheds and landscapes. (Lee et al. 1997, Gresswell 1999).

Fifth, restoring aquatic processes will also be a high priority because of their importance to watershed integrity overall (Franklin et al. 2010). Fixing failed culverts and other road crossings is a fairly straight-forward way to address some of these problems. Issues associated with "throughfall" and flow regimes in logged areas can be more complex, especially in karst watersheds (Prussian, 2010).

Finally, it will be important to plan for access. Restoration may require multiple visits and it would behoove us to maintain roads for the work. In other areas it may be suitable to decommission roads or down-grade them to trails. Access is one of several resource issues that can be integrated through action planning.

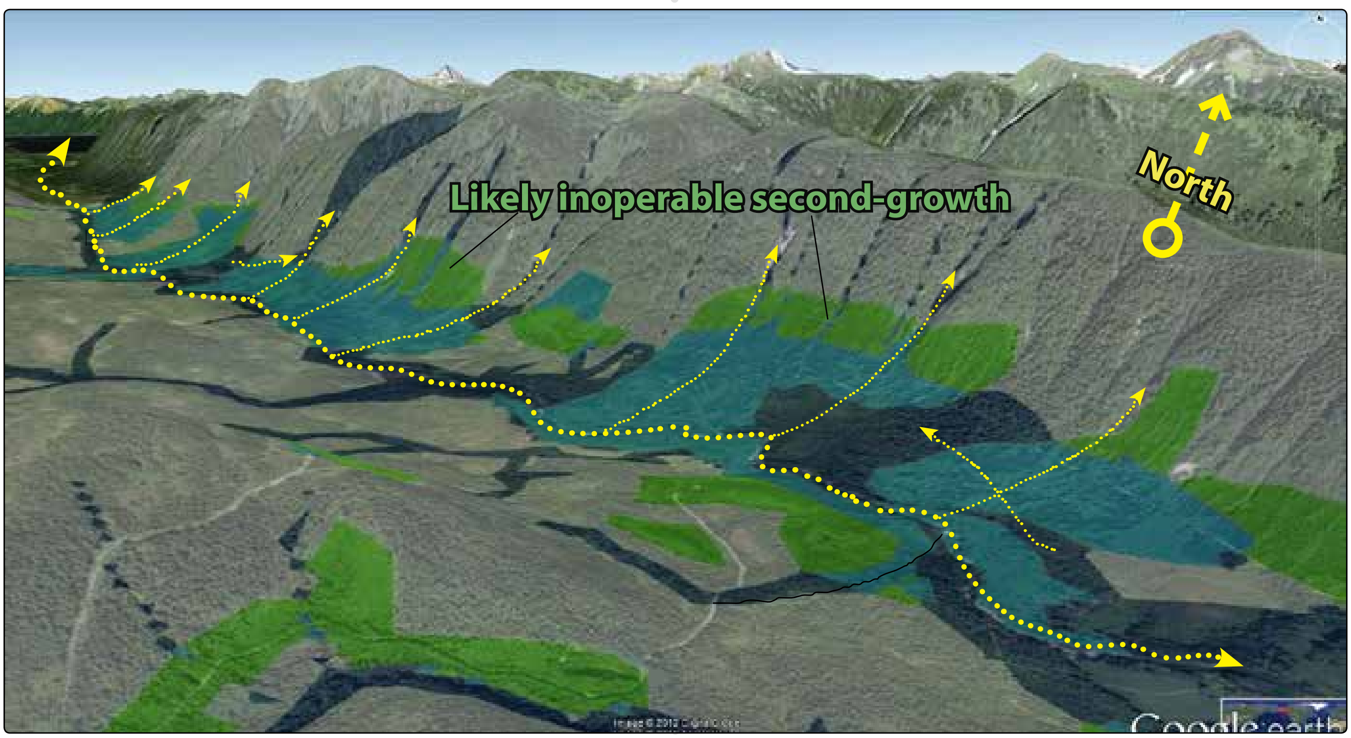
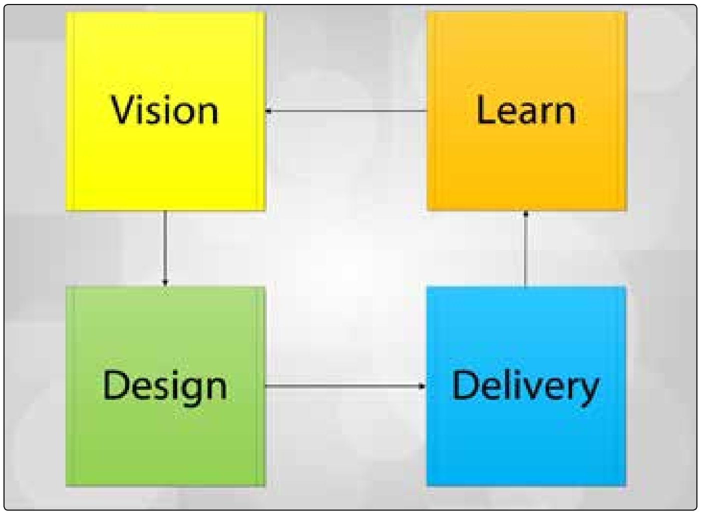


Figure 22. Example of key components of watershed restoration design for Sitkoh river area: riparian habitats. Dark blue areas are existing reserves, mostly intact. The light blue areas are logged riparian habitats that are well suited to restoration of productivity and connectivity through a combination of selection and VDT thinning with skips and gaps. The light green areas are considered suitable second-growth, although the smaller patches that lay above the unsuitable riparian second-growth are probably impractical for future logging.



ACTION PLANS, IMPLEMENTATION AND ADAPTIVE MANAGEMENT

Another way of looking at the strategic planning process outlined here is that it is a process for:

- facilitating a common vision of restoration;
- designing how to make the vision a reality;
- delivering measurable improvements to ecological and social resilience; and,
- learning to improve upon the results.

The strategic planning sections described so far cover the collaborative and conceptual work of creating a vision and a well-planned design for getting there. The next three steps in our strategic plan bring a project down to earth by addressing the material details of getting the work done and insuring it informs future efforts.

Action Plans

Action plans provide instructions for the acquisition and use of resources to meet specific restoration objectives and cover the who, what, where and when of getting restoration work done on the ground. Action plans should also cover a fund-raising strategy, including support for monitoring. This is especially true for collaborative projects that seek to balance appropriated dollars with private and foundation dollars.

Implementation

Implementation provides an opportunity to:

- dovetail restoration plans with other resource management opportunities;
- increase overall planning efficiencies,
- streamline field logistics,
- simplify red tape; and,
- identify opportunities for collaboration.

Implementation is the place to develop synergies between ecological integrity, a stable program of work and local economic benefits with tools such as Integrated Resource Management Plans (IRMP) and Stewardship Contracting Authorities (Kerkvliet 2010).

Adaptive Management

Adaptive management (AM) is a scientifically sound approach to learning how to do ecological restoration by doing it and evaluating results. Adaptive management is a research and monitoring approach that holds great promise for guiding stewardship in a complex and rapidly changing world. The importance of AM can't be overstated but sadly we do not have the time or space to due the topic justice here.

It is worth noting that although adaptive management has been around for a number of years, there have been limited successes thus far. There is an excellent paper written by Allen & Gunderson (2010) where they identify nine "pathologies" that commonly lead to failure in adaptive management. We reproduce the list here as a starting point for collaborating on doing a better job with this tool locally.

Common reasons for failure:

1. Lack of stakeholder engagement;
2. Experiments are difficult;
3. Surprises are suppressed;
4. Prescriptions are followed;
5. Action procrastination: learning and discussion remain the only ingredients
6. Learning is not used to modify policy and management;
7. Avoiding hard truths: decision makers are risk averse;
8. The process lacks leadership and direction;
9. Focus on planning, not action.

> **"Because we are extrapolating from oversimplified concepts, ignoring uncertainty may result in surprise and failure because we have not created a system capable of adapting or responding to future drivers or events. Restorations should not be one-time events, but are likely to require periodic attention and adaptive management to increase the chances of responsive, adaptive, and successful projects." - Hilderbrand et al. 2005**

CONCLUSION

TAKE HOME MESSAGE

> **"Ecologically sound forest restoration provides us with the opportunity to heal the land and to restore a viable community connection that in practice achieves an integrated vision of biocultural restoration. To ensure that this vision becomes reality, we must continue efforts to bring community forestry and conservation groups together. We must commit to thoughtful, science based restoration to ensure that future generations can experience and enjoy intact, diverse forested landscapes having the highest ecological integrity." - DelaSalla et al. 2003**

In the process of writing this report the author reviewed a number of documents that present a compelling case that ecological restoration can help our communities bounce back from the environmental and social forms of impoverishment that have been left in the wake of the boom and bust of industrial timber development. If done well, ecological restoration can improve ecosystem integrity while positively contributing to both the short-term (jobs) and long-term social gains (improved fish and wildlife productivity).

Based on the literature review conducted for this report, as well as 20 years personal experience working in the woods with some excellent naturalists, ecologists and foresters; we have covered what we believe are some of the most important ingredients to a recipe for success in ecological restoration:

- Defining what restoration is;
- Describing what is good for;
- Summarizing some key aspects of our setting;
- Providing detailed descriptions of specific techniques for conducting ecological restoration of forest habitats in southeast Alaska; and
- Drafting a Strategic framework for identify high priority watersheds based on ecological need an social priority and emphasizes a watershed based approach to landscape scale restoration planning.

Each of the topics covered should be expanded on through collaboration between the scientific community, resource specialists and community members. Given the changes that are taking place in local community and the Forest Service paradigms, the timing for this collaboration is ripe. As a gesture in that direction we include here some restoration rules of thumb.

> **"The time is right for a restoration economy. The Forest Service is tailoring its programs and projects to a new management environment associated with climate change, demographic growth, and other large-scale drivers of landscape changes that are undermining the health of America's forests and grasslands. Restoration treatments are based on collaboration with stakeholders to achieve mutual goals across entire landscapes, leading to more jobs and a better future for forest-based communities hard hit by recession." - Tom Tidwell 2011, USFS Chief**

RESTORATION RULES OF THUMB

- Be wary of modifying habitats that you think society may someday wish to restore in the future. Rare habitats and slow growing habitats, for example, are risky to modify. The expense of restoration is so great that we can only regret having impacted them looking back from the future.
- Address causes of degradation, not just symptoms. This has been done to some degree through the establishment of protected areas and the TLMP conservation strategy (passive restoration), however, the remaining timber lands are crucial to the function of many watersheds and landscapes. Moving away from clearcut logging and protecting vertical and horizontal connectivity in timber lands is essential to efficacy of active restoration efforts in nearby locations.
- Conduct ecological assessments at the landscape scale and restoration planning at the watershed scale.
- Balance need and opportunity for prioritization but be cautious and accountable with including timber as a by-product of restoration.

- Design restoration projects into comprehensive planning objectives that include complimentary efforts such as: road work, fish habitat restoration, recreation development, etc.
- Build off of existing nodes of old-growth as well as other types of habitat (wetlands, alder thickets) that enhance stand values because of proximity.
- New road construction should be avoided and road rehabilitation should be accompanied by strict guidelines for use to protect wildlife.
- Base stand designs on pre-logging conditions and reference sites when available, however, diversity is the rule. Don't be afraid to experiment, especially if you can commit to monitoring.
- Keep impacts to soils and hydrology to a minimum but don't be afraid to "break some eggs" for a long-term gain.
- Don't be myopic about desired future conditions for a particular species. Generally focusing on a singles species for conservation objectives has been shown to be an ineffective approach to ecological resilience.
- Take adaptive management seriously!
- Make an effort to integrate local people in restoration activities and education.

Given the level of commitment that Chief of the Forest Services has toward ecological restoration nationwide and the introduction of the Tongass Transition Framework in 2010, their is a prime opportunity for developing a comprehensive restoration plan for the Tongass National Forest and putting it into action ASAP. We believe that there are several critical elements to such a process, including:

- **A sober assessment of habitat degradation and the full costs of management activities;**
- **A scientific and socially credible approach to identifying restoration needs and prioritizing restoration actions; and**
- **A well funded and expertly staffed regional forest restoration program that is collaboratively oriented and tightly integrated with other Tongass programs (i.e. old-growth conservation, fish and wildlife habitat, recreation and timber management).**

CAVEATS AND CHALLENGES

Restoration is both a practice and a science that is still in its formative stages. It is important to acknowledge the limitations of our current understanding and to be cautious in our tinkering with nature. It is equally important that we do not get bound up in "analysis paralysis" and let the perfect get in the way of the good. Learning to do good ecological restoration will take considerable investments in time and resources, and a willingness to take risks and learn along the way, but we believe that with a sound adaptive management framework, the creativity of restoration practitioners and the resourcefulness of rural communities these investment will prove well worth future dividends.

A "word cloud" scales the size of words based on the number of times it is used in a document. This one derives from the Final EIS for the 2008 TLMP, within which the word timber can be found almost 3,000 times; restoration less than 20; zero of which referred to forests.

Restoration faces considerable challenges that must be overcome to fully realize the ecological and social benefits it has the potential to offer, but before we can make meaningful material progress in that regard it will need to be made a higher priority than it is currently. The 2008 TLMP documents provide a notable lack of direction for the role ecological restoration of second growth stands play in public lands.

Second growth management on the Tongass has been limited primarily to pre-commercial thinning and a more robust approach is just getting its feet wet. Given its central role in the "Transition Framework" for the Tongass National forest and the National emphasis on restoration it is not surprising that a robust "young growth" management strategy is currently being developed by local USFS staff (USFS 2008). This draft effort includes an encouraging list of objectives, a very useful distinction between second-growth management with a timber emphasis, riparian emphasis and wildlife emphasis and a variety of prescriptions that respond to site productivity and existing management direction emphasis. The first draft of this document appears to still be applying a somewhat timber-centric approach that utilizes various forms of conventional thinning for wildlife habitat restoration and enhancement. We are hopeful that future iterations of this strategy will integrate some of the additional ecological restoration tools described here, as well as promote an approach that addresses landscape and watershed scale patterns and processes.

It is important to note that ecological restoration is not holistic conservation, nor is it likely to save Southeast Alaska's economy. Restoration is an important tool for improving ecological integrity that can provide a wide range of other social benefits, but it does not diminish the importance of a functional reserve system, the need for biodiversity conservation within the "managed landscape", and a rational and sustainable approach to the production of material goods; a balance that has been aptly described as "ecological forestry" (Franklin et al. 2007).

Of course it will be necessary to revise the Tongass Land Management Plan to provide direction to the USFS young growth management program. With the emergence of a new National planning rule it seems likely that the USFS young growth management strategy document will soon be informing a TLMP revision.

At the time that this document is being written a number of collaborative efforts are working on bringing restoration to the forefront of USFS management priorities on the Tongass and to address additional gaps in our region's ability to do the work on the ground. There is widespread recognition that there are gaps in terms of environmental analysis, funding, our use of contemporary contractual tools and workforce capacities. Community engagement , entrepreneurial ingenuity, market development, more holistic methods of ecosystem service valuation, etc., are of equal importance to a TLMP revision that integrates restoration. We would do well to understand and communicate the many ways that ecological restoration can provide clear benefits to the average person: money in the pocket, food on the plate, clean air, clean water and a landscape that can inspire a balanced vision of resilience and prosperity.

CASE STUDIES

There are a number of projects that can provide useful case studies for using ecological restoration to increase ecological integrity and provide social benefits. We encourage the reader to use internet tools like Google to review ongoing developments on several relevant projects:

- Colville National Forest Restoration
- Siuslaw National Forest Restoration
- White Mountain Forest Restoration
- Beaverhead-Deerlodge Partnership

We also refer the reader to local examples of forest restoration planning efforts included in the references section:

- Christensen et al. 2006, 2008
- Anderson 2007
- Howell et al. 2008
- USFS & Seeley 2010

We also strongly encourage local readers to contact their district forest service offices to find out what kind of forest restoration activities are taking place locally, and how they might get involved.

"For those who say that times are tough, that we can ill afford sweeping changes because the existing system is already broke or hobbled, consider that the U.S. and the former U.S.S.R. spent over $10 trillion on the Cold War, enough money to replace the entire infrastructure of the world, every school, every hospital, every roadway, building and farm. In other words, we bought and sold the world in order to defeat a political movement. To now assert that we don't have the resources to build a restorative economy is ironic, since the threats we face today are actually happening, whereas the threats of the postwar nuclear stand-off were about the possibility of destruction." - Hawken 1994

REFERENCES

Alaback, P. B. Dynamics of understory biomass in Sitka spruce-western hemlock forests of southeast Alaska. Ecology 63, 1932–1948 (1982).

Alaback, P. B. Plant succession following logging in the Sitka spruce-western hemlock forests of southeast Alaska: implications for management. (US Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 1984).

Alaback, P. B. Ecological Characteristics of Temperate Rain Forests: Some Implications for Management of Bald Eagle Habitat. (2010).

Alaback, P. B. An evaluation of canopy gaps in restoring wildlife habitat in second growth forests of Southeastern Alaska. (A cooperative project with The Nature Conservancy-Alaska, Thorne Bay Ranger District and Craig Ranger District, Tongass National Forest, and POW-TEC: Prince of Wales Island, 2010).

Albert, D., Baker, L., Howell, S., Koski, K. V. & Bosworth, R. A Framework for Setting Watershed-scale Priorities for Forest and Freshwater Restoration on Prince of Wales Island. (2008).

Allen, C. R. & Gunderson, L. H. Pathology and failure in the design and implementation of adaptive management. Journal of environmental management (2010).

Almond, L., Deal, R. L. & Harrington, C. A. The value of red alder as an integrated pest management tool for controlling weevil damage to sitka spruce. UNITED STATES DEPARTMENT OF AGRICULTURE FOREST SERVICE GENERAL TECHNICAL REPORT PNW 669, 55 (2006).

Anderson, Y. G. Kosciusko EIS Young-Growth Management Update. (2007).

Ares, A., Neill, A. R. & Puettmann, K. J. Understory abundance, species diversity and functional attribute response to thinning in coniferous stands. Forest Ecology and Management (2010).

Aronson, J. & Le Floc'h, E. Vital landscape attributes: missing tools for restoration ecology. Restoration Ecology 4, 377–387 (1996).

Aukema, J. E. & Carey, A. B. Effects of Variable-Density Thinning on Understory Diversity and Heterogeneity in Young Douglas-fir Forests. PNW-RP-575 (2007).

Baichtal, J. F. & Swanston, D. N. Karst Landscapes and Associated Resources: A Resource Assessment. UNITED STATES DEPARTMENT OF AGRICULTURE FOREST SERVICE GENERAL TECHNICAL REPORT PNW (1996).

Baron, J. S. et al. Meeting ecological and societal needs for freshwater. Ecological Applications 12, 1247–1260 (2002).

Beier, C. M., Lovecraft, A. L. & Chapin III, F. S. Growth and collapse of a resource system: an adaptive cycle of change in public lands governance and forest management in Alaska. Ecology and Society 14, 5 (2009).

Beier, C. M. Influence of Political Opposition and Compromise on Conservation Outcomes in the Tongass National Forest, Alaska. Conservation Biology 22, 1485–1496 (2008).

Bengtson, G. W. Forest Fertilization in the United States: Progress and Outlook. Journal of Forestry 77, 222–229 (1979).

Berg, A. B. & Doerksen, A. Natural fertilization of a heavily thinned Douglas-fir stand by understory red alder. (1975).

Bormann, B. T. & Or.), P. N. F. and R. E. S. (Portland Early wide spacing in red alder (Alnus rubra Bong.): effects on stem form and stem growth. (U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 1985).

Restoration of endangered species. (Cambridge university press: 1994).

Bradshaw, A. D. Handbook of Ecological Restoration: Volume 1 Introduction and Philosophy. 1, (Cambridge university press: 2002).

Brian Palik Variable Retention Harvesting and Variable Density Thinning. (USFS Northern Research Station: 2011).

Brown, T. K. Creating and maintaining wildlife, insect, and fish habitat structures in dead wood. General technical report PSW-GTR-181 883–892 (2002).

Bull, E. L., Parks, C. G. & Torgersen, T. R. Trees and logs important to wildlife in the interior Columbia River basin. (1997).

Burns, R. M. & Honkala, B. H. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654, US Dept. of Agriculture, Forest Service, Washington, DC 2, (1990).

Cairns, J. Setting ecological restoration goals for technical feasibility and scientific validity. Ecological Engineering 15, 171–180 (2000).

Cairns Jr, J. Eco-societal restoration: re-examining human society's relationship with natural systems. ESEP BOOKS 21 (2002).

Caouette, J. P. & DeGayner, E. J. Predictive mapping for tree sizes and densities in southeast Alaska. (2005).at <http://www.treesearch.fs.fed.us/pubs/20446>

Carey, A. B. Induced spatial heterogeneity in forest canopies: responses of small mammals. (2001).at <http://www.treesearch.fs.fed.us/pubs/6103>

Carey, A. B. Active and passive forest management for multiple values. Northwestern Naturalist 87, 18–30 (2006).

Carey, A. B., Colgan, W., Trappe, J. M. & Molina, R. Effects of forest management on truffle abundance and squirrel diets. Northwest Science 76, 148–157 (2002).

Carey, A. B. & Harrington, C. A. Small mammals in young forests: implications for management for sustainability. Forest Ecology and Management 154, 289–309 (2001).

Carey, A. B., Kershner, J., Biswell, B. L. & Dominguez de Toledo, L. S. Ecological scale and forest development: squirrels, dietary fungi, and vascular plants in managed and unmanaged forests. Wildlife Monographs 3–71 (1999).

Carey, A. B., Thysell, D. R. & Brodie, L. C. The Forest Ecosystem Study: background, rationale, implementation, baseline conditions, and silvicultural assessment. (1999).at <http://www.treesearch.fs.fed.us/pubs/2984>

Carey, A. B. Biocomplexity and restoration of biodiversity in temperate coniferous forest: inducing spatial heterogeneity with variable-density thinning. Forestry 76, 127 (2003).

Carey, A. B. Restoration of landscape function: reserves or active management? Forestry 76, 221 (2003).

Carey, A. B. & Curtis, R. O. Conservation of biodiversity: a useful paradigm for forest ecosystem management. (1996).at <http://www.treesearch.fs.fed.us/pubs/6161>

Carey, A. B., Horton, S. P. & Biswell, B. L. Northern spotted owls: influence of prey base and landscape character. (1992).at <http://www.treesearch.fs.fed.us/pubs/6171>

Carey, A. B. & Johnson, M. L. Small mammals in managed, naturally young, and old-growth forests. (1995).at <http://www.treesearch.fs.fed.us/pubs/6167>

Carey, A. B., Lippke, B. R. & Sessions, J. Intentional systems management: managing forests for biodiversity. (1999).at <http://www.treesearch.fs.fed.us/pubs/2842>

Carey, A. B. & Thysell, D. R. Foundations of biodiversity in managed Douglas-fir forests. (1996).at <http://www.treesearch.fs.fed.us/pubs/5529>

Carstensen, R. Terrestrial Habitats of Southeast Alaska. (2007).

Carstensen, R. Natural History of Juneau Trails. (2011).

Carstensen, R. & Christensen, R. E. 2008 TLMP TCC Essay. (Southeast Alaska, 2008).

Carstensen, R. & Connor, C. Reading Southeast Alaska's Landscape. (2011).

CHAPIN III, F. S., HENRY, L. & LA'ONA, D. Wilderness in a Changing Alaska. Journal of Wilderness 10, 9 (2004).

Choi, Y. D. Restoration ecology to the future: a call for new paradigm. Restoration Ecology 15, 351–353 (2007).

Christensen, R. E. & Bjorum, E. Hoonah Community Forest Report. (2008).

Christensen, R. E. & Campen, S. Kake Community Forest Report. (2011).

Clewell, A. F. & Aronson, J. Motivations for the restoration of ecosystems. Conservation Biology 20, 420–428 (2006).

Cole, E. C., Hanley, T. A. & Newton, M. Influence of precommercial thinning and herbicides on understory vegetation of young-growth Sitka spruce forest in southeastern Alaska. Canadian Journal of Forest Research 40, 619–628 (2010).

Cole, E. C., Newton, M. & Hanley, T. A. Influence of precommercial thinning on understory vegetation of young-growth Sitka spruce forests in southeastern Alaska [electronic resource]. Canadian journal of forest research 40, 619–628 (2010).

Colgan, W., Carey, A. B., Trappe, J. M., Molina, R. & Thysell, D. R. Diversity and productivity of hypogeous fungal sporocarps in a variably thinned Douglas-fir forest. (1999).at <http://www.treesearch.fs.fed.us/pubs/6157>

Committee on Protection and Management of Pacific Northwest Anadromous Salmonids, National Research Council Upstream:Salmon and Society in the Pacific Northwest. (The National Academies Press: Washington, D.C., 1996).

Committee on Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy; National Research Council Restoration of Aquatic Ecosystems:Science, Technology, and Public Policy. (The National Academies Press: Washington, D.C., 1992).

Cullen, P. L. Using soil and landform characteristics to predict site productivity on Prince of Wales Island. Alaska. (Senior paper for Soil Sci. Dept., Calif. Polytechnic State Univ., San Luis Obispo, CA.: 1987).

de Montigny, L. & Stearns-Smith, S. Pruning density and severity in coastal western hemlock: 4-year results. (British Columbia Ministry of Forests Research Program: 2001).

Deal, R. L. Management strategies to increase stand structural diversity and enhance biodiversity in coastal rainforests of Alaska. Biological Conservation 137, 520–532 (2007).

Deal, R. L., Barbour, R. J., Mcclellan, M. H. & Parry, D. L. Development of epicormic sprouts in Sitka spruce following thinning and pruning in southeast Alaska. Forestry 76, 401 (2003).

Deal, R. L. & Harrington, C. A. Red alder: a state of knowledge. Notes (2006).

Deal, R. L., Oliver, C. D. & Bormann, B. T. Reconstruction of mixed hemlock-spruce stands in coastal southeast Alaska. CAN. J. FOR. RES./J. CAN. RECH. FOR. 21, 643–654 (1991).

Deal, R. L. & Russell, J. M. The potential role of red alder to increase structural and biological complexity in even-aged hemlock-spruce stands of Southeast Alaska. UNITED STATES DEPARTMENT OF AGRICULTURE FOREST SERVICE GENERAL TECHNICAL REPORT PNW 733, 135 (2008).

Deal, R. Red alder stand development and dynamics. Notes (2006).

Dellasala, D. A. et al. Effects of silvicultural modifications of temperate rainforest on breeding and wintering bird communities, Prince of Wales Island, southeast Alaska. Condor 98, 706–721 (1996).

DellaSala, D. A. et al. A Citizen's Call for Ecological Forest Restoration: Forest Restoration Principles and Criteria. Ecological Restoration 21, 14 (2003).

DellaSala, D. A. et al. Temperate and Boreal Rainforests of the Pacific Coast of North America. Temperate and Boreal Rainforests of the World: Ecology and Conservation 42–81 (2011).

DeMars, D. J. Stand-density study of spruce-hemlock stands in southeastern Alaska. General Technical Report-Pacific Northwest Research Station, USDA Forest Service (2000).

Doerr, J. G., DeGayner, E. & Ith, G. Winter Habitat Selection By Sitka Black-tailed Deer. Journal of Wildlife Management (2005).

Doyle, F. I. When do naturally regenerating and pre-commercially thinned second growth forests attain attributes that will support Northern Goshawks (laingi subspecies) and Marbled Murrelets on Haida Gwaii. Cascadia FP Ltd, Parks Canada (2006).

Drever, C. R., Peterson, G., Messier, C., Bergeron, Y. & Flannigan, M. Can forest management based on natural disturbances maintain ecological resilience? Canadian Journal of Forest Research 36, 2285–2299 (2006).

Drever, R. A Cut Above - Ecological Principles for Sustainable Forestry on BC's Coast. (2000).

Durbin, K. Tongass: pulp politics and the fight for the Alaska rain forest. (Oregon State University Press: 1999).

Dykstra, P. R. Thresholds in habitat supply: a review of the literature. BC Minist. Sustainable Resour. Manage. Ecosystem Conserv. Section, and BC Minist. Water, Land and Air Protection Biodiversity Branch, Victoria, BC. Wildl. Rep (2004).

Elliot, R. Faking Nature. Inquiry 81–93 (1982).

Restoring biodiversity. (Island Press: 1996).

Falk, D. A., Palmer, M. A. & Zedler, J. B. Foundations of restoration ecology. (Island Pr: 2006).

Farmer, C. J., Person, D. K. & Bowyer, R. T. Risk factors and mortality of black-tailed deer in a managed forest landscape. Journal Information 70, (2006).

Franklin, J. F., Mitchell, R. J., Palik, B. & Station, U. S. F. S. N. R. Natural disturbance and stand development principles for ecological forestry. (US Dept. of Agriculture, Forest Service, Northern Research Station: 2007).

Franklin, J. F. et al. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. Forest Ecology and Management (2002).at <http://www.treesearch.fs.fed.us/pubs/6026>

Franklin, J. F. & Johnson, K. N. Applying Restoration Principles on the BLM O&C Forests in Southwest Oregon. (2010).

Franklin, J. F. Preserving biodiversity: species, ecosystems, or landscapes? Ecological Applications 202–205 (1993).

Frost, N. J. Southeast Alaska Timbe Cruise Report. (1928).

Gende, S. M., Quinn, T. P., Willson, M. F., Scott, T. M. & Heintz, R. A. Magnitude and Fate of Salmon-Derived Nutrients and Energy in a Coastal Stream Ecosystem. Journal of Freshwater Ecology (2003).

Gessel, S., Miller, R. & Cole, D. Relative importance of water and nutrients on the growth of coast Douglas fir in the Pacific Northwest. Forest Ecology and Management 30, 327–340 (1990).

Graham, R. T., Harvey, A. E., Jain, T. B. & Tonn, J. R. The effects of thinning and similar stand treatments on fire behavior in western forests. (US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station: Oregon, 1999).

Gresswell, R. E. Fire and aquatic ecosystems in forested biomes of North America. Transactions of the American fisheries society 128, 193–221 (1999).

Groenier, J. S. & Rosquist, A. S. Using Scarification, Wood Shreddings, and Seeding To Rehabilitate Disturbed Sites. (2008).

Gunderson, L. H., Allen, C. R. & Holling, C. S. Foundations of ecological resilience. (2009).

Gunderson, L. H. & Holling, C. S. Panarchy: understanding transformations in human and natural systems. (Island Pr: 2002).

Hall, F. C. & Pacific Northwest Research Station (Portland, O.) Ground-based photographic monitoring. (US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station: 2001).

Hallett, J. G., Lopez, T., Borysewicz, M. & others Decay dynamics and avian use of artificially created snags. (2001).

Hammond, H., Hammond, S. & Bradley, T. An Ecosystem-Based Landscape Plan for the Slocan River Watershed. Silva Forest Foundation, Slocan Park (1996).

Hanley, D. P., Chappell, H. N. & Nadelhoffer, E. H. Fertilizing coastal Douglas-fir forests. Washington State University Extension Bulletin (2006).

Hanley, T. A. Potential management of young-growth stands for understory vegetation and wildlife habitat in southeastern Alaska. Landscape and Urban Planning 72, 95–112 (2005).

Hanley, T. A. & Barnard, J. C. Red Alder, Alnus rubra, as a Potential Mitigating Factor for Wildlife Habitat Following Clearcut Logging in Southeastern Alaska. (1998).

Hanley, T. A. & Hoel, T. Species composition of old-growth and riparian Sitka spruce–western hemlock forests in southeastern Alaska. Can. J. For. Res 26, 1703–1708 (1996).

Hanley, T. A., Smith, W. P. & Gende, S. M. Maintaining wildlife habitat in southeastern Alaska: implications of new knowledge for forest management and research. Landscape and Urban Planning 72, 113–133 (2005).

Hanley, T. A. Balancing economic development, biological conservation, and human culture: the Sitka black-tailed deer Odocoileus hemionus sitkensis as an ecological indicator. Biological Conservation 66, 61–67 (1993).

Harding, K. A. & Ford, D. C. Impacts of primary deforestation upon limestone slopes in northern Vancouver Island, British Columbia. Environmental Geology 21, 137–143 (1993).

Harding, K. A. & Ford, D. C. Impacts of primary deforestation upon limestone slopes in northern Vancouver Island, British Columbia. Environmental Geology 21, 137–143 (1993).

Hardy Remeasurement of 2nd Growth Permanent Sample Plots on Moresby Island. (MSRM, Nanimo, BC., 2005).

Harrington, C. A., Roberts, S. D. & Brodie, L. C. Tree and understory responses to variable-density thinning in western Washington. UNITED STATES DEPARTMENT OF AGRICULTURE FOREST SERVICE GENERAL TECHNICAL REPORT PNW 635, 97 (2005).

Harrington, C. A. Let's Mix it up: The benefits of Variable Density Thinning. (2009).at <http://www.fs.fed.us/pnw/sciencef/scifi112.pdf>

Harrington, C. A. & Devine, W. Stand development following precommercial thinning and fertilization treatments in a western redcedar (Thuja plicata) dominated forest. (2010).at <http://ddr.nal.usda.gov/handle/10113/48043>

Harrington, C. A., Roberts, S. & Brodie, L. C. Understory and Tree Responses to Variable Density Thinning in Western Washington. (2004).

Harrington, T. & Nicholas, G. Managing for Wildlife Habitat in Westside Production Forests. 35 (2007).

Harris, A. S. & Farr, W. A. The forest ecosystem of southeast Alaska: 7. Forest ecology and timber management. Notes (1974).

Harris, A. S. & Pacific Northwest Research Station (Portland, O.) Wind in the forests of southeast Alaska and guides for reducing damage. (US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station: 1989).

Hassan, R. M., Scholes, R. & Ash, N. Ecosystems and human well-being. (Island Press: 2005).

Hawken, P. The ecology of commerce: A declaration of sustainability. (Harper Paperbacks: 1994).

Hayles, N. K. Searching for common ground. Reinventing nature: responses to postmodern deconstruction 47–64 (1995).

Heaton, T. & Grady, F. The Late Wisconsin Vertebrate History of Prince of Wales Island, Southeast Alaska. The Late Wisconsin History of Prince of Wales Island, Southeast Alaska (2003).

Heiken, D. Restoration Thinning in Young Plantations West of the Cascades: Science Summary and Synthesis. (2007).

Heller, D. A Paradigm Shift in Watershed Restoration. (2004).

Hennon, P. E., D Amore, D. V., Wittwer, D. T. & Caouette, J. P. Yellow-cedar decline: conserving a climate-sensitive tree species as Alaska warms. UNITED STATES DEPARTMENT OF AGRICULTURE FOREST SERVICE GENERAL TECHNICAL REPORT PNW 733, 233 (2008).

Hennon, P. E. & McClellan, M. H. Tree mortality and forest structure in the temperate rain forests of southeast Alaska. Canadian Journal of Forest Research 33, 1621–1634 (2003).

Hennon, P. E. & Loopstra, E. M. Persistence of western hemlock and western redcedar trees 38 years after girdling at Cat Island in southeast Alaska. Notes (1991).

Hennon, P. E. Alaskan Yellow-cedar: Developing a management strategy for a tree impacted by climate change. (2006).

Higgs, E. The Two-Culture Problem: Ecological Restoration and the Integration of Knowledge. Restoration Ecology 13, 159–164 (2005).

Higgs, E. S. What is good ecological restoration? Conservation Biology 11, 338–348 (1997).

Higgs, E. Expanding the Scope of Restoration

Ecology. Restoration Ecology 2, 137–146 (1994).

Hilderbrand, R. H., Watts, A. C. & Randle, A. M. The myths of restoration ecology. Ecology and Society 10, 19 (2005).

Hobbs, R. J. et al. Restoration ecology: the challenge of social values and expectations. Frontiers in Ecology and the Environment 2, 43–48 (2004).

Hobbs, R. J. Handbook of Ecological Restoration: Volume 1 Principles of Restoration. 1, (Cambridge university press: 2002).

Hobbs, R. J. et al. Novel ecosystems: theoretical and management aspects of the new ecological world order. Global Ecology and Biogeography 15, 1–7 (2006).

Hobbs, R. J., Higgs, E. & Harris, J. A. Novel ecosystems: implications for conservation and restoration. Trends in Ecology & Evolution 24, 599–605 (2009).

Hobbs, R. Disturbance regimes in remnants of natural vegetation. Nature conservation: the role of remnants of native vegetation 233–240 (1987).

Howell, S. et al. Cobble Landscape Assessment. (2004).

Howell, S., Tierney, P. & Slayton, R. Staney Creek Vegetative Management Plan. (2008).

Isackson, K. USDA Blog » An Old Adversary Becomes a New Friend. USDA Blog (2011).at <http://blogs.usda.gov/2011/11/16/an-old-adversary-becomes-a-new-friend/>

Joe Kerkvliet The Practice and Economics of Stewardship Contracting: A Case Study of the Clearwater Stewardship Project. Forest Products Journal 60, (2010).

Jordan, W. R., Gilpin, M. E. & Aber, J. D. Restoration ecology: a synthetic approach to ecological research. (Cambridge Univ Pr: 1990).

Jordan III, W. R. Rituals of restoration. Humanist 23–26. (1993).

Katz, E. The big lie: human restoration of nature. Environmental Ethics: An Anthology 390–397 (2003).

Keeton, W. S. Managing for late-successional/old-growth characteristics in northern hardwood-conifer forests. Forest Ecology and Management 235, 129–142 (2006).

Keyes, C. R., Perry, T. E. & Plummer, J. F. Variable-density thinning for parks and reserves: An experimental case study at Humboldt Redwoods State Park, California. Notes (2010).

Kramer, M. G., Hansen, A. J., Taper, M. L. & Kissinger, E. J. Abiotic controls on long-term windthrow disturbance and temperate rain forest dynamics in southeast Alaska. Ecology 82, 2749–2768 (2001).

Larson, A. J., Lutz, J. A., Gersonde, R. F., Franklin, J. F. & Hietpas, F. F. Potential site productivity influences the rate of forest structural development. Ecological Applications 18, 899–910 (2008).

Larson, A. J. L. A. J. & Churchill, D. C. D. Spatial patterns of overstory trees in late-successional conifer forests. Canadian Journal of Forest Research 38, 2814–2825 (2008).

Lautenschlager, R. A., Sullivan, T. P. & Wagner, R. G. Using herbicides for wildlife management in northern ecosystems. Proceedings for Second International Conference on Forest Vegetation Management (RE Gaskin and JA Zabkiewicz, eds.). New Zealand Forest Research Institute, Bulletin 152–154 (1995).

Lee, D. C. et al. Broadscale assessment of aquatic species and habitats. (1997).

Lehmkuhl, J. F. & Ruggiero, L. F. Forest fragmentation in the Pacific Northwest and its potential effects on wildlife. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNWGTR-285. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station 35–46 (1991).

Leighty, W. W., Hamburg, S. P. & Caouette, J. Effects of Management on Carbon Sequestration in Forest Biomass in Southeast Alaska. Ecosystems 9, 1051–1065 (2006).

Leopold, A. A Sand County almanac: With essays on conservation from Round River. (Random House, Inc.: 1949).

Lertzman, K. P., Sutherland, G. D., Inselberg, A. & Saunders, S. C. Canopy gaps and the landscape mosaic in a coastal temperate rain forest. (1993).at <http://cat.inist.fr/?aModele=afficheN&cpsidt=3117455>

Lertzman, K. & MacKinnon., A. Why Watersheds: Evaluating the Protection of Undeveloped Watersheds as a Conservation Strategy in Northwestern North America. Ecology and Conservation of North Pacific Rainforests (2012).

Lewis, S. B. Clearcutting on Karst: Soil erodes into limestone caves. (1995).

Lewis, S. B. Breeding season diet of northern goshawks in southeast Alaska with a comparison of techniques used to examine raptor diet. (2001).

Light, A. 'Faking Nature' Revisited. The Beauty Around Us: Environmental Aesthetics in the Scenic Landscape and Beyond. Albany, NY: SUNY Press, forthcoming (2007).

Light, A. & Higgs, E. S. The politics of ecological restoration. Sciences 1, 25–51 (1993).

Lindenmayer, D. & Fischer, J. Habitat fragmentation and landscape change: an ecological and conservation synthesis. (Island Pr: 2006).

Lindenmayer, D. & Franklin, J. F. Conserving forest biodiversity: a comprehensive multiscaled approach. (Island Pr: 2002).

London, S. G. Spatial distribution of understory vegetation in tree canopy gaps of the Pacific Northwest. (1999).

Loomis, J. B. Can environmental economic valuation techniques aid ecological economics and wildlife conservation. Wildlife Society Bulletin (2000).

Loucks, D. M., Knowe, S. A. (Steven A., Shainsky, L. J., Pancheco, A. A. & Oregon State University. Forest Research Laboratory Regenerating coastal forests in Oregon : an annotated bibliography of selected ecological literature. (1996).at <http://ir.library.oregonstate.edu/xmlui/handle/1957/7659>

Lowe, K. & Moote, M. A. Collaboration as a Tool in Forest Restoration. (2005).

Ludwig, D. The era of management is over. Ecosystems 4, 758–764 (2001).

MacDonald, S. O. & Cook, J. A. Mammals and Amphibians of Southeast Alaska. (The Museum of Southwestern Ecology: 2007).

Mackovjak, J. Tongass Timber: A History of Logging and Timber Utilization in Southeast Alaska. (Forest History Society: 2010).at <http://www.foresthistory.org/publications/booksgen.html>

Management, N. R. C. (US). C. on W. New strategies for America's watersheds. (Natl Academy Pr: 1999).

Manning, T. Fungal inoculation of trees as a habitat enhancement tool in second-growth forests–TFL 37 operational trial, 2002 (year 1) progress report. Report prep. for Canadian Forest Products Ltd., Englewood Div., Woss, BC June (2003).

Matsuoka, S. M. & Dellasala, D. A. Succession of bird and vegetation communities in young temperate rainforests following thinning. (2007).

Mazurek, M. J. & Zielinski, W. J. Individual legacy trees influence vertebrate wildlife diversity in commercial forests. Forest Ecology and Management 193, 321–334 (2004).

McCarthy, M. A. & Lindenmayer, D. B. Incorporating metapopulation dynamics of greater gliders into reserve design in disturbed landscapes. Ecology 80, 651–667 (1999).

McClellan, M. H. Recent research on the management of hemlock-spruce forests in southeast Alaska for multiple values. Landscape and Urban Planning 72, 65–78 (2005).

McGarigal, K. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. (2012). at <http://www.umass.edu/landeco/research/fragstats/fragstats.html>

Miller, R. & Fight, R. Fertilizing Douglas-fir Forests. 34–43 (1978).

Moores, Macguire & Puettman Intensive Silviculture of Coastal Douglas-Fir in the Pacific Northwest. (2004).

Naiman, R. J., Bisson, P. A., Lee, R. G. & Turner, M. G. Approaches to management at the watershed scale. Creating a forestry for the 21st century: the science of ecosystem management 239–253 (1997).

Newbold, S. C. Integrated Modeling for Watershed Mangement: Multiple Objectives and

Spatial Effects. JAWRA Journal of the American Water Resources Association 38, 341–353 (2002).

Nie, M. Governing the Tongass: National forest conflict and political decision making. Envtl. L. 36, 385–1445 (2006).

Nowacki, G. J., Region, U. S. F. S. A., Service, U. S. N. P. & (US), G. S. Ecological subsections of southeast Alaska and neighboring areas of Canada. (US Dept. of Agriculture, Forest Service, Alaska Region: 2001).

Nowacki, G. J. & Kramer, M. G. The effects of wind disturbance on temperate rain forest structure and dynamics of southeast Alaska. (US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station: 1998).

Nyberg, J. B. et al. Integrated management of timber and deer: coastal forests of British Columbia and Alaska. (Pacific Northwest Research Station: 1989).

Nyland, R. D. Silviculture: concepts and applications. (McGraw-Hill New York, NY: 1996).

Odum, E. The strategy of ecosystem development. Science 164, 262–270 (1969).

Ogg, C. W. & Keith, G. A. New Federal Support for Priority Watershed Management Needs1. JAWRA Journal of the American Water Resources Association 38, 577–586 (2002).

Ohmann, J. L. & Gregory, M. J. Predictive mapping of forest composition and structure with direct gradient analysis and nearest-neighbor imputation in coastal Oregon, USA. Canadian Journal of Forest Research 32, 725–741 (2002).

Ohmann, J. L., McComb, W. C. & Zumrawi, A. A. Snag abundance for primary cavity-nesting birds on nonfederal forest lands in Oregon and Washington. Wildlife Society Bulletin 22, 607–620 (1994).

Oliver, C. D., Larson, B. C. & others Forest stand dynamics. (McGraw-Hill, Inc.: 1990).

Omule, S. A. ., Mitchell, A. K., Wagner, W. L. & Centre, C. W. F. Fertilization and Thinning Effects on a Douglas-fir Ecosystem at Shawnigan Lake: 32-year Growth Response. (Canadian Wood Fibre Centre: 2011).

Oregon Department of Fish and Wildlife (ODFW) Strategy Habitat: Late Successional Conifer Forests (low and mid-elevations). (2006).

Ormerod, S. J. Restoration in applied ecology: editor’s introduction. Journal of Applied Ecology 40, 44–50 (2003).

Ott, R. A. & Juday, G. P. Canopy gap characteristics and their implications for management in the temperate rainforests of southeast Alaska. Forest Ecology and Management 159, 271–291 (2002).

Parker, K. L., Robbins, C. T. & Hanley, T. A. Energy expenditures for locomotion by mule deer and elk. The Journal of wildlife management 474–488 (1984).

Parker, V. T. & Pickett, S. T. . Restoration as an ecosystem process: implications of the modern ecological paradigm. Restoration Ecology and Sustainable Development 17 (1997).

Parks, C. G. Artificially created snags for cavity nesters–what’s working. Western International Forest Disease Workshop conference proceedings. Hood River, Oregon (1996).

Perera, A. H., Buse, L. J. & Weber, M. G. Emulating natural forest landscape disturbances: concepts and applications. (Columbia Univ Pr: 2004).

Person, D. K., Bowyer, T., Darimont, C. & Paquet, P. C. Succession Debt: Effects of Clear-cut Logging on Wolf-deer Predator-prey Dynamics in Coastal British Columbia and Southeast Alaska. (2003).

Petruncio, M. D. Effects of pruning on growth of Western Hemlock (Tsuga heterophylla (Raf.) Sarg.) and Sitka Spruce (Picea sitchensis (Bong.) Carr.) in Southeast Alaska. Unpublished Ph. D. dissertation, University of Washington, College of Forest Resources, Seattle, Washington, USA 160 pp (1994).

Piccolo, J. J. & Wipfli, M. S. Does red alder (Alnus rubra) in upland riparian forests elevate macroinvertebrate and detritus export from headwater streams to downstream habitats in southeastern Alaska? Canadian Journal of Fisheries and Aquatic Sciences 59, 503–513 (2002).

Poiani, K. A., Richter, B. D., Anderson, M. G. & Richter, H. E. Biodiversity conservation at multiple scales: functional sites, landscapes, and networks. BioScience 50, 133–146 (2000).

Pringle, C. M. Hydrologic connectivity and the management of biological reserves: a global perspective. Ecological Applications 11, 981–998 (2001).

Puettmann, K. J., Coates, K. D. & Messier, C. C. A critique of silviculture: managing for complexity. (Island Pr: 2008).

Pulliam, H. R. Sources, sinks, and population regulation. American Naturalist 652–661 (1988).

Reeve, T., Lichatowich, J., Towey, W. & Duncan, A. Building Science and Accountability into Community-based Restoration: Can a New Funding Approach Facilitate Effective and Accountable Restoration? Fisheries 30, (2006).

Reeves, G. H., Benda, L. E., Burnett, K. M., Bisson, P. A. & Sedell, J. R. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. American Fisheries Society Symposium 17, 334–349 (1995).

Reid, L. M., Ziemer, R. R. & Furniss, M. J. Watershed analysis on federal lands of the Pacific northwest. Notes (1994).

Reimchen, T. E. Salmon nutrients, nitrogen isotopes and coastal forests. Ecoforestry 16, 13–16 (2001).

Ruth, R. H. & Harris, A. S. Management of western Hemlock-sitka spruce forests for timber production. Notes (1979).

Salafsky, N. Integrating development with conservation:: A means to a conservation end, or a mean end to conservation? Biological Conservation 144, 973–978 (2011).

Salafsky, N., Margoluis, R., Redford, K. H. & Robinson, J. G. Improving the Practice of Conservation: a Conceptual Framework and Research Agenda for Conservation Science. Conservation Biology 16, 1469–1479 (2002).

Sarr, D., Puettmann, K., Pabst, R., Cornett, M. & Arguello, L. Restoration ecology: New perspectives and opportunities for forestry. Journal of forestry 102, 20–24 (2004).

A conservation assessment for the coastal forests and mountains ecoregion of southeastern Alaska and the Tongass National Forest. The coastal forests and mountains ecoregion of southeastern Alaska and the Tongas National Forest. Audubon Alaska and The Nature Conservancy, Anchorage, Alaska, USA (2007).

Schoen, J. W. & Kirchhoff, M. D. Seasonal habitat use by Sitka black-tailed deer on Admiralty Island, Alaska. The Journal of Wildlife Management 371–378 (1990).

Sedell, J., Sharpe, M., Apple, D. D. & Furniss, M. Water and the Forest Service. (2000).

Shapiro, E. Restoring habitats, communities, and souls. Ecopsychology: restoring the Earth, healing the mind 224–239 (1995).

Simenstad, C., Reed, D. & Ford, M. When is restoration not? Incorporating landscape-scale processes to restore self-sustaining ecosystems in coastal wetland restoration. Ecological Engineering 26, 27–39 (2006).

Smith, D. M. & Hawley, R. C. The practice of silviculture. 578, (Wiley New York: 1962).

Smith, J. R. Seral stage, site conditions, and the vulnerability of understory plant communities to forest harvesting. (2005).

Smith, W. P. & Nichols, J. V. Demography of two endemic forest-floor mammals of southeastern Alaskan temperate rain forest. Journal of Mammalogy 85, 540–551 (2004).

Society for Ecological Restoration, (SER) Ecological Restoration: A Means of Conserving Biodiversity and Sustaining Livelihoods. (2004).

Society for Ecological Restoration, (SER) Guidelines for Developing and Managing Ecological Restoration Projects. (2005).

Soulé, M. E. & Simberloff, D. What do genetics and ecology tell us about the design of nature reserves? Biological conservation 35, 19–40 (1986).

Spies, T. A. & Franklin, J. F. The structure of natural young, mature, and old-growth Douglas-fir forests in Oregon and Washington. L. E Ruggiero, KB Aubry, AB Carey, and M. Huff, technical coordinators. Wildlife and vegetation of unmanaged Douglas-fir forests. General technical report PNW-GTR-85. US Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, Oregon 91–109 (1991).

Stanford, J. A. & Ward, J. An ecosystem perspective of alluvial rivers: connectivity and the hyporheic corridor. Journal of the North American Benthological Society 48–60 (1993).

Subgroup, S. of A. F. S. I. Silviculture Terminology: With Appendix of Draft Ecosystem Management Terms. (1994).

Swanson, M., Imaki, H. & Lippke, B. R. The Rural Technology Initiative Working Paper 10: Literature Review on Innovative Silviculture and Management Practices Supportive of Conservation Values. (2009).at <http://www.ruraltech.org/pubs/working/10/index.asp>

Sweeney, S. Different means, shared ends: environmental restoration and restoration ecology. Biologica 38, 129–136 (2000).

Tappeiner, J. C., Huffman, D. W., Marshall, D., Spies, T. A. & Bailey, J. D. Density, ages, and growth rates in old-growth and young-growth forests in coastal Oregon. Canadian Journal of Forest Research 27, 638–648 (1997).

Tappeiner, J. C. & Alaback, P. B. Early establishment and vegetative growth of understory species in the western hemlock- Sitka spruce forests of southeast Alaska. CAN. J. BOT./J. CAN. BOT. 67, 318–326 (1989).

Tappeiner, J. C., Maguire, D. A. & Harrington, T. B. Silviculture and ecology of western US forests. (Oregon State Univ Pr: 2007).

Tarrant, R. F. & Trappe, J. M. The role of Alnus in improving the forest environment. Plant Soil 35, 335–348 (1971).

Throop, W. & Purdom, W. T. . Wilderness Restoration: The Paradox of Public Participation. Wilderness (2005).

Thysell, D. R. & Carey, A. B. Manipulation of density of Pseudotsuga menziesii canopies: preliminary effects on understory vegetation. Canadian journal of forest research 31, 1513–1525 (2001).

Tidwell, T. USDA Blog » Moving Toward a Restoration Economy. USDA Blog (2011).at <http://blogs.usda.gov/2011/11/22/moving-toward-a-restoration-economy/#more-36962>

Tiegs, S. D. et al. Timber harvest transforms ecological roles of salmon in southeast Alaska rain forest streams. Ecological Applications 18, 4–11 (2008).

Tongass National Forest Tongass Evaluation and Monitoring Report: TWYGS. (2008).

Tyler, R. W. & Gibbons, D. R. Observations of the effects of logging on salmon-producing tributaries of the Staney Creek watershed and the Thorne River watershed and of logging in the Sitka District, Final Report. (1973).at <https://digital.lib.washington.edu/researchworks/handle/1773/3793>

USDA, F. USFS Interim Directive on Forest Restoration and Resilience. (2010).

USFS Congruent Management of Multiple Resources: Proceedings from the Wood Compatibility Initiative Workshop. (2002).at <http://ocid.nacse.org/nbii/density/pdfFiles/Wood_Compat_Wrkshp_2002_GTR_563a.pdf#page=59>

USFS USFS Renewable Resources Handbook. (U.S. Department of Agriculture, Forest Service: 2005).

USFS Tongass Land Management Plan ROD-2008. (2008).

USFS Tongass Land Management Plan 2008 - FEIS. (2008).

USFS West Alsea Landscape Management Project: Environmental Assessment. (2008).

USFS Watershed Condition Framework. (US Department of Agriculture, Forest Service: 2011).

USFS USDA Investment Strategy in Support of Rural Communities in Southeast Alaska. (2011).

USFS & Seeley, S. KMRD Beach Fringe Wildlife Habitat Restoration-Shoal Cove Area. (2009).

USFS Restoration Framework Team Ecosystem restoration: A framework for restoring and maintaining the national forests and grasslands. (2006).

Wallmo, O. C. & Schoen, J. W. Response of Deer to Secondary Forest Succession in Southeast Alaska. Forest Science 26, 448–462 (1980).

Walters, C. J. & Holling, C. S. Large-scale management experiments and learning by doing. Ecology 71, 2060–2068 (1990).

Whittington, J., St. Clair, C. C. & Mercer, G. Spatial Responses of Wolves to Roads an Trails in Mountain Valleys. Ecological Applications 15, 543–553 (2005).

Williams, J. E. Watershed restoration: principles and practices. (Amer Fisheries Society: 1997).

Willson, M. F. Dispersal of seeds by frugivorous animals in temperate forests. Revista Chilena de historia natural 64, 537–554 (1991).

Willson, M. F. Mammals as seed-dispersal mutualists in North America. Oikos 159–176 (1993).

Willson, M. F. & Traveset, A. The ecology of seed dispersal. Seeds: The ecology of regeneration in plant communities 85–110 (2000).

Wilson, D. S. & Puettmann, K. J. Density management and biodiversity in young Douglas-fir forests: challenges of managing across scales. Forest ecology and management 246, 123–134 (2007).

Wilson, E. O. The Future of Life. (2002).

Wilson, E. O. The diversity of life. (W. W. Norton & Company: 1999).

Wilson, T. M. & Carey, A. B. Legacy retention versus thinning: influences on small mammals. (2000).at <http://www.treesearch.fs.fed.us/pubs/6152>

Yoda, K. Self-thinning in over-crowded pure stands under cultivated and natural conditions.(In-traspecific competition among higher plants. XI.). J Biol Osaka City Univ 14, 107–129 (1963).

Zobrist, K. W. & Hinckley, T. M. A literature review of management practices to support increased biodiversity in intensively managed Douglas-fir plantations. Rural Technology Initiative (2005).

ACKNOWLEDGEMENTS AND AUTHOR INFO

The Wilderness Society is the leading public-lands conservation organization working to protect wilderness and inspire Americans to care for our wild places. Founded in 1935, and now with more than 500,000 members and supporters, TWS has led the effort to permanently protect 110 million acres of wilderness and to ensure sound management of our shared national lands. www.wilderness.org.

This project would not be possible without the support of Southeast Alaska Wilderness Exploration, Analysis and Discovery (SEAWEAD), the Environmental Systems Research Institute (ESRI) and Google Earth. The photos used in this report were taken by Bob Christensen except where noted.

The graphic artwork was provided by Richard Carstensen except where noted.


photo by Scott Harris

Bob Christensen was raised in Washington state by a family of land developers and antique dealers. Bob slowly worked his way through college until 1996 when he received a degree in "Living Systems Design" from the department of Applied Human Ecology and Appropriate Technology at the Huxley College of Environmental Science in Bellingham, Washington. The culmination of this degree was the collaborative design of an imagined self-reliant rural community of 400 people in Southeast Alaska. Since that time Bob has made his home at a remote island in Southeast Alaska. For the past 15 years he has filled the role as the lead naturalist and ecologist with Southeast Alaska Wilderness Exploration, Analysis and Discovery (SEAWEAD) and has worked with a wide range of state and federal resource agencies, conservation groups, community groups and private developers on fish and wildlife studies and construction projects throughout Southeast Alaska. In recent years Bob has found his way back to his passion for sustainable community design while developing ideas on how ecological restoration can serve to heal and strengthen community resilience.