KRUZOF AND BARANOF ISLANDS INTEGRATED NATURAL RESOURCE MANAGEMENT ASSESSMENT

by

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We would like to dedicate this project to Bennett "Iris Meadows" Harvanek and his family.

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Report Abstract

The Kruzof and Baranof Islands Integrated Natural Resource Management Assessment evaluates and offers recommendations for current management initiatives while identifying strategies for future management, restoration, and outreach plans for the U.S. Forest Service Sitka Ranger District. The project report is divided into three main focus areas: Community Engagement, Restoration, and Education. The community engagement component aims to assess the perceptions and opinions of area residents and stakeholders regarding natural resource management within the study area, utilizing community surveys, participatory GIS (Geographic Information Systems), and extensive stakeholder interviewing. The restoration component evaluates restoration efforts that have been implemented since 1980 on Kruzof and Baranof Islands, by assessing the success of past restoration and gathering baseline information to provide monitoring data and better understand the natural succession after clear-cut harvest disturbances. The education component is geared towards creating awareness of marine invasive species through the creation of lessons and encouraging future monitoring through the development of field labs. Integrated project recommendations for future land management include: (1) limited future old-growth harvesting, (2) thinning of the riparian canopy where stem-exclusion is occurring, (3) increased restoration monitoring, (4) a trial-period of young-growth subsistence firewood opportunities, (5) utilization of hands on educational curriculum, and (6) improved signage and increased restoration and maintenance work on Kruzof Island.

Executive Summary

Introduction

The *Kruzof and Baranof Islands Integrated Natural Resource Management Assessment* evaluates and offers recommendations for current management initiatives while identifying strategies for future management, restoration, and outreach plans for the surrounding area. Our project is divided into three main focus areas: Community Engagement, Restoration, and Education.

I. Community Engagement Summary & Results

The Community Engagement component of our project aims to assess the perceptions and opinions of area residents and stakeholders regarding natural resource management within the Sitka USFS Ranger District. Our team employed two methods to obtain and assess this information. First, we designed a cross-sectional survey questionnaire featuring a mix of open-ended, closed-ended, and contingency assessment questions. The survey also included a novel participatory mapping component, which collected information on areas of special significance to area residents. In September of 2014, 2,300 of these questionnaires were distributed through the Sitka Sentinel newspaper and through online surveying software. Additionally, survey results are complemented by the findings of 11 in-person and 5 telephone interviews with key public, state, and federal stakeholders from Sitka and the greater Tongass National Forest. Survey results and stakeholder analysis are synthesized with outside research on existing community forestry and firewood procurement agreements in the final report. All findings are supported by a two-week information-gathering period on the ground in Sitka and on Kruzof Island.

Survey findings indicate that not only does Kruzof Island boast a high existence value among area residents, but also hosts a broad range of uses and activities. Survey respondents generally trended toward lower impact uses, such as hiking and camping, subsistence hunting and gathering, and wildlife-viewing/bird-watching. Participatory GIS data further demonstrates the remarkable range and diversity of activities across the landscape. Findings indicate that Kruzof hosts high-levels of subsistence utilization (hunting, gathering, and fishing), and that such subsistence can be a critical livelihood component for area residents. Data provided by respondents demonstrates the diversity of subsistence harvest on the island, which occurs year round.

Survey findings also strongly indicated that future management priorities for Kruzof Island should focus on protection and restoration of wildlife habitat, as well as maintenance of recreation infrastructure. Harvest of forest products, including logging, was routinely ranked the lowest priority. Respondents also ranked increased habitat preservation and an improved trail system as the changes they would most like to see made on Kruzof. Respondents demonstrated a strong negative perception of continued logging on the island.

Survey respondents strongly identified logging, ATV-use, and overdevelopment as the greatest ecosystem threats to Kruzof Island and the Sitka Ranger District. When survey respondents selected desired types of timber harvest for Kruzof Island the majority chose the collection of fallen/cut wood from tree thinning projects for commercial or personal use, followed most closely by preferences for selective young-growth harvesting, or no timber harvest of any kind.

In evaluating the feasibility of establishing a firewood collection program on Kruzof Island, a contingency structure used to determine if respondents collect firewood for their personal use indicated that roughly half of the 114 respondents do (47%). Of that half, about 54% would be interested in firewood collection opportunities on Kruzof Island.

Community Engagement Recommendations

The Community Engagement project component integrates findings from background research, survey results, general information and exemplary quotes extracted from stakeholder interviews, and the findings of the Restoration and Education portions of the project. Drawing from this body of work, we provide the following recommendations for balancing the multiple uses of and demands upon Kruzof Island resources:

1. Limit old-growth logging
2. Support and facilitate subsistence access to and uses of Kruzof Island
3. Pilot community firewood harvesting
4. Continuing support of and investment in restoration projects
5. Cultivate strong communication and stakeholder engagement
6. Improve signage

II. Restoration Summary & Results

The Restoration component evaluates restoration efforts that have been implemented since 1980 on Kruzof and Baranof Islands, and continue to play an important role in land management. Although the U.S. Forest Service continues to conduct large scale restoration projects within the study areas, the effects of past restoration projects on habitat quality have not been systematically assessed. Additionally, the natural succession of ecosystems after clear-cutting harvests are not well documented in the project study areas. The restoration assessment portion of this project aims to 1) assess the success of past restoration and 2) gather baseline information to provide monitoring data and better understand the natural succession after clear-cut harvest disturbances. This process included a bio-assessment to determine the success of past restoration and gather baseline information after clear-cut harvesting. The bio-assessment analyzed aquatic and riparian health by measuring indicators in sites that had been disturbed, sites that were left undisturbed and when possible, sites that have experienced restoration work.

The Shelikof Creek pre-restoration aquatic assessment compared two sites, disturbed and undisturbed, in order to assess the impacts of previous timber harvesting. No significant differences were found between the disturbed and undisturbed sites based on substrate size, woody debris, or width to depth ratio. The disturbed site actually exhibited slightly better quality in terms of macroinvertebrates, substrate, and large wood. Both sites exhibited poor substrate quality, large amounts of fine sediment undesirable for spawning habitat, and high water quality, based on the macroinvertebrate metrics. The low quality aquatic characteristics of Shelikof Creek do not appear to be a result of timber harvest activities, since the undisturbed sites were not of higher quality than the disturbed in most of the indicator variables. Future restoration efforts in Shelikof Creek should aim to decrease the amount of fine sediment and increase available habitat for fish spawning.

The riparian assessment for Shelikof Creek also compared two sample sites: undisturbed and disturbed. These sites were analyzed to determine the effects of clear-cut harvest on forest structure and composition. In the disturbed site, the effects of clear-cut harvest were visible in the overall density of trees and understory composition. Both the disturbed and undisturbed sites exhibited an uneven forest structure indicating that although the disturbed site may have once been in a stem exclusion phase, it is no longer. This could be due to self-thinning of the forest or the short life-cycle of the alder species prevalent in the disturbed riparian areas. In addition, the understory composition in the disturbed site exhibited lower amounts of desirable tree and shrub species, such as the *Vaccinium*, which serve as an important food source for deer, and hemlock and spruce, which are regenerative species. In terms of snags, the snag to tree ratio was significant between the disturbed and undisturbed sites, but there was no significance of snags or deadwood. The undisturbed site exhibited a linear relationship in terms of snag to tree ratio, where those locations with more trees also tended to contain a greater abundance of snags. The disturbed site, however, failed to display this relationship and showed 7% of the forest volume as deadwood in comparison to 23% for the undisturbed site, which is similar to standards set by previous studies.

The aquatic assessment for Starrigavan Creek compared three sites: undisturbed, restored, and disturbed. All three sites significantly differed in substrate size and macroinvertebrate metrics. The results of the macroinvertebrate multimetric index suggests that the undisturbed site displayed the highest quality and the disturbed site the lowest. The restored site had the highest proportion of small particles, which harm salmon spawning and survival. The undisturbed site, on the other hand, had a much higher portion of larger particles, which are preferred for salmon spawning. The disturbed sites had poorer water quality, more fine sediment, and smaller substrate sizes compared to the undisturbed. Additionally, restoration work in Starrigavan has appeared to successfully improve macroinvertebrate metrics, indicating improved water quality, and width to depth ratio, most likely due to the introduction of large wood to form pools and stabilize the streambank. On the other hand, the restoration work has not improved substrate quality or the amount of woody debris. The restored site tended to have lower quality than the undisturbed site, however, indicating that future restoration work is still necessary. Overall, since water quality, substrate size, and macroinvertebrate composition have not been shown to negatively impact salmonids and are providing adequate water quality and food sources in Starrigavan Creek, restoration work in the areas with adequate hydrology have the ability to be successful in improving aquatic health and should continue to focus on increasing the amount and quality of fish habitat via large wood introductions, and preventing further disturbances such as stream erosion.

The riparian assessment for Starrigavan Creek analyzed the effects of clear-cut harvest on forest structure and composition. Three sample sites were compared: undisturbed, restored, and disturbed. Effects of the clear-cut harvest were visible in the forest structure and composition of the restored and disturbed sites. In the disturbed and restored riparian areas, the overall density of trees was significantly less than the undisturbed. Alder, an early successional species found in areas that have experienced a large-scale disturbance, was only present in the disturbed and restored sites. In terms of forest structure, the disturbed site of Starrigavan was not an uneven aged stand, signifying that the forest was experiencing stem exclusion. This occurs when the understory fails to obtain enough sunlight to regenerate or provide enough shrub cover to support deer populations in the winter (Aikan & Watinson, 1979). The restored Starrigavan site exhibited a low overall abundance of trees. The structure was of an uneven age, however, so the restoration has proved successful in making structural improvements. Disturbed and restored sites exhibited understory populations consisting of fewer regenerative species (hemlock and spruce) and less edible vegetation (blueberry, hemlock, and spruce) compared to the undisturbed. This phenomenon indicates unsuccessful restoration in improving habitat for deer and indicates that the long-term succession of the forest may not be healthy due to the lack of saplings able to grow into the overstory. In terms of snags, no significant difference was found between each of the three sites. The restored site had no presence of snags and there was no significance for the snag to tree ratio between the three sites. The undisturbed site displayed a linear relationship, in which those locations with more trees contained a greater abundance of snags, whereas the disturbed displayed no relationship. More monitoring points are needed to be able to define the trend for snags and deadwood in these systems.

Restoration Recommendations

1. Increase future monitoring of post-restoration work to produce more robust results, help confirm the results from our study, and determine the impacts of restoration work in order to advise future work
2. Conduct fish sampling at key sites in order to obtain more direct results and aid in quantifying results based upon fish abundance in a manner easily relatable to stakeholders
3. Increase monitoring efforts to assess the prevalence of pool formation from large woody debris deposits for salmonid spawning habitat
4. Observed impacts of past timber clear-cuts display the need to prevent or minimize future disturbances from timber harvest
5. Future stream restoration work should include preventing streambank erosion and decreasing fine sediment in Shelikof Creek and increasing the amount and quality of fish habitat (large and key wood) in Starrigavan Creek
6. Include restoration planting of ideal species (hemlock, spruce, and blueberry) within light gaps.
7. Where stem exclusion is occurring, create light gaps by thinning small adult trees in the 20-40cm diameter at breast height (DBH) size class. Some thinned trees can be dedicated to firewood harvesting. Other trees within the dedicated light gap area can be girdled to create snags, which are important habitat for birds. Leave a portion of the thinned trees fallen on the ground to replenish the soil

III. Education Summary & Results

The Educational component of this project is geared towards creating awareness of marine invasive species as well as teaching students the importance of monitoring ecological health. After conducting interviews with scientists and teachers in Sitka, we identified a need for materials specific to certain grade levels that complement Alaska State Standards. This process included the development of lesson plans and a field guide for 6th grade students on area marine invasive species, along with the creation of aquatic and riparian monitoring field labs. These field labs are a continuation of the monitoring and data collection the restoration team conducted in June 2014. Overall, the educational component of this project serves to help younger generations understand and explore ecological issues that are affecting Southeast Alaska.

The Stream Monitoring Field Guide provides background information, step-by-step field methods, data analysis steps, and discussion questions for analyzing stream quality using three methods not described in the preexisting 7th grade Stream Team Manual. These three methods include: width to depth ratio, amount of woody debris, and a pebble count to describe substrate size. This new guide gives students the ability to analyze data collected in the field and compare it to previous data. Along with the stream sampling protocols, riparian field and analysis protocols were created to add to the baseline data that the restoration team collected in June. The Riparian Field Lab targets high school students and teaches them how to monitor the success of past riparian restoration efforts. By using field methods to sample undisturbed, restored, and disturbed sites and by comparing these three areas students can analyze past restoration efforts to make recommendations on improvements for future management practices. Both riparian and stream team lesson plans integrate appropriate grade-level Alaska State Standards into the content.

The Marine Invasive Species lesson plans were created for 6th grade students who cover the topic of Life Science in their science class. With the help of local scientists and teachers, we were able to create extensive lessons that give students a background on what defines invasive species as well as their effects on the local ecosystem in Sitka. These lessons are supported by an extensive field guide of invasive and non-invasive marine species, which helps students understand and identify the species more easily. The field guide is an accessible tool for students to learn about invasive and native species as it provides students with background and identification information. We also included a European Green Crab monitoring protocol that was created for an 8th grade science club. This monitoring protocol requires adult supervision on a boat, therefore it is on a smaller scale and is for a higher grade level.

The goals of the lesson plans are to help school teachers teach their students about local, place-based environmental issues and ecology. The lessons are set up in a way that is easy to follow and comprehend for teachers who might not have a strong background on the subject. The clear list of Alaska State Standards at the beginning of each lesson helps teachers assess the topics covered. The supporting materials like PowerPoint presentations, worksheets, activities and rubric at the end of each lesson give teachers all the tools needed to teach specific topics. The goal of creating the restoration monitoring field labs is to engage students in important "real world" work, to help determine success of restoration projects, and to advise future land management work.

Education Recommendations

1. Engage students in more hands-on environmental activities and projects as a part of the school curricula across all subjects
2. Expand current science curricula in Sitka to include more lessons that promote community-level environmental awareness
3. Engage students in monitoring projects for marine invasive species that include an outdoor collection and an analysis component
4. Engage students in monitoring projects related to restoration efforts and land management in order to collect and analyze data that can be used to make recommendations for future management practices
5. Communicate with students the "real world" impacts of their monitoring and other citizen science efforts, giving them tools to help solve environmental issues in the community

IV. Recommendations

We conclude our project by integrating all of our work into six overall recommendations.

a) **Large-scale old growth harvesting is not recommended on Kruzof Island, and should be undertaken with caution in other areas of the Sitka Ranger District.** Results from our analysis of the stream and riparian data show that long-term ecological effects are still apparent from clearcuts that ended in the 1970s. The majority of survey respondents have specified that they do not want large-scale old growth logging within the Sitka area. Our survey analysis indicates that the most supported activities utilizing natural resources on Kruzof Island are those related to habitat restoration, tourism, and recreation. We suggest that the U.S. Forest Service Sitka Ranger District direct their funding and attention to management efforts and projects that support and further those three activities.

b) Where stem-exclusion exists, thinning canopy to create light gaps. Since our results show that areas that were clear-cut harvested are now experiencing low sapling densities, the stands are likely in a stem exclusion phase. Stem exclusion occurs when there are more adult trees than saplings. Dense adult populations diminish the amount of light that enters the understory which limits understory species' growth. Without a dense understory, there is little food for deer to eat in the winter and few species that can regenerate into the overstory.

We recommend that where stem-exclusion exists, thin the canopy to create light gaps. Light gaps should have a diameter that is 150% the average height of surrounding trees. Gap areas should be located where there is a clustering of trees within the 20-40cm DBH range. If trees with a DBH larger than 40cm exist within the gap area, they should be left standing alive. 20% of the trees from within designated gap area should be girdled to create snags, which allow for bird habitat. 20% of trees should be left to decompose and replenish the soil with nutrients. Fallen trees should be moved into the nearby stream to add complexity to the channel and increase habitat for stream biota.

c) Increase restoration monitoring to understand potential impacts of disturbances and restoration efforts. The results obtained from the monitoring efforts should be used to advise future management and restoration techniques in the area. The data will also be valuable for increasing the robustness of and certainty in current baseline data. The monitoring should also include community participation in order to engage the community and increase ecological knowledge. To improve on current methods, which do not involve wildlife data, monitoring of target species, such as salmonids and deer, should be incorporated in order to directly observe the impacts of disturbances and restoration efforts. Additionally, tying the success and/or failure of work to these key species will allow the results to be better understood by the public. Finally, coordination of annual sampling efforts should be done in collaboration with agencies, like Alaska Fish & Game, and local groups in order to concentrate sampling efforts at key sites, such as those that scheduled for restoration.

d) Open up young-growth subsistence firewood opportunities on Kruzof Island for a trial period. As Sitka residents express a continuing need for firewood harvesting opportunities, making by-product available could limit illegal harvesting and demonstrate follow-through on solicited public input. While survey responses are split on the economic feasibility of by-product utilization on Kruzof, certain users are well-equipped and highly interested in the opportunity. A trial period could mitigate local need while allowing for monitoring of the small-scale experiment.

e) Use hands-on educational curriculum to encourage community engagement and improve ecological awareness of local and regional land management issues. Maintain long-term environmental education programs within the Sitka School District by encouraging educators to take part in science curriculum enhancement trainings and workshops through partnerships with government agencies, non-profit organizations, and scientist in the area. Use partnerships between the schools and local organizations to create more interactive, investigation based science lessons for in and out of classroom use. Focus on teaching students subjects that include the scientific process, ecology, impacts of disturbances, timber harvest, marine invasive species, and local science issues. Overall, focus on integrating local environmental issues and consequences into current science curriculum for all grade levels.

f) Improve signage and increase restoration and maintenance work on Kruzof Island. Survey responses indicate that there is a need for better directions and support of recreation activities, particularly at Mud Bay, North Beach, Iris Meadows, and along the road and trail systems. Respondents also expressed a desire for information indicating and describing ongoing restoration work.

Chapter 1 | Community Engagement Assessing a Multiple Use and Value Landscape

U.S. Forest Service Sitka Ranger District
Community Engagement Team Members: Katherine Browne, Sara Cawley

I. Background

A. Ongoing Management of the Tongass National Forest

Containing over 17 million acres of land, the Tongass National Forest is the largest national forest in the United States, and represents nearly one-third of the old-growth temperate rainforest left in the world (Sisk, 2007). Located on the Alaskan archipelago, the Tongass takes up 80 percent of Alaska's southern land base (Alaback, 2007). The Forest provides a wide array of natural resources utilized for economic, cultural, and recreational purposes, in addition to providing significant ecosystem value to southeastern Alaska. From an ecological perspective, these benefits include clean water, carbon storage, intact wildlife corridors, and extensive fish habitat. From an economic perspective, the Tongass has and continues to provide employment in timber and wood products, commercial fishing and fish processing, recreation, tourism, and mining and mineral development.

Created in 1907 by President Roosevelt, the Tongass is managed by the United States Forest Service (USFS). Under the National Forest Management Act of 1976, the USFS is required to undertake a review of the Tongass' managing Forest Plan every five years (USFS, 2008). Prior to the most recent assessment in 2013, the USFS was given a directive by Tom Vilsack, the Secretary of Agriculture and the head of the USFS' managing department, to transition the Tongass into young-growth timber management (USFS, 2013). Timber has played a significant economic and cultural role on the Tongass for decades under USFS management. Yet, as the USFS transition intent document states, "Ecological, social and economic considerations, and longstanding conflict over large scale clearcutting of old growth forests, necessitate a shift to forest management that conserves the forest's rich resources while supporting vibrant economies and local communities" (USFS, 2013).

In 1973, the Tongass produced a historic annual timber peak of 591 million board feet (TNC, 2015). Timber production has declined since then, due to the 1990 passage of the Tongass Timber Reform Act, and a combination of changing market conditions and increasing public opposition to clear-cut logging within national forests (Primary source interviews, 2015; Sisk, 2007). 2012's estimated annual harvest was only 12 million board feet, in comparison to the bountiful harvests of the 1960s and 1970s (TNC, 2015). Today, the timber industry makes up only a small portion of southeastern Alaska's economic base. In light of this declining timber productivity, and in recognition of the need to shift to economies that are sustainable under current economic, ecological, and social conditions; natural resource managers, and public and private stakeholders are engaged in an ongoing dialogue on how best to balance multiple management demands on the Tongass.

In 2014, the USFS created the Tongass Advisory Committee (TAC) to aid with the transition process (USFS, 2014). It is common for advisory committees to be convened in order to provide recommendations for federal directives. Fifteen members were selected from a pool of seventy-five applicants by the Secretary of Agriculture after a lengthy selection process (USFS, 2014). The TAC features representatives from the timber industry, environmental organizations, federal, state, and local government, as well as the federally-recognized Sitka Tribe of Alaska and Sealaska, an Alaska native corporation (USFS, 2014). The TAC has been mandated to provide the Secretary of Agriculture and USFS Chief Robert Bonnie with a set of recommendations on how to support the management transition and to bolster implementation of a young-growth timber supply, as well as to identify the key economic and natural resource elements to be considered under a potential Forest Plan modification (USFS, 2014).

B. Project Study Areas and Southeastern Alaska's Economic Drivers

The Tongass National Forest contains ten ranger districts: Ketchikan-Misty Fiords Ranger District, Craig Ranger District, Thorne Bay Ranger District, Wrangell Ranger District, Petersburg Ranger District, Hoonah Ranger District, Juneau Ranger District-Admiralty National Monument, Yakutat Ranger District, and the Sitka Ranger District, the geographic focus area for this project (USFS, 2015). The Sitka Ranger District encompasses Baranof Island, Kruzof Island, and the southern portion of Chichagof Island. Most land in the District is owned by the federal government and the Native corporation Sealaska. The largest settlement in the District is Sitka: a unified city-borough of roughly 9,000 people centered around the Sitka Sound on the southwestern shore of Baranof Island (SEDA, 2014).

Sitka's largest current employers are the South East Alaska Regional Health Consortium (SEARHC) and the Sitka School District (SEDA, 2014), but recreation and tourism interests in Sitka have seen a bump in popularity due to a rise in cruise ship traffic. More Sitka residents are employed in the fishing industry than any other individual sector, which has replaced the timber industry as the primary employment sector in southeastern Alaska (Sisk, 2007). According to the U.S. Department of Commerce, regional timber industry jobs accounted for 1.1 percent of total private employment in 2012. An additional 41 self-employed individuals worked in the timber industry in 2012, or 0.5 percent of all self-employed people in southeastern Alaska. In the interim, the recreation and fishing sectors have both experienced substantial economic growth, particularly the latter. Sitka hosts three commercial-grade seafood processing plants and the largest commercial fishing fleet in Southeast Alaska (SEDA, 2014). The Sitka Economic Development Association estimates that 19% of Sitka's population over age 16 are directly employed or involved in some aspect of the seafood industry (SEDA, 2014).

Along with Sitka, Kruzof Island is the primary study area evaluated in this project. Kruzof Island is an uninhabited island ten miles off the western coast of Baranof recognized for its cultural significance, recreation value, and scenic beauty. A prime example of this beauty is Mount Edgecumbe, a dormant 3,200 foot stratovolcano frequented by hikers and known locally as a perennial image of the Sitka skyline. Up until the mid-1970's, Kruzof Island was primarily managed by the USFS for timber purposes. Today, Kruzof has four Land Use Designations (LUDs): Modified Landscape, Old-Growth Habitat, Semi-Remote Recreation, and Special Interest Areas (USFS, 2013), but the Island is most utilized by the Sitka community for year-round subsistence and recreation uses, both low and high-impact in nature. Evaluating how to appropriately balance multiple and sometimes competing community uses on Kruzof's landscape is one of the primary aims of this project, particularly in light of the economic shifts occurring within the Sitka area and the greater Tongass National Forest.

C. Importance of Subsistence Activities

Many Sitka residents depend on subsistence hunting and fishing to meet their basic needs. The National Interest Lands Conservation Act of 1980 (ANILCA) lists subsistence as a priority use of Alaska's federal lands. ANILCA defines subsistence as "the customary and traditional uses by rural Alaska residents of wild, renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools or transportation; for the making and selling of handicraft articles out of non-edible byproducts of fish and wildlife...; for barter, or sharing for personal or family consumption; and for customary trade" (Sisk, 2007). In fact, Sitka is the largest federally-recognized subsistence community in the United States (SEDA, 2014). In a nutshell, subsistence classification means that residents can legally fish, hunt, and harvest to provide for their non commercial and cultural uses. As the Alaska Department of Fish and Game (ADFG) outlines, "Subsistence hunting, fishing and gathering are not solitary pursuits. Subsistence involves structured and predictable cooperation in the production, distribution, and exchange of wild foods. Most households in rural Alaska receive wild foods from a traditional network. Some - like the elderly - receive most of their wild foods from shared production" (Sisk, 2007).

Subsistence encompasses a number of activities, ranging from extended hunting and fishing excursions to daily gathering sessions during each resource's respective harvest season. The Sitka black-tailed deer, halibut, and sockeye salmon are thought to be the three species providing the greatest amount of subsistence products in the Southeast (Sisk, 2007). Aquatic vegetation such as seaweed and bull kelp; herring and salmon roe; native shellfish; mushrooms, berries, tree bark, spruce roots are also frequently harvested in the Sitka area. All subsistence activities and resources are dependent upon a healthy forest ecosystem and watershed, which are highly sensitive to disturbances such as degradation from overfishing, extensive old-growth forest harvesting, and the construction and maintenance of road systems.

D. Alaska Native Presence in the Sitka Area

Many Alaskans participate in subsistence activities, regardless of their cultural, ethnic, or economic background. However, the Alaska Native tribes have the longest tradition of subsistence uses in the Sitka area. The Tlingit people are the indigenous group maintaining the largest current Native presence within the Sitka area. In fact, the word "Sitka" is derived from *Sheet'ká*, a contraction of the Tlingit word *Shee At'iká*, meaning "People on the Outside of Baranof Island" (NPS, 2015). The most important distinction between the federally-recognized Sitka Tribe of Alaska and the native corporation Sealaska deals with land ownership, or a lack thereof. ANILCA divided the State of Alaska into twelve sections. Native individuals living in each section enrolled with their respective regional for-profit corporation, which then selected land holdings in and around Native villages in proportion to enrolled Native populations (Sisk, 2007). In southeastern Alaska, Sealaska is the established regional Native corporation and the largest regional private landholder. The Sitka Tribe of Alaska is a governing body for more than 4,000 native people, but lacks the economic power of Sealaska, having no claim on large tracts of land or subsurface mineral rights.

In summary, the natural resources, subsistence amenities, and recreation activities provided and supported by the Tongass National Forest form the basis of quality of life for many people living within the Sitka Ranger District. Since the majority of land in the District as well as within the region is owned by the federal government or private interests, appropriate management of the Tongass' ecosystem services is crucial for the sustained health and vitality of Sitka and the rest of southeastern Alaska. The Community Engagement portion of our project provides an assessment of the Sitka community's natural resource values, management priorities, and perspective on the future of timber harvesting within the Sitka Ranger District. In doing so, we aim to provide the Sitka Conservation Society, the U.S. Forest Service Sitka Ranger District, and other interested parties with an independent analysis of current natural resource considerations that will be of service in navigating the Tongass management transition.

II. Methodology

A. Overview of Methodology Section

The social component of the project aims to assess the perceptions and opinions of area residents and stakeholders regarding natural resource management within the Sitka USFS Ranger District, focusing on Baranof and Kruzof Islands. Our team employed two primary methods to obtain and assess this information. First, we designed a cross-sectional survey questionnaire featuring a mix of open-ended, closed-ended, and contingency assessment questions. The purpose of the surveys was to gauge public perceptions of current land management policies and to assess the social dynamics at play within the Sitka area. Additionally, both the process of survey formulation and results analysis were complemented by the findings of sixteen stakeholder interviews, conducted with key public, state, and federal stakeholders from Sitka and the greater Tongass National Forest.

The goal of the methodology section is to clarify these methods for gauging public perception, and to outline potential limitations and biases of our findings. In the following sub-sections, we will discuss: (B) the University of Michigan Internal Review Board (IRB) process and approval; (C) community survey design, distribution, and response; (D) survey analysis, discrepancies, and potential biases; (E and F) Participatory Geographic Information Systems (PGIS) technique, data collection, and analysis; (G and H) stakeholder interviews data collection and analysis; (I) supplementary ATV interviews; and, (J) potential dissemination of findings.

B. Internal Review Board (IRB)

As with all academic research involving human subjects, our survey and interview methods were subject to a thorough internal review through the University of Michigan Internal Review Board (IRB) for Health Sciences and Behavioral Sciences. Both members of the project "social team" completed the required training module, PEERRS (Program for Education and Evaluation in Responsible Research and Scholarship) human subject training, and received certification in May 2014. Working with the IRB Research Compliance Specialist, the project application was submitted in June 2014 under the title "Kruzof Island Resource Perception and Value Assessment." Faculty project advisor, Dr. Robert Grese, was included on this application.

After review, the IRB granted our study exempt status on July 3rd, 2014, under the following federal exemption category:

EXEMPTION #2 of the 45 CFR 46.101.(b)

> "Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation."

The exemption indicates that the study has been deemed low risk to the human subjects involved and does not require ongoing IRB review.

C. Community Surveys

Design Our community survey aimed to assess the opinions and values of Sitka residents regarding management of natural resources on Kruzof Island and within the broader Sitka USFS Ranger District. Drawing upon two weeks fieldwork in the Sitka area and a series of informational interviews with various stakeholders (see Section VII below), we worked closely with SCS to design questions which met project objectives. Through exchange of a series of drafts, we collaborated to create a cross-sectional, fully anonymous questionnaire which featured a mix of closed-ended, open-ended, and contingency questions. Particular emphasis was placed on current natural resource uses, suggested management improvements, and opinions on future timber management. In an effort to reach a broader audience, both a paper and an online survey were created for distribution. We chose to use the online survey software Qualtrics, because of the University of Michigan's partnership and team members' previous positive experience with the platform. Qualtrics software allows users to create an online survey and provide anonymous access through a link. Due to some of the constraints of online formatting, the Qualtrics version was divided into 22 separate questions, while paper surveys had only 15. The content of the questions, however, was identical.

Promotion and Distribution With limited funds, manpower, and time on the ground in Sitka, our team chose to roll out the survey by stuffing 2,300 paper copies in the September 19, 2014 edition of the *Daily Sitka Sentinel* newspaper. Costs for printing, envelopes (which were stapled to paper copies to expedite return), and distribution were shared between project members and SCS. The online survey was opened simultaneously with the paper distribution and the link was advertised on fliers placed around town (including at the Highliner, the Backdoor, SCS, the Larkspur, the Sitka Visitor Center, and the Kettleson Memorial Library) and on the Kettleson Library's website. The survey was also announced on Raven Radio's Community Calendar directly prior to its release on September 19th and its close on November 15th.

Response 119 surveys were completed and returned, for a 5.2% response rate. 101 of these were paper surveys, delivered to the SCS office in Sitka either in person or by mail. 18 surveys were completed online, with an additional 6 started but not completed (a 25% drop-out rate for the online surveys).

D. Community Survey Analysis

Analysis Upon receiving shipment of the paper surveys to Michigan in December 2014, two team members manually entered each survey into Qualtrics in order to standardize the responses for analysis. Qualtrics automatically assigned an identification number to each survey, thereby removing any identifying traits to the responses and ensuring survey anonymity. The software generated response tables and provided the statistical information for each question that serves as the foundation of our analysis. The majority of figures included in this report were also created through Qualtrics, though limitations dictated that a few figures be created through R, a separate software for statistical computing and graphics available free online.

Survey Discrepancies In a few limited instances, a lack of clarity in the paper survey directions led to divergences in responses problematic for analysis. The primary example of this discrepancy is the following two-part question which asks: "Which of the following activities do you think brings the most economic benefit to the Sitka Community?" First, "Out of activities taking place on Kruzof Island?" and second, "Out of activities taking place in the overall Sitka Ranger District?" [This question was #10 on the paper survey and #13 and #14 on the online survey]. While the question was designed for only a single answer, paper respondents frequently disregarded the directions and selected multiple responses. In the online survey, only one response was allowed.

The discrepancy was significant enough on the paper surveys- 47 respondents selected more than one option- that it was not feasible to throw out responses that did not follow directions. Likewise, it was not possible to conjecture which single selection a respondent would have chosen first. To resolve this issue and retain the information for analysis, we divided the respondents into single- and multiple-response and reentered the information into Qualtrics in separate categories. The resulting analysis is thus fragmented but reliable.

Potential Biases/Limitations The decision to use the newspaper as the primary vehicle of distribution stratified our target respondents by newspaper subscribers and purchasers, which may have significantly impacted the demographics (particularly age and race) of our survey respondents. In terms of age, respondents were skewed dramatically toward older demographics, registering only 5% below 30 years and more than 44% above 60. This can likely be attributed not just to the distribution method, but also the time required to complete the survey (at least 10 to 15 minutes). The time of year selected for survey distribution- September, during which time many residents depart the area, including possibly younger residents- may also have impacted the demographics of respondents.

Possibly for similar reasons, Caucasian responses were overly represented in contrast to American Indian and Alaska Native responses.

AGE	18-29	30-44	45-60	60+
Survey Proportion	4%	14%	37%	44%
Census (2010) Proportion	12.7%	20.3%	24%	17.2%

RACE	Caucasian	Alaska Native/American Indian
Survey Proportion	81%	15%
Census (2010) Proportion	65%	16.8%

Table 1.1 Race and age of survey respondents as compared to 2010 Sitka Census data.

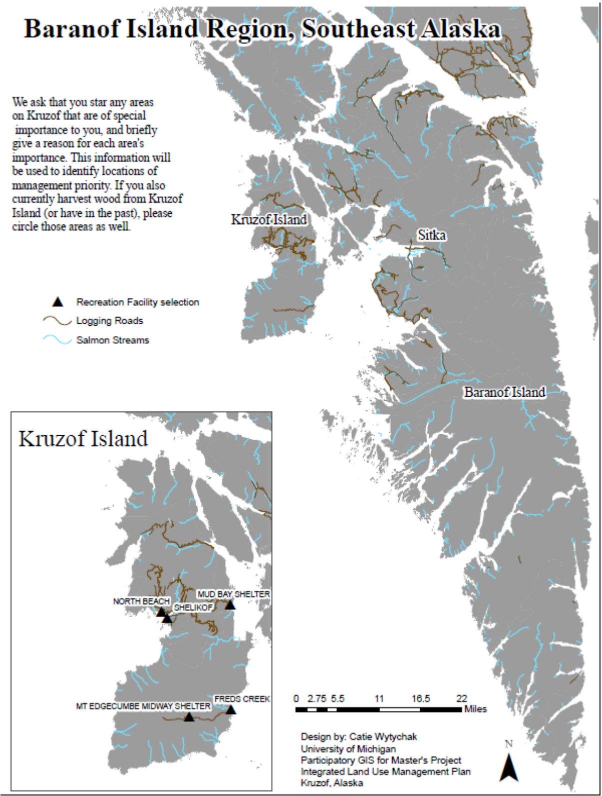
The second limitation of the survey findings, which could itself be a reflection of the respondent demographics, is a potential oversampling of individuals who prioritize low-impact uses (e.g. hiking, camping, bird-watching) as opposed to more intensive recreational uses, namely ATV-riding. Only 13 of the 118 total respondents indicated that they used the island for ATV-riding. Analysis of the Participatory GIS component of the survey (see Section VII below) indicated, however, that 20 respondents used the North Beach cabin, which is more frequently utilized by ATV users than lower-impact recreation visitors. Though we acknowledge that this user-demographic may be slightly underrepresented in the general survey, with the addition of the ATV-specific surveys, we do not consider the shortcoming significant enough to invalidate the findings.

E. Participatory Geographic Information Systems (PGIS)

Background Our community surveys featured a novel participatory mapping component, Participatory Geographic Information Systems (PGIS), which collected information on areas of special significance to Sitka residents. PGIS developed out of participatory approaches to planning, spatial information, and communication management. It serves as an interactive vehicle for information exchange, analysis, and decision-making. PGIS also implies making geographic information technologies available to disadvantaged groups in society, in order to enhance their capacity for generating and communicating spatial information.

Data Collection Using a map of Kruzof and Baranof Island created particularly for the PGIS instrument in ArcGIS 10.2, respondents on the paper surveys were asked to circle or star areas of importance to them and write what activities corresponded to the selected area(s). The online version of the survey employed the Qualtrics heat map feature, which presented the respondent with a map and invited him or her to click anywhere on the image. A corresponding write-in area collected information on the significance of locations selected. Qualtrics then provides a graph for each heat map question answered, overlaying the heat map image with a map of where participants clicked.

Response Given the novelty of the PGIS instrument, and the time required to thoroughly complete it, our team was both pleased and surprised to receive 67 responses; a number representing more than half of all respondents (54.6%). 57 of these were completed on paper; 10 were completed online through the Qualtrics heat map instrument. Respondents marked a total of 502 locations.



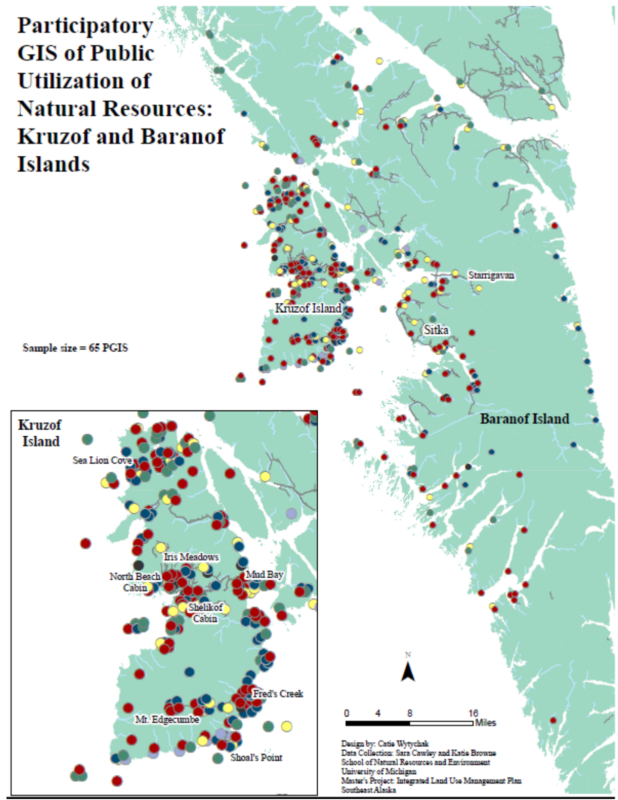


Figure 1.1 Map of Kruzof and Baranof Island created for online and paper survey PGIS.
Figure 1.2 PGIS locations categorized by activity type.

F. Participatory GIS Analysis

Completed paper and online versions of the PGIS map were digitized into ArcMap (a tool of ESRI's ArcGIS platform) and categorized by type of land utilization, if specified by the respondent. Summary data for the percentage of designated land utilization by type is included in the map legend. A Kernel Density (Spatial Analyst) tool was used to calculate the density of points in a neighborhood around each point. The map shows areas that were frequently designated by survey respondents as important locations. Some respondents had extreme interpretations of the PGIS instructions, which led to them circling or starring nearly the entire study area. We did not feel that our assessment should involve judging the validity of PGIS entries, so we resolved the issue of response discrepancies by through the Kernel Density approach. Thus, all indicated locations were included within the heat map, but more weight was given to areas indicated by the majority of respondents. It should also be noted that one PGIS respondent asked for his/her map to not be included in the digitization part of our analysis, since he had circled areas of cultural and spiritual importance that he/she did not want published.

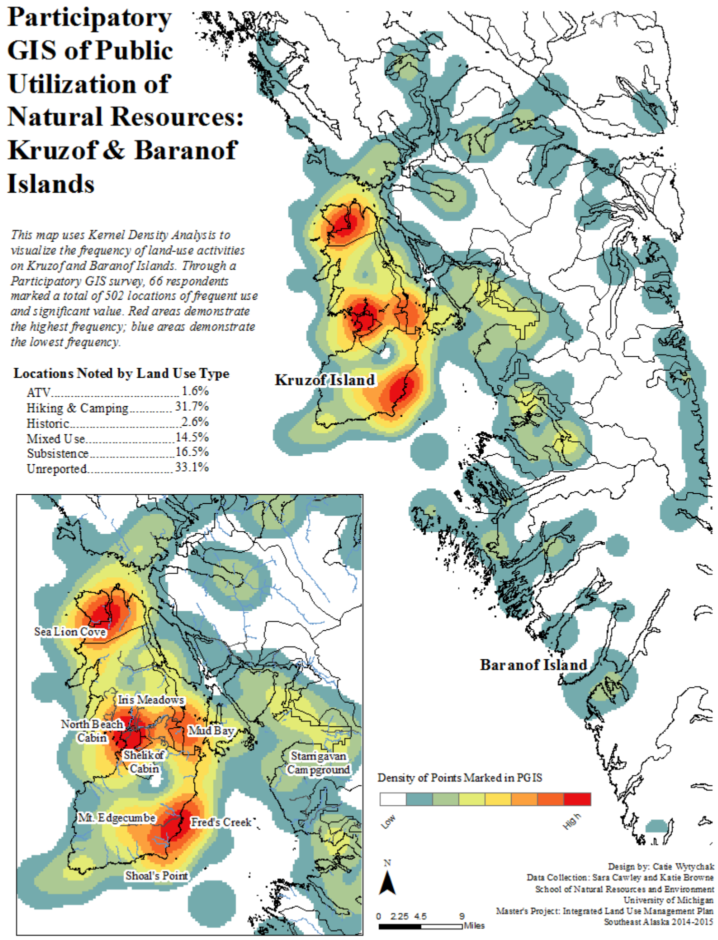


Figure 1.3 - PGIS Kernel Density Analysis

G. Stakeholder Interviews

As part of a two week information-gathering period in Sitka and on Kruzof Island, our team conducted 11 in-person and 5 telephone interviews with key public, state, and federal stakeholders. Initial interviewees were identified through research and dialogue with our client, SCS. Thereafter, we utilized the "snowball method," in which interviewees were asked to identify further stakeholders and interested parties. The objectives of the interview were to expand our understanding of the dynamics, perceptions, and values around land management of Kruzof Island and the broader Tongass National Forest. We employed a semi-structured interviewing technique in which we developed a separate "interview guide" for each stakeholder, with a list of questions and topics we hoped to cover during the conversation. While we followed the guide throughout the interviews, we were also able to stray off course as dictated by the interests and insights of the interviewee. All interviews, both in-person and over the phone, were recorded with either the Voice Memo Application on the iPhone, or a hand-held Sony voice recorder.

Interviewee	Organization	Date	Phone/In-Person	Duration (mins:secs)
Bennett, Anna	Artisan, U.S. National Park Service	8/16/14	In-Person	47:28
Chew, Gordon	Tenakee Logging Co.	1/29/15	Phone	44:05
Edwards, Perry	U.S. Forest Service	8/13/14	In-Person	43:27
Hoffman, Robert	Artisan, Friends of Sheldon Jackson Museum	8/13/14	In-Person	18:30
Horan, Josh	Shee'Atika Inc.	8/19/14	In-Person	49:55
Feldpausch, Jeff	Sitka Tribe of Alaska	8/17/14	Phone	52:25
LaPalme, Ann Marie	U.S. Forest Service	8/13/14	In-Person	43:27
Leeseberg, Chris	U.S. Forest Service	8/13/14	In-Person	43:27
Moselle, Kyle	Alaska Department of Natural Resources	12/16/14	Phone	54:25
Nudelman, Joel	Alaska Department of Natural Resources	12/8/14	Phone	30:25
Portner, Diana	Meridian Institute	1/21/15	Phone	1:00:33
Rofkar, Teri	Artisan	8/18/15	In-Person	1:17:40
Rush, Keith	The Nature Conservancy	1/29/15	Phone	54:41
Thoms, Andrew	Sitka Conservation Society	8/15/14	In-Person	21:37
White, Gary	Sitka Economic Development Assoc.	8/17/14	In-Person	50:12

Table 1.2 Stakeholder Interview Information

H. Stakeholder Interview Analysis

All interviews were transcribed from the audio files using either ExpressScribe or iTunes, and stored in the online drive Dropbox. Information from the interviews informed both the survey design and the discussion, findings, and recommendations of this report.

I. Supplementary ATV Surveys

Although the questions for our primary survey were finalized after completing preliminary fieldwork and stakeholder interviews, a preliminary survey was also created and given to the team members to test during their trip to Kruzof Island in June. The test survey consisted of fifteen questions assessing respondee background, preferred activities, management priorities, and opinions on timber harvesting. A draft participatory GIS map was also placed on the last page of the survey, and dictated to participants. The draft map was not included in the final PGIS analysis, but served as an important test run of the instrument.

Twenty-eight total surveys were administered to individuals and groups passing through Kruzof's landing area at Mud Bay, though eight of these were discarded during the analysis stage because the respondents were not native to the Sitka area. Several surveys were also lefts on ATVs parked at Mud Bay, and also in the Forest Service cabin at Shelikof Bay. Two of the surveys distributed in this manner were mailed back to Sitka Conservation Society at a later date. As a result, twenty-one surveys were collected from this test cycle in total.

As this was a preliminary survey, there was no target response rate. Seven of the questions from the test survey were integrated into primary survey, while more general questions were omitted or edited to better reflect focus decided upon post-interviews. Analysis of the ATV-specific surveys can be found in Section VIII of the following Results section, and serve as an important supplement to the broader community surveys.

J. Potential Dissemination of Findings

In addition to the final report submitted to our client, Sitka Conservation Society, and to meet the requirements of our Master's Opus at the University of Michigan, the findings here may yet be disseminated in several forms. We anticipate that survey findings will be presented in early May to the Tongass Advisory Committee, a stakeholder committee convened to advise the Secretary of Agriculture, through the Chief of the US Forest Service, by providing recommendations for sustainable forest management. At least one project team member will attend this meeting. Further, findings may be adapted for published representation in format(s) most useful to the client and interested stakeholder groups (for example, in report, booklet, poster, or website form). Finally, collected information may also be used through materials and education sessions to inform the general public and stakeholder groups about the Resource Management Plan's goals and recommendations for the balanced use of Kruzof Island and Sitka Ranger District resources.

III. RESULTS

A. Section Overview

The following section will summarize the findings of the project's community surveys and supplementary ATV surveys, administered in the summer and fall of 2014. As discussed in the methodology, findings may be limited by a few potential demographic biases. The age of respondents (n=114) is strongly skewed towards older demographics; respondents' race (n=112) over-represents Caucasians and slightly under-represents American Indians and Native Alaskans; and occupation (n=112) significantly over-represents retirees. Nevertheless, while we believe it is important to be aware of these potential limitations, we do not consider them significant enough to invalidate the survey findings.

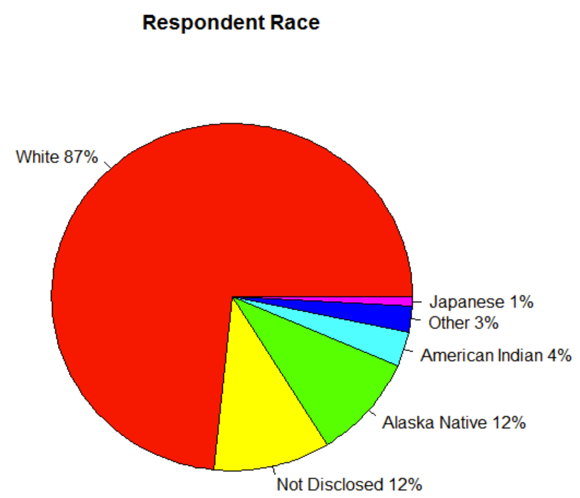


Figure 1.4 Race of Community Survey Respondents

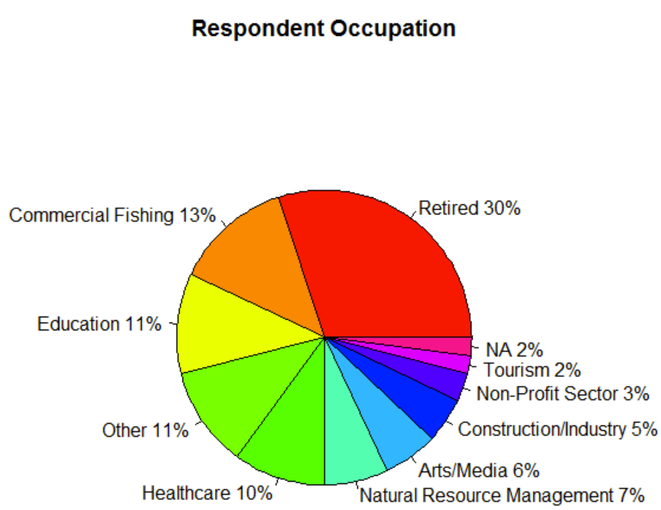


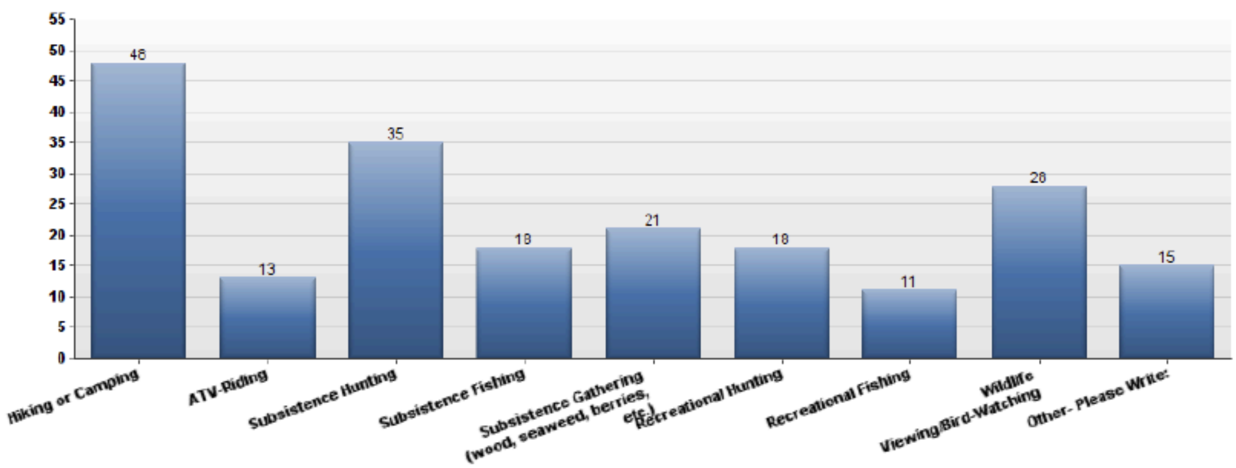
Figure 1.5 Occupation of Respondents

In the following sub-sections, we will discuss: (B) Kruzof Island's multiple uses and activities, (C) public management priorities, (D) perceived ecosystem threats, (E) opinions of future timber management, (F) community firewood harvesting interest and viability, (G) desired changes, and (H) supplementary ATV-specific findings. Full survey results, including all write-in responses and basic statistical analysis, can be found in Appendix 1-A.

B. Kruzof Island Uses and Activities

Survey findings indicate that not only does Kruzof Island boast a high existence value among area residents, but also hosts a broad range of uses and activities, especially a diversity of subsistence uses. Although only 58% of survey respondents visit Kruzof every six months, the forty-nine respondents who do not frequently visit still consider its management worth the time to fill out and return the survey. This level of response and interest indicates that area residents do not necessarily require utility be derived from direct use of the island's resources, but rather that certain utility comes from simply knowing that the resources exist.

Kruzof also hosts a wide-variety of activities, though survey participants generally trended toward lower impact uses. A multiple-response question, answered by 65 of 67 respondents who frequently visit Kruzof, asked which activities he or she does on the island. The most frequent responses were: hiking and camping (73%), subsistence hunting (53%), wildlife viewing/bird-watching (42%), subsistence gathering (32%), subsistence fishing (27%), and recreational hunting (27%). ATV-riding (20%) and recreational fishing (17%) were less common answers, though still relatively frequent. Write-in responses in the "Other" category further diversified these activities, including: beach-combing, surfing, working,



mountain-biking, paddle-boarding, harvesting artistic materials, educational programs, and visiting the World War II bunker.

Figure 1.6 Percentage of Community Survey Respondents who Participate in each activity on Kruzof Island

As the survey data above indicates, Kruzof hosts high-levels of subsistence utilization. The diversity and extent of this utilization was further clarified by the responses of 74 participants who answered the write-in question: "If you visit Kruzof Island or other areas within the Sitka Ranger District for subsistence activities, what time of year do you visit?" Drawing upon these responses, we assembled a calendar of subsistence utilization which can be seen in simplified form below. (A more detailed version is available in Appendix 1-C).

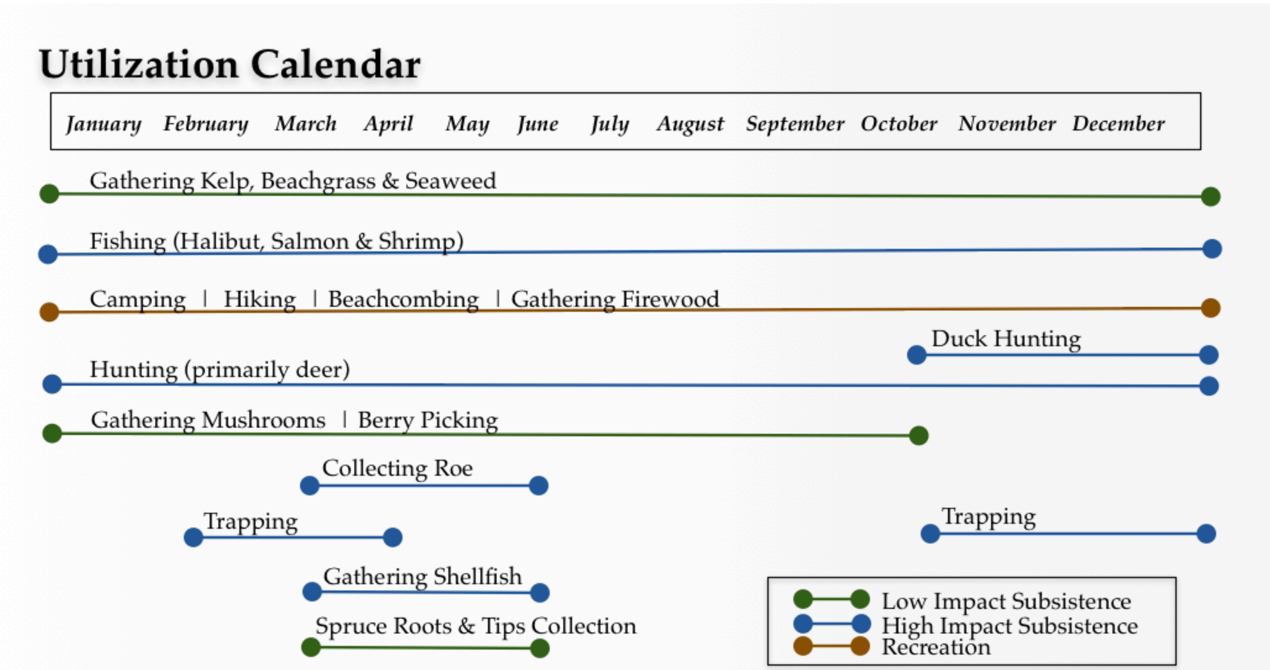


Figure 1.7 Utilization Calendar of Subsistence Activities on Kruzof Island

Survey data further indicates that subsistence can, and often does, serve as a critical livelihood component for area residents. 82 respondents calculated their estimated annual value of subsistence goods in a write-in question. Of the 69 respondents who provided numeric values, the mean was $2,204.57, with a range of 0-$20,000 and a standard deviation $3,450.89. While the relatively high mean value supports the argument that subsistence is critical to local ways of life, the range and standard deviation demonstrate to just what a degree this value can vary from individual to individual, family to family. Among non-numeric answers were four responses of "priceless;" several examples of percentage of total intake, such as "Enough to feed a family of four that eats 99% fish and wild game;" and, highly specific responses, such as "Unknown $ value- most of our diet is gathered or hunted, so we buy very little meats, no jams, no seafood. Eat garden greens and make dog food for our dog."

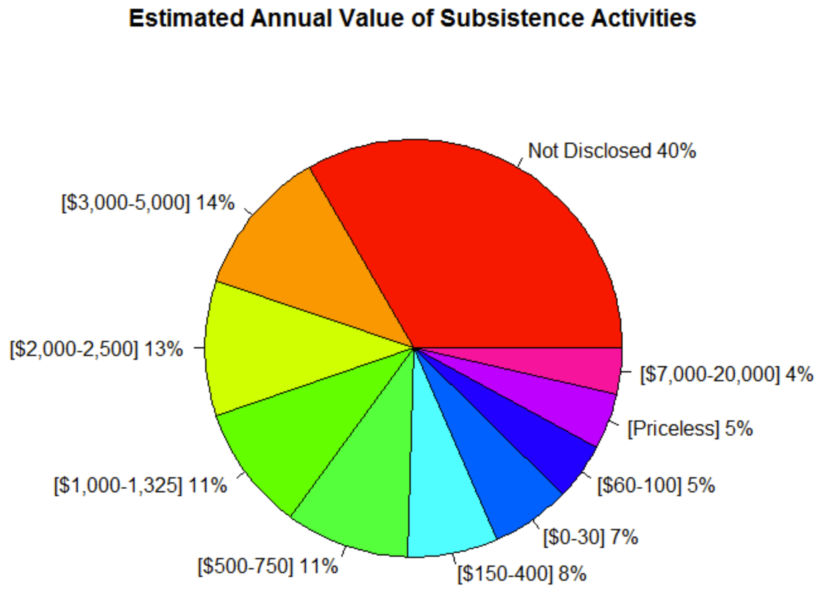


Figure 1.8 Community Survey Respondents' Estimated Annual Value of Subsistence Activities

C. Management Priorities

Survey respondents strongly indicated that future management priorities for Kruzof Island should focus on protection and restoration of wildlife habitat, as well as maintenance of recreation infrastructure. Harvest of forest products, including logging, was frequently ranked the lowest priority.

Respondents were asked to rank management priorities 1 to 5. Out of 107 responses, "protecting fish and wildlife habitat" was the clear majority (47.6%), followed by "providing and maintaining multiple use trails" (20.6%), "restoring and maintaining fish and wildlife habitat" (15.0%), and "providing and maintaining scenic hiking trails" (9.3%). Only three respondents (2.8%) ranked "harvest of forest products" as the highest management priority. In fact, when considering the mean values of each ranking, "harvest of forest products" averaged 4.53, indicating it was routinely ranked lowest of the options.

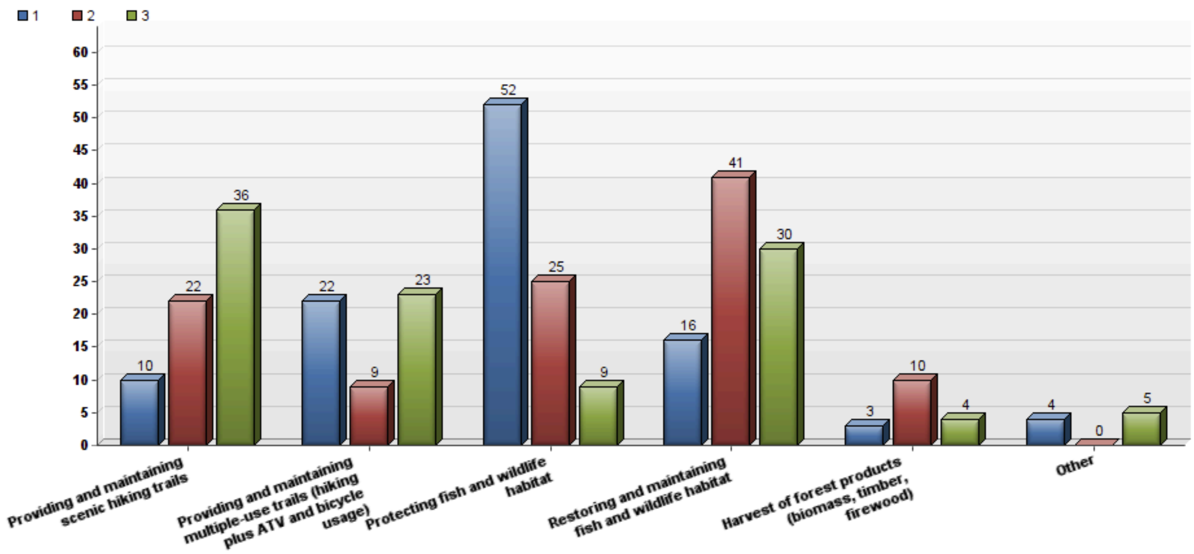


Figure 1.9 Community Survey Respondents' Management Priorities by Rank
(Blue=Top Priority, Red=Second Priority, Green=Third Priority)

The twenty write-in responses for the "other" category further support these findings. Most (10) emphasize recreation, including four separate suggestions for additional cabins and cabin maintenance. Several others focus on "balance of harvest and recreational activities," "sustainability," and "limiting commercial impact." None of the responses suggest increased logging.

D. Ecosystem Threats

Survey respondents strongly identified logging, ATV-use, and overdevelopment as the greatest ecosystem threats to Kruzof Island and the Sitka Ranger District. In assessing these perceived threats, the survey posed the following open-ended questions: "What do you see as the greatest risk to Kruzof Island's ecosystem, if anything?" and "What do you see as the greatest risk to the land within the larger Sitka Ranger District?"

The first of these questions received 81 write-in responses, with the most common responses of: logging (38.3%), excessive use or misuse of ATVs and other motorized vehicles (21.0%), and over-development/over-commercialization (14.8%). Other multiple-response answers included: garbage/ocean pollution (7.4%), climate change impacts (4.9%), and humans (2.5%). Only one respondent indicated that lack of harvesting and commercial opportunities posed an ecosystem threat.

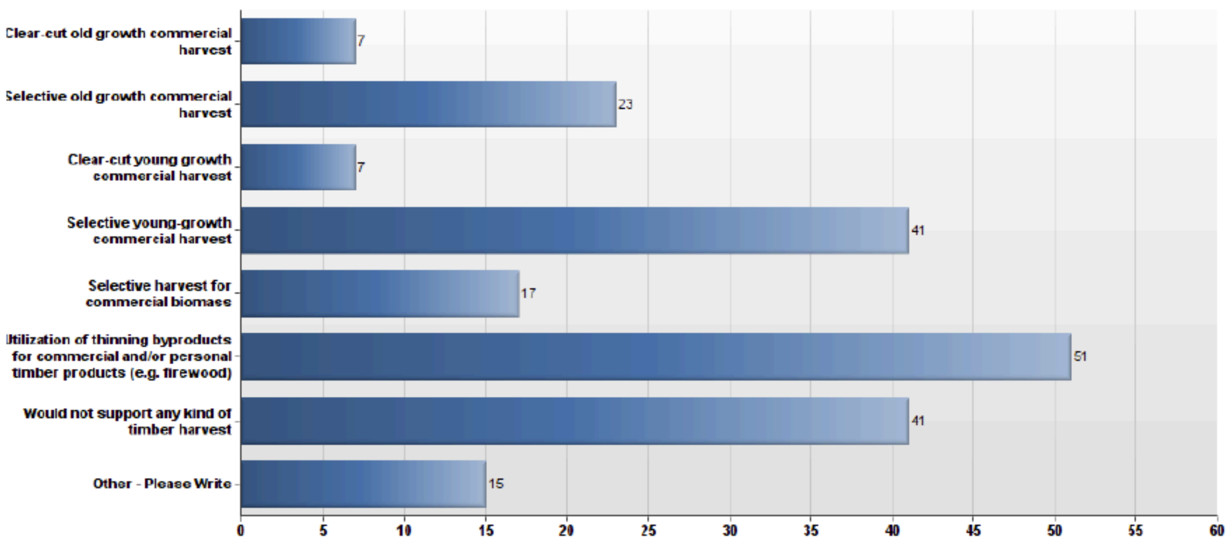
The second question, addressing the larger Sitka Ranger District, received fewer responses (41), possibly because participants found it repetitive. Responses largely mirrored that of the Kruzof-specific inquiry, though were somewhat broader in scope. Most frequent responses were again: logging (22%), commercialization/over-development (14.6%), ATVs/motorized vehicles (9.7%), and climate change (14.6%). Other multiple-response answers included: mining (4.9%) and inadequate funding for the Forest

Service (4.9%). A few of the other perceived threats were: undervaluing recreation, undervaluing subsistence, sediment run-off, road-building, and poor tourism management. Again, only one respondent indicated that elimination of commercial harvest represented an ecosystem threat.

E. Opinions on Timber

When survey respondents selected desired types of timber harvest for Kruzof Island the majority chose the collection of fallen/cut wood from tree thinning projects for commercial or personal use, followed most closely by preferences for selective young-growth harvesting, or no timber harvest of any kind.

Respondents were asked to mark all types of timber harvest they would support taking place on Kruzof Island. The question garnered 113 responses in total, the majority of which favored utilization of thinning byproducts for commercial use and personal firewood (44%). Closely tied were those who would not support any kind of timber harvest (36%), and respondents who would favor selective young-growth harvesting (35%). Only 20% of respondents favored a selective old-growth commercial harvest. Clearcut harvesting of both young and old-growth was selected by only 12% of respondents (6% for each type).



Write-in answers for preferred types of timber harvest on Kruzof represented a number of perspectives ranging from selective cutting to thinning for wildlife habitat or clearcutting on a small-scale.

Figure 1.10 Community Survey Respondents' Timber Harvest Types Supported by Percentage

The survey's second question assessing opinions on timber management asked respondents to select one level of intensity for their suggested harvesting activities. 111 responses were collected overall, most indicating a preference for no logging activity (40%). *Logging activity at levels compatible with a multiple use plan* (27%) and *logging as a limited activity* (26%) were close in rank, but *logging as the dominant activity on the island* was only selected by one respondent (1%). Write-in answers (6%) emphasized selective harvesting and the need to keep forest health in mind.

F. Viability of Firewood

In evaluating the feasibility of establishing a firewood collection program on Kruzof Island, a contingency structure used to determine if respondents collect firewood for their personal use indicated that roughly half of the 114 respondents do (47%). Of that half, about 54% would be interested in firewood collection opportunities on Kruzof . 54 out of 114 respondents indicated that they collect firewood for personal use. Although 60 respondents indicated no, some still answered the following question assessing interest in collecting firewood on Kruzof. Their write-in answers all named the high cost of boat fuel, and the time and distance required to travel out to Kruzof as barriers.

G. Desired Changes

Survey respondents ranked increased habitat preservation and an improved trail system as the changes they would most like to see made on Kruzof Island. 109 respondents ranked a provided list of proposed changes to Kruzof Island, selecting as many or as few changed as deemed necessary. Increased habitat preservation was ranked first by 35 respondents, while an improved trail system was put first by 23 people. 17 people felt that no changes were necessary, and 14 people expressed a desire to see an increased in habitat restoration and maintenance activities. Increased visitor amenities - such as additional bathrooms and campsites- and increased logging opportunities were ranked first by 5 and 6 respondents, respectively.

Additionally, 69 respondents indicated locations on Kruzof where they would most like to see the suggested changes occur. The majority of suggestions lay along the current road system stretching from Mud Bay to North Beach, or at/near Mt. Edgecumbe. Areas close to the road system, such as Iris Meadows, Shelikof Beach, and Brent's Beach, were also frequently mentioned. Several requests for a moorage buoy at Mud Bay were made. Less site-specific answers cited a need for stream restoration, improvements to all existing cabins, and increased directional and interpretive signage.

H. Primary Economic Benefit

Respondents indicated that they view commercial and charter salmon fishing as the activity bringing the most economic benefit to the communities living within the Sitka Ranger District and surrounding Kruzof Island. Two close-ended questions were constructed to evaluate which activity respondents feel brings the most economic benefit to the communities adjacent to the project study areas. Respondents were asked to select one activity, but many interpreted the question phrasing as an invitation to select multiple activities. Therefore, responses to these two questions were split for analysis depending upon whether more than one activity had been chosen. It should be noted that all surveys taken online were single response, due to their formatting.

When the two questions were analyzed with multiple responses, commercial and charter salmon fishing, tourism and recreational activities, and subsistence activities were closely ranked for each study area. For example, out of 46 respondents commenting on the communities surrounding Kruzof Island, 30 selections were made for recreation, 28 selections were made for commercial and charter salmon fishing, and 27 selections were made for subsistence activities. However, when examining the questions where one response was given, commercial and charter was far and away the winner, receiving 28 out of 56 votes for Kruzof Island, and 34 out of 56 votes for the Sitka Ranger District.

I. Supplementary ATV-Surveys

Though the preliminary survey results cannot be integrated into the analysis of our primary survey, they present useful implications for interpretation of the primary survey and its limitations. Twelve out of thirteen respondents reported visiting Kruzof Island to ride ATVs, which indicates that our primary survey distribution method may have failed to capture that segment of the Sitka recreation community. However, it is also just as likely that the ATV users were oversampled during the test survey due to the method and locations of the test execution. All ATV users must come ashore and set up their equipment at Mud Bay, giving our teammates the opportunity to engage them. The North Beach cabin where several surveys were left is also most often visited by ATV users, as North Beach is the only beach in that area accessible by road.

Nearly all the test respondents also ranked ATV riding second to hiking in their preferred activities. Interestingly, the majority of respondents listed providing scenic hiking trails and multiple use trails as the top management priorities for Kruzof Island, and logging (both future and past) combined with ATV overuse as the greatest risk to the sustained health of Kruzof's ecosystem. Eleven out of thirteen test survey respondents support some form of logging on Kruzof Island. Respondents were tied on whether the logging should be limited or at levels compatible with a multiple-use plan, but preferred that any logging avoid old-growth stands; instead targeting young-growth stands and serving subsistence firewood and biomass needs for the Sitka community.

IV. DISCUSSION

A. Section Overview

The following Discussion section will integrate findings from background research, survey results, general information and exemplary quotes extracted from stakeholder interviews, and the findings of the Restoration and Education portions of the project. Drawing from this body of work, we will provide the following recommendations for balancing the multiple uses of and demands upon Kruzof Island resources:

1. *Limit old-growth logging*
2. *Support and facilitate subsistence access to and uses of Kruzof Island*
3. *Pilot community firewood harvesting*
4. *Continuing support of and investment in restoration projects*
5. *Cultivate strong communication and stakeholder engagement*
6. *Improve signage*

The Community Engagement recommendations found here are also presented in the overall project's executive summary (pg.6), where they are fully integrated with the findings and deliverables of the Restoration and Education teams to provide interdisciplinary recommendations.

B. Limit old-growth logging

As the Restoration portion of our project will further detail in Part II, negative ecological effects from the old-growth timber clearcuts of the 1960s and 1970s still persist at the project test sites on Kruzof Island and Baranof Island. The survey results assessing management priorities, perceived ecosystem threats, current natural resource utilization, and perspectives on the future role of timber harvesting within the Sitka Ranger District all indicate that, although residents favor small-scale and limited logging under certain conditions, old-growth logging is overwhelmingly considered the greatest threat to the continued health of the Tongass ecosystem. Therefore, we recommend that no old-growth logging be undertaken on Kruzof Island. Old-growth logging should only be pursued under selective or limited clear-cut conditions within the greater Sitka Ranger District, after the USFS ensures that the public has been adequately engaged and informed on the respective treatment or timber sale's scale, effects, and goals.

In keeping with the Tongass Transition, young-growth timber management should be prioritized. However, it remains to be seen what kind of a young-growth economy will result from the management transition. There are economic, cultural, and geographic factors at play affecting the form of a young-growth timber industry. Alaskan timber already faces fierce competition within its own state borders from Washington State and Oregon imports. Whereas the federal government manages most forested land within Alaska, in Washington and Oregon, private timber mills own vast swaths of forest and can log as they please without concern for federal regulation. Portions of the Tongass are also known to grow more slowly than forest in the other two states. When rising fuel costs and transportation distances within Alaskan markets and to the contiguous U.S. from Alaskan ports are added into the equation, it seems unlikely that an Tongass young-growth industry will be able to reach competitiveness on a large scale under current conditions. Sitka Conservation Society Executive Director Andrew Thoms theorizes that it's all a question of preferred scale and perspectives on what viability means on the ground. "So, do you want a fully computerized mechanized mill that can churn out 2x4s: is that your definition of viable? Or is an operator providing logs for local companies to build cabins, flooring, and cabinets, is that viable? Going toward high-volume mills that have a huge initial capitalization cost and churn out production in the most efficient way possible is probably never going to happen here, because we can't compete with those other places."

Other major factors affecting the viability of market for young-growth Tongass timber are the quality of the young-growth wood, and the wood's temporal availability. From a logger's perspective, the payoff is much greater with old-growth timber. According to one miller, "You imagine taking a big log to your lumber mill, and then you saw and saw and saw, and at the end of the day, you have this huge pile of lumber. And then if you imagine taking a young growth tree...at the end of the day you have half as much lumber and it's lower quality." The current USFS transition timeline plans for a large amount of the proposed young-growth stands to be ready for harvest within the next 10-15 years (Shoenfeld, 2015). Some support this timeline - at least for a small-scale young-growth timber market - but others claim that the necessary volume of trees simply won't be ready at that point in time, pointing out, even if enough trees are ready, what happens when those stands are cut? They worry that the transition timeline may not be adequately structured to ensure a sustainable volume of young-growth (Langelois, 2015; Schoenfeld, 2015).

Finally, the reality of much of the old-growth harvesting that currently occurs within the Tongass should be acknowledged. Viking Lumber is the only mill on the Tongass capable of the large-scale production historically associated with logging in the forest. The majority of mill operators operate on a small-scale, primarily pursuing selective old-growth timber sales. The Tongass management transition threatens their current way of business, which is often more precarious than imagined. Gordon Chew, who owns and operates Tenakee Lumber in Tenakee Springs, also works in construction and carpentry throughout the year to make ends meet. Chew runs the company with the help of his son, although they often employ a handful of short-term workers (2-5 personnel) to assist with their larger timber sales.

Recognizing the situation these small mills face under the transition, the TAC has been discussing the possibility of a grandfather clause for mills below a certain size threshold. When asked if Tenakee Lumber would be able to remain in operation under the current transition terms, Chew was not optimistic. "Not in our present condition. The timber we're selling and that's being asked by consumers for is old-growth. Old-growth is three times as valuable at market. So, no, I don't think so." Chew does mention that it would be possible for mils to pursue pellet or other small-scale heat products rather than traditional timber, but stresses that scenario would be impossible for Tenakee Lumber with its present operating set: "We would need all new equipment; a lot of high speed stuff to help us transition." Another potential solution to the mills' dilemma is a ramp-up timeline for the transition, allowing the them additional time to transition their operating procedures and equipment to be able to handle the wood products most in demand from young-growth timber.

C. Support and facilitate subsistence access to and uses of Kruzof Island

As outlined in the background section, Sitka is the largest federally-recognized subsistence community in the United States, meaning that its residents can legally fish, hunt, and harvest to provide for their non-commercial and cultural uses. As emphasized by the Alaska Department of Fish and Game (ADFG), most households in rural Alaska receive at least some wild foods from a traditional network and certain demographics, like the elderly, receive most of their wild foods from shared production. Subsistence is thus a critical consideration in management of Kruzof's natural resources, not only for the broader Sitka community, but also especially for vulnerable demographics.

As discussed in the results (Section B), survey findings provide further evidence that subsistence harvest is a critical livelihood component. Of 69 respondents who provided numeric values for their annual harvest, the mean was $2,204, with some responses as high as $10,000 or $20,000. More than half of visitors (53%) to Kruzof engaged in subsistence hunting, with an additional third participating in subsistence gathering (32%), and a quarter in subsistence fishing (27%). The comprehensive utilization calendar (Results Section B, or Appendix 1-C) also demonstrates the diversity of subsistence activities, which occur year round on the island, with particularly intensive periods during the spring and fall.

Subsistence is also a primary concern of Native tribes and corporations in the Sitka region. As Jeff Feldpausch, Director of the Resource Protection Department of Sitka Tribe of Alaska, says: “Our major concern with the management of the timber resources on the USFS land is protection of the natural resources for subsistence purposes.” This sentiment was seconded by Josh Horan, a member of the Shee’Atika Inc. board of directors, who acknowledged that it is a “huge issue.” While both the Forest Service and SCS acknowledge this priority, there may still be opportunities to build trust and recognize local needs.

One under-recognized area of collaboration would be with local artisans, whose access to subsistence and culturally valuable materials on Kruzof Island is limited by current restrictions. Several local artists emphasized their interest in increased communication and collaboration on access issues, including Teri Rofkar, a local weaver who asked: “As a subsistence community of this size, how can we be a role model for bringing that to a larger venue?”

D. Pilot community firewood harvesting

Although only a small majority of survey respondents expressed interest in collecting community firewood from Kruzof Island in the event that the USFS begins a pilot program, we strongly recommend that this opportunity be further explored. A lack of places to gather firewood was one complaint that our team heard repeatedly while on site in Sitka. All current places set aside by the USFS for community firewood collection are only accessible by boat, which is a major barrier for a portion of the Sitka community’s population.

Concerns from both survey respondents and the USFS Sitka Ranger District citing fuel costs and transportation time to and from Kruzof Island are indeed valid. But in spite of those concerns, a pilot project should still be explored. Why? Well, as Garry White of Sitka Economic Development Association explains, folks in Alaska are used to doing things the hard way: “You know folks that live here, and anywhere in Alaska, you gotta understand that it is a little bit tougher. Yeah, you can go buy a quart of wood for 300 bucks. I’m not spending 300 bucks on a quart of wood. I can go get that myself in my free time.”

Our team's survey analysis also shows that the majority of the ATV users captured expressed interest in a firewood pilot project on Kruzof, likely because they already make frequent trips to the Island and have the capability to travel across large distances. If the USFS is already planning on carrying out young-growth thinning projects on Kruzof Island, making arrangements for a small-scale pilot project would not require extensive additional resources beyond the setup stage, besides occasional monitoring and assessment. If the project works on a small-scale, the USFS can work with local partners to tackle larger logistics issues, like Kruzof's limited road system and transportation infrastructure. Finally, even if the pilot project is successful or fails, it may provide more insight into how the USFS can support a community firewood gathering location on Baranof Island, in a place where a boat is not required for access.

E. Continuing support of and investment in restoration projects

Up until the mid-1970's, Kruzof Island was primarily managed by the USFS for timber purposes. The restoration section of this report highlights the lasting effects of this timber-focused management on the landscape, particularly clear-cutting. Considering continuing declining timber production, strong public use of and appreciation for Kruzof's recreational and scenic beauty, success of ongoing restoration projects, high public perception of restoration value, and extensive subsistence utilization dependent upon healthy ecosystem services, we recommend continuing support of these restoration efforts.

Among respondents' primary activities on Kruzof Island, the six most frequent (hiking and camping, subsistence hunting, wildlife-viewing/bird-watching, subsistence gathering, subsistence fishing, and recreational hunting) would all benefit from improved habitat restoration. Furthermore, even among ATV-specific survey respondents, hiking and recreation was the island's primary use. Respondents' management priorities (Results Section C) also strongly indicate support of wildlife habitat protection and restoration.

Findings from this project's Restoration Assessment also demonstrate that while there are lasting impacts from clear-cut logging in both riparian and forest ecosystems, Forest Service restoration projects have been effective in mitigating these impacts.

F. Cultivate Strong Communication and Stakeholder Engagement

A major takeaway from the stakeholder interviews and survey results is that communication and engagement with stakeholders within the Sitka Ranger District could be improved upon. Our client and the USFS do not need the survey results to know that there are divergent perspectives within the Sitka community over how the natural resources on the Tongass should be managed - but the survey results do show that these perspectives may not always be as divergent as they first appear. Little support for unchecked and old-growth logging exists, and most residents seem to recognize the need for a cautious approach to timber management in the District. But there is support for future logging projects that meet community requirements; namely wood for infrastructure expansion and improvement, heating purposes, and restoration projects that sustain and protect resources for subsistence needs.

For the USFS to successfully handle the management transition on the Tongass, it is necessary for them to pursue management actions that help them shed their image as an uncaring, bureaucratic monolith of an agency. Sitka Ranger District has recently been pursuing smaller-scale timber sales, a decision that appears to be in line with public desires for timber management and the needs of local timber mills. But it is unclear how much of the USFS's effort is being accurately communicated to the general public. For example, rangers from the Sitka Ranger District discussed a holistic approach to timber management with our team in August, explaining that "goals for a Land Use Designation can be future timber harvesting, but it doesn't mean that necessary treatments won't help wildlife or fisheries, or general stand conditions." But intentions don't matter in the grand scheme of things if Sitka residents don't understand the rationale behind USFS management decisions.

For many residents, their most recent experience with USFS public engagement was a series of recreation-focused listening sessions that occurred roughly four years ago. As one interviewee recalls, "[the public] came up with a great list of important items and suggested improvements. People really liked their trails, they liked their cabins, they liked their abilities to have, say, mooring buoys and cabins that are stocked. And they didn't mind paying a little bit more for that, too. And none of it has been implemented." This experience seems to have negatively colored many local residents' perception of the USFS, and dimmed their outlook on the effectiveness of any future public engagement. The Sitka Ranger District recently experienced a leadership transition, and management actions so far have given some residents hope that the office will be more responsive in the future.

But, USFS management decisions on the larger Tongass are also being publicly questioned, perhaps rightly so. The Research firm Headwaters Economics recently released a report showing that timber expenditures on the Tongass still receive a disproportionate amount of funding in comparison to the fishing and recreation sectors - despite what the Tongass management transition leadership has stated (Alexander, 2014). It is understandable that a transition of this magnitude will take time and experience set-backs. But questions over the USFS priorities continue linger in the public's mind. The Sitka Ranger District has no control over the public's overall perception of the ongoing transition, but employing focused and sustained public engagement as tools in the District's future natural resource management projects is strongly recommended.

G. Improve signage

Survey respondents indicated a strong need for better or increased directional and interpretive signage on Kruzof Island. When our team stayed at Shelikof Cabin, a USFS recreation cabin, we made a point of reading all past visitor entries in the cabin logbook. The majority of entries, especially those from large groups and family users, mentioned some variation of getting lost or confused while finding their way to Shelikof. As of August 2014, when our team made the fifteen-mile round trip trek out to the cabin, there are two specific points along the path that need improved signage. Iris Meadows is a large, often-waterlogged meadow frequented by Kruzof grizzly bear population. The trailhead to Shelikof Cabin is not visible from the entrance to the meadow, resulting in confusion and an increased risk of injury when visitors are crossing a flooded area with wild animals present.

There is also very limited cell phone reception on Kruzof Island, severely limiting visitors' use of mapping applications. A large map of the entire trail system at the Mud Bay landing site would be very valuable for visitors seeking to orient themselves and calculate their expected travel time. Several survey respondents expressed concern over ATV users and hikers passing through ecologically-sensitive areas on Kruzof. Placing interpretive signs explaining the sensitivity of those natural areas might go a long way in raising awareness among all user groups. At the very least, indicating treatment and restoration areas on Kruzof with signage is highly suggested to limit accidental disturbances.

If the USFS is serious about supporting the management transition, investing the necessary time and money to support an adequate recreation infrastructure within the Tongass in vital. The USFS needs to ensure they evaluate what outreach improvements or additions the public values. Our team personally experienced the gap that can exist between USFS intentions and the public's needs. A USFS ranger in Sitka expressed confusion over how we had possibly managed to get lost in Iris Meadows, and disclosed the existence of another trail to the cabin - please note, a trail that does not appear on hiking maps. In this ranger's eyes, the signage is not a problem, because of familiarity with Kruzof Island. But this will not be the case for other visitors to Kruzof, who will increase in number if the USFS is able to successfully complete an economic diversification on the Tongass. Predicting, assessing, and being responsive to visitor needs should be an area of increased management focus within the Sitka Ranger District.

Community Engagement Appendices

1A. Full Qualtrics Results

Initial Report

Last Modified: 02/09/2015

1. What is your primary occupation?

Text Response
Natural Resources Manager
retired
sports instructor
writer/editor
Artist
Retired Commercial Fisherman
Supervisor
retired
Commercial fisherman
Grant Writer
Librarian
Fisherman
Health Care
fisherman
Retired Teacher
retired
Photographer
Traffic control flagger
Land Management
Research forester at USFS
Retired teach but still a naturalist for Allen Marine
Health Education
Retired
Teacher
Volunteer
Retired Archivist
Retired
Educator
RN, nurse practioner
Retired
Teacher
Commercial Fisherman- Salmon Troller
Commercial fishing
Retired nurse
I have three jobs and they are all of equal importance. Mayor, web + graphic design + executive director of a non-profit (affordable housing)
Media
Fishing guide
Retired from City of Sitka (27 years)
Commercial Fishing
Artist/Media
Homemaker and economic resource advisor
Administration (H.R. and budget); fisherman
Medical Professional
Retired educator
Teacher
Wildlife tour operator
Warehouse/purchasing
Commercial fisherman

Mental health clinician
fisherman
Pharmacist
Retired
Retired Fish and Game Biologist
RN
Retired- Non-profit Controller
Health care management
Retired
Fisherman
Retired
Writer
Doing this as a family
Own a boat repair shop
Retired
Elementary School Teacher (5th grade)
Commercial fishing
Maintenance manager
Own and run a Bed and Breakfast
Heavy Equipment Operator
US Forest Service- Retired
Retired
Entrepreneur
Self-employed
Bureaucrat/Adminstrator
Director of a nonprofit
Receptionist
Fisheries biologist
Retired Fisheries Scientist
Retired
Healthcare
Retired
Retired Teacher; Self-employed education contractor
Maintenance
Retired
Retired
Schoolteacher
Retired
Services
Commercial fisherman/fisheries science
Social Worker
Physician
Pilot
Retired Executive Secretary, UAS Sitka
Teacher
Disabled
Retired from forestry and commercial fishing
Retired Teacher
Retired
Retired
Commercial Fishing
Fisherman
This table has more than 100 rows. Click here to view all responses

Statistic	Value
Total Responses	113

2. What is your age group?

#	Answer	Bar	Response	%
1	Under 18 years		1	1%
2	18-29 years		5	4%
3	30-44 years		16	14%
4	45-60 years		42	37%
5	Above 60 years		51	44%
	Total		115	

Statistic	Value
Min Value	1
Max Value	5
Mean	4.19
Variance	0.81
Standard Deviation	0.90
Total Responses	115

3. Do you regularly visit Kruzof Island (at least once every six months)?

#	Answer	Bar	Response	%
1	Yes		68	58%
2	No		49	42%
	Total		117	

Statistic	Value
Min Value	1
Max Value	2
Mean	1.42
Variance	0.25
Standard Deviation	0.50
Total Responses	117

4. If yes, please select below which activities you do while on the Island.

#	Answer	Bar	Response	%
1	Hiking or Camping		48	73%
2	ATV-Riding		13	20%
3	Subsistence Hunting		35	53%
4	Subsistence Fishing		18	27%
5	Subsistence Gathering (wood, seaweed, berries, etc.)		21	32%
6	Recreational Hunting		18	27%
7	Recreational Fishing		11	17%
8	Wildlife Viewing/Bird-Watching		28	42%
9	Other- Please Write:		15	23%

Other- Please Write:
use anchorages
mountain biking
Harvesting matierial for my Tlingit Art
Bicycling on Trails; Viewing WWII Steps and Bunker
Beachcombing
Beachcombing
working
Trapping
Building Logging Road
Beachcombing, surfing, paddleboarding, picnicking
Surfing
Scenery
Natural history educational programs
Surfing
Beachcombing

Statistic	Value
Min Value	1
Max Value	9
Total Responses	66

5. What do you think should be the management priorities for Kruzof Island? Please rank your top choices by dragging and ordering the options, with 1 as the highest priority. Feel free also to write in your own suggestion.

#	Answer	1	2	3	4	5	6	Total Responses
1	Providing and maintaining scenic hiking trails	10	22	36	27	12	0	107
2	Providing and maintaining multiple-use trails (hiking plus ATV and bicycle usage)	22	9	23	39	12	2	107
3	Protecting fish and wildlife habitat	52	25	9	12	7	2	107
4	Restoring and maintaining fish and wildlife habitat	16	41	30	11	7	2	107
5	Harvest of forest products (biomass, timber, firewood)	3	10	4	14	62	14	107
6	Other	4	0	5	4	7	87	107
	Total	107	107	107	107	107	107	-

Other
Providing recreation facilities to reduce impacts to resources & ensure high quality recreation opportunities (e.g., provide toilet or hardened campsites at N. Beach)
Restoring the commercial viability of the island to recreate year-round employment and get off of the tourism/seasonal job merry-go-round which pays ow and jobs are seasonal.
Keeping Four Wheelers off
Cultural Resource Inventory
A balance of harvest and other recreational opportunities!
Build a dock at Mud Bay
multiple use, multiple purpose
Subsistence razor clam harvest at Brent's Beach
Maintaining Wildlife
More USFS cabins
Camping
cabins
Limit ATV usage
Providing recreational cabins
Marine debris
Limiting commercial impact on Kruzof (tours, harvesting, etc)
Protect the Island with Wilderness designation
Maintaining, while not taking our rights and freedoms to use the island away
Sustainable Timber and Fish
Cabin Maintenance

Statistic	Providing and maintaining scenic hiking trails	Providing and maintaining multiple-use trails (hiking plus ATV and bicycle usage)	Protecting fish and wildlife habitat	Restoring and maintaining fish and wildlife habitat	Harvest of forest products (biomass, timber, firewood)	Other
Min Value	1	1	1	1	1	1
Max Value	5	6	6	6	6	6
Mean	3.08	3.15	2.09	2.61	4.53	5.53
Variance	1.29	1.88	1.92	1.37	1.50	1.36
Standard Deviation	1.13	1.37	1.38	1.17	1.22	1.17
Total Responses	107	107	107	107	107	107

6. Please rank the following changes you would like to see to Kruzof Island, with 1 as the most important. Rank as many or as few as you feel necessary. You may also write your own suggestion.

#	Answer	1	2	3	4	5	6	7	8	Total Responses
1	An improved trail system	23	12	26	10	4	2	0	0	78
2	Better signage and trail markers	5	12	8	26	12	3	0	0	67
3	Additional visitor amenities (bathrooms, campsites, etc.)	5	7	13	6	26	8	1	0	67
4	Increased habitat restoration and maintenance activities	14	35	14	12	6	1	0	0	82
5	Increased habitat preservation	35	13	5	9	11	8	1	0	82
6	Increased logging opportunities	6	5	3	3	4	24	1	1	47
7	No changes needed	18	2	4	0	0	2	2	1	29
8	Other - Please Write	4	2	3	2	1	1	3	0	16
	Total	110	88	76	68	64	49	8	2	-

Other - Please Write
Increased forest products opportunities (other than standard timber harvesting), e.g., music wood, spruce tips for food products (e.g., syrups), berry picking, etc...help develop more opportunitie for developing new local businesses.
Selective logging for local use. Maybe scrap timber for pellet fuel.
Stop Four Wheeling
Protection of Iris Meadows
Other cabins- above twin lake perchance, for Sitkans to use
Build a dock at Mud Bay
get rid of predators, i.e. sea otters
Make Kruzof Island a National Protected Wilderness Area.
Additional USFS cabins
Limit ATV usage
No commercial logging
No new trails; No commercial activity added (too much already)
Use best science available!
Pursue national wilderness or park status
Take those water divits out, they are very dangerous.

Statistic	An improved trail system	Better signage and trail markers	Additional visitor amenities (bathrooms, campsites, etc.)	Increased habitat restoration and maintenance activities	Increased habitat preservation	Increased logging opportunities	No changes needed	Other - Please Write
Min Value	1	1	1	1	1	1	1	1
Max Value	102	101	100	6	7	8	8	7
Mean	3.83	5.01	5.48	2.56	2.71	4.60	2.34	3.56
Variance	128.50	143.41	139.74	1.48	3.54	4.03	4.88	5.06
Standard Deviation	11.34	11.98	11.82	1.22	1.88	2.01	2.21	2.25
Total Responses	78	67	67	82	82	47	29	16

7. Where on Kruzof Island would you most like to see these changes? (Please see map below for reference). Example: "Improved trail signage at ________________."

Text Response
Improve signage at N. Beach - beach grass areas to keep ATVs on designated trails. Toilet at N. Beach, besides the cabin toilet, one that is available for general public use. Improved access and mooring at Mud Bay. Habitat restoration where there are thickets of tree growth from past logging.
It would be very nice if there were an outhouse for day-users of the island somewhere along the Mud Bay-Iris Meadows-Shelikof Route. Perhaps one could be added where the ATV/bike road from Mud Bay intersects with the hiking trail to Shelikof Bay..
Improve access to outer coast Improve trails, expand trails for all forms of recreation Create more destination areas for recreation... cabin sites, tent platforms, outhouses, landing sites
It's hard for me to view only Kruzof Island. My scope is the Sitka Local Use Area. Morris reef on the east, all of West Chichagof Island, all of outside Baranof Island. I don't see the advantage to any signage. If people need signs to direct them they shouldn't be out there alone.
all ATV trails (logging roads)
Improved trails from Mud Bay to North Beach
The whole island
Mud Bay to Shelikof Bay
None
Trails and along beach areas and clean up, and do wayside exhibits at WWII sites.
Maybe a sign on the logging road that talks about the uniqueness of the meadows.
More signage near the super curvey segment almost to north beach trail
Where there is suitable timber which is renewable.
All
Around the campsites and on the trail to the tap.
All over
More riding areas. The forest is so thick you cannot just go and ride like up North. So utilize the existing roads.
ATVs/logging
Don't know
All forks in the road in Irish meadows.
Along the existing road system.
The areas that enhance the above in 3 and 5
When they are needed- I am not familiar enough with the island to be specific.
Habitat stream restoration where there is still evident degradation from logging four centuries (decades) ago. Logging of secondary growth if it is harvestable.
Mud Bay
I think the entire island should be made a national protected wilderness area. If that is not possible than the outer coast should be protected as a "wild and scenic coastline."
Improvements at Shelikof cabin and the Mud Bay shelter.
Cabin by Gilmer Bay, cabin by Kalinin Bay
Mt. Edgecumbe
In previously logged areas.
I would like to see the island designated a wilderness area.
Mt. Edgecombe
Multiple use trails,
Campsites
Kalinin Bay
Emphasis on restoring/maintaining natural ecology of island.
Shelikof--Mud Bay- North Beach needs developed campsites - gets too much use for an undeveloped site.
Trail system on outside coast. Brent's Beach to Shelikof Cabin.
More campsite/cabin spaces would be nice. So many people go to Kruzof and in the winter, its easier to go if you have a cabin vs. tent.
N/A
Take better care of the logging roads so they can be used by bikes, ATVs, etc. Take out humps across road.
Don't waste your money.
Dock facility at trailhead.
More campsites overall and moorage buoys on SE side of island
Habitat restoration at clear cut areas.
Mud Bay, on trail system (i.e. "this way to lakes/tower etc.")
Northern part of Kruzof. Also logging roads aren't well marked.
Unsure. Haven't been to Kruzof terribly often (Sealion Cove mostly).

Repair of ATV damage and beach clean-up
any of the present campsites
trailheads
More trails for 4-wheeling and hiking (multiple uses)
Improved outhouse facilities on trail from Fred's Creek to Mt. Edgecombe.
Habitat preservation and restoration should be done everywhere there is a human impact. Kruzof does not need more trails/amenities and there should not be logging or commercial harvesting.
On logging roads.
Increase habitat restoration at Iris Meadows and improve trails ad signage at Mud Bay and volcano trail improvements. Need shelter at Brent's Beach.
The whole island
Commercial harvest in 40 year-plus stands of second growth and recovery of mortality losses in old growth stands.
ATVs have too much access. No more vehicular trails.
Campsites at Sea Lion Cove
Maintenance of Mt. Edgecumbe road and ATV road
The water ditches need to come out. If not, better signage to mark them is needed. Do not interfere with our ability to enjoy this island as we always have.
no changes needed
Improved signage to the track going to the non-ATV accessible cabin.
Improved signage island wide. Different areas serve different user groups.
I don't know.
Preservation = everywhere (all of Kruzof) Signage = turn off to Shelikoff Beach
North end for logging
Parking lot improvements at Mud Bay. There is no organization there and ATVs go anywhere.

Statistic	Value
Total Responses	69

8. What do you see as the greatest risk to Kruzof Island's ecosystem, if anything?

Text Response
Uncontrolled, unregulated ATV use = damage to sensitive areas.
Commercial use.
I don't currently see a huge risk to the ecosystem of Kruzof Island.
Climate change and people loving it to death
Thousands of tourists.
Clear cut logging, or the cutting of small trees to enhance larger trees. If you cut the trees, clear them out!
No risk at this time
commercial resource extraction
Logging. Careless atv's
Logging
Logging and excessive ATV use
Overdevelopment
Motorized Vehicles
Wheeled vehicles - wheelers, bikes
?
Humans
Invasive plants from town- and tree die-off from pests.
Not being ran like the campgrounds without a couple of hosts to help oversee the use of the land.
Nothing but natural disasters.
Logging
Things grow so fast in SE Alaska. You ride a 4-wheeler on beach, tide change all tracks gone. I've seen more damage from beach erosion.
Atv's/logging
Increased visitor usage on road system - atv's
Unknown
Neglect.
Logging is the greatest risk, especially old growth logging.
Clearcut logging of old growth (both)
Erosion caused by vehicles being used off trail.
Development
Humans
Logging and ATVs
Lack of harvesting/guiding/user access/commercial use that will lead to less cash flow for maintenance there by the Forest Service, who will cut off access since they trying to do this in other areas.
People leaving garbage
1) Logging: industrial/clear-cut logging. 2) Unchecked tourism/development. 3) OCean pollution: garbage on beaches.
Climate Change
Logging
Not sure
If the Forest Service logged North Kruzof.
Logging, motorized access
Logging
Resource extraction of industrial scale, primarily additional logging and road construction. (Does not include commercial fishing adjacent to Kruzof).
Logging; tearing up the trails by inconsiderate people; trash.
Logging
Treating our stressed wild spaces as resource banks as opposed to necessary living systems for all creatures continued existence.
Logging
1) The possibility of significant commercial logging and timber sales, 2) Large-scale tourism, 3) Increased ATV use
Large-scale logging
Many items build up on the beaches such as foam, bottles, and miscellaneous trash.
Nothing
The Government.
Greatest risk is commercial timber sales.
Overuse of highly accessible areas.
Clearcut logging
The Forest Service poses the greatest threat to Kruzof Island's ecosystem.
Global warming
More ATV use
Resource extraction- increased tourism.
Return of industrial logging
People leaving behind only footprints.
More human encroachment
People getting off the trails, and digging up with 4-wheelers
Clear cut logging.
Logging
Increased human traffic
Allowing ATVs to go off the prescribed trail system. Allowing ATVs on any beaches. Allowing guided tours and/or guided hunting to use Kruzof and the Sitka Ranger District has made locals have to travel further away at increased time and expense to get peace and privacy in nature.
nothing
It might be ATVs running amok in Iris Meadows
Logging
Improper recreation use- 4 Wheelers off-trail.
Logging. Over development for tourism (too many trails and cabins).
Ocean acidification
Uncontrolled human impact
The lack of subsistence. Overgrowth, deer/bear population. An ecosystem can only support so much. Everything in moderation.
1) Helicopter touring, 2) Too much guided tourism, 3) Logging
Clearcut logging and off-trail motorized vehicles
Clear cut logging.
Too many people
Over use. Logging. Commercial Harvesting.
Overuse
Ocean garbage
More plentiful large scale logging. Otherwise ATVs.

Statistic	Value
Total Responses	81

9. What do you see as the greatest risk to the land within the larger Sitka Ranger District, if anything?

Text Response
Inadequate funding to the Forest Service to manage visitor/recreation use. Tourism is one of the largest economic drivers in Southeast Alaska; this should be a priority for funding. Unmanaged visitor use has a negative impact on the businesses that depend on the type of "wild Alaska" experience provided by the Tongass.
Commercial use
In general I think the biggest threat is to the water not the land. I think that we need to be careful not to overharvest salmon or herring through the commercial or charter fishing sectors. We also need to be mindful of pelagic and non-pelagic rockfish bycatch. Sometimes I suspect the overall biomass estimates of certain fish are not conservative enough leading to over-allocation and over-exploitation of fisheries resources.
Climate change and people not caring about it
Tourism management and eco-fanatics. Sitka is an opportunity graveyard with seasonal, non-profit, government of all strips and levels being the main employers. There are few year-round family wage jobs to be had outside of the above. With the lack of taxable property (see above major employers) City income is almost wholly dependent on taxing residents. If one is not fortunate enough to find one of the few family wage jobs outside of the above major employers taxes are nearly confiscatory, with the City planning on implementing a "Road Usage Fee" for all vehicles registered in the community. In other words, the more land which is locked up into a "Private Idaho" the more only the wealthy, retired with an independent income stream, or one who works for one of the above mentioned major employers can afford to live here.
Not recognizing the asset recreation and access can be. Subsistence activities, with sustainable harvesting would be a great fit
When I moved to Sitka in the early 60s Sitka supported 7 logging camps. Now there are none so I don't see any risk to the land.
industrial scale timber harvest
Mining, logging
Trail and road sediment going into salmon streams
Overdevelopment
Motorized Vehicles
See above
Humans
Any move completely eliminate(ing?) harvesting
Logging
Unknown
The ATV activities worry me.
Lack of sufficient funding to properly take care of the district. Insufficient staffing, lack of USFS focus on transition framework. Imbalanced focus on timber harvest sales in other districts.
Humans, but I'm okay with that - we are part of the ecosystem.
Global climate change
Not sure
Mining
Logging
Logging
Logging, roadbuilding
Large-scale logging
Clearcut logging and unrestricted use by tourism groups. Too many people visiting trails keep locals away and then no one cares about these places anymore. Some selective logging is useful and necessary.
Too much vehicular traffic
Global warming
Public not following trail systems
Return of industrial logging
Logging without thinning. Thinning and extracting biomass is a great need on Kruzof.
ATV overusage, esp. on off-trail places I guess
Logging
4 wheelers damage habitat when they go off-trail. Accidents happen move often off-trail.
Resource development
ocean acidification
Bugs (spruce bud worm); global warming; ocean acidification
Climate change, diseased fish coming in, overuse by visitors, native use should be primary
Use by people who dont care and don't take care of the environment

Statistic	Value
Total Responses	41

10. Which of the following programs are you familiar with? Check to show whether you or a family member have participated in each program, or have only heard of the program. If you know the organization that sponsors a program, please write it in the space provided below the program name.

#	Question	Have participated in:	Have heard of:	Total Responses	Mean
1	Starrigavan Habitat Restoration	9	73	82	1.89
2	Sitka Herring Restoration Plan	8	55	63	1.87
3	Energize Sitka!	12	54	66	1.82
4	Local Foods Initiative	35	71	106	1.67
5	Science Mentor Program	8	71	79	1.90
6	Sitka WhaleFest	59	52	111	1.47
7	Fish to Schools	30	82	112	1.73

Starrigavan Habitat Restoration	Sitka Herring Restoration Plan	Energize Sitka!	Local Foods Initiative	Science Mentor Program	Sitka WhaleFest	Fish to Schools
USFS, SCS			SCS, SLNF, Food Co-op	Science Center?, USFS		SCS
SCS	STA		Various entities	SSS Center	SSS Center	SCS
USFS	STA		SLFN	SSSciC	SSSciC	SCS
USFS, ADFG, State of AK	Sheeatika, ADFG	City of Sitka		UAS, Sitka SD,		Sitka Sound Seafoods
Too big of gravel		Community Health Forum		Sitka Sound Science Center		Community Health Forum
SCS	STA		SLFN	SSSC		SCS
USFS					SSSC	
Need to make firewood more available						
SCS	SCS	SCS	SCS	Sitka Science Center/SCS	Sitka Science Center/SCS	SCS
SCS, USFS	STA, Sealaska		Sitka Local Foods Network		SSSC	SCS
Forest Service/Schools	Sitka Tribe of Alaska	Chamber/SCVB/Health Summit	Lisa Sadler	SSSC	Sitka Whalefest	
SCS, USFS, UAS	STA			Science Center	Science Center, UAS	SCS
USFS and SCS	ADFG		SCS	SCS	SSSC	SCS
	Sitka Tribe					
	not heard of			not heard of		
	not heard of					
	not heard of	not heard of				
	Unnecessary- Herring are a healthy and well-managed resource					
	No such effort to reduce having overharvest					
	No need to restore					
	Sitka Tribe of AK		Local Food Network	SSSC	SSSC	SCS
		Revitalize Sitka group			Supporter	Great project!
		SCS				
			SLFN/Artchange		SSSC	SCS
			Sitka Local Kids Network Health Summit	SSSC		SCS
			Sitka Local Foods Network			
				SSSC	SSSC	SCS
					Sitka Whalefest/ Sitka Sound Science Center	Sitka Conservation Society
					SSSC	SCS
						My grandchildren
						comment!
						SCS
						Blatchley Middle School
						SCS- I donate fish
						SCS

Statistic	Starrigavan Habitat Restoration	Sitka Herring Restoration Plan	Energize Sitka!	Local Foods Initiative	Science Mentor Program	Sitka WhaleFest	Fish to Schools
Min Value	1	1	1	1	1	1	1
Max Value	2	2	2	2	2	2	2
Mean	1.89	1.87	1.82	1.67	1.90	1.47	1.73
Variance	0.10	0.39	0.20	0.22	0.14	0.25	0.20
Standard Deviation	0.31	0.62	0.45	0.47	0.37	0.50	0.44
Total Responses	82	69	67	106	80	111	112

11. If you visit Kruzof Island or other areas within the Sitka Ranger District for subsistence activities, what time of the year do you visit? Please write the month range and the most frequented locations, or N/A if not applicable.

Text Response
July - October for mushroom gathering, berry picking. Nakwasina sound area, Krestof Island, Mosquito Cove, Indian River
May to September
I do not typically visit Kruzof for subsistence activities.
Summer - Redoubt, Summer areas around Sitka, fall areas around Sitka,
May- August, October-December
Spring primarily for seaweed, for spruce roots, for clams, Summer for beach asparagus Summer and Fall for Salmon
Pretty much year round Whale Bay to Morris Reef.
June, July, August - southern shore; October, November, December, January - eastern shore
November. Gilmore bay, goleta cove
Hunting: mid-August until the end of January Fishing: Mid-May thru September.
April - September
Spring-Fall
yes - year-round
June- August: Shelikof Cabin for Cabin Camping July/August-September: Hiking Mt. Edgecombe and Sea Lion Cove
Sept-Dec, Krestoff Sound - hunt; Sept-Dec, Kalinan Bay - hunt; Sept-Dec, Gilmore Bay - hunt.
June-August
Any time - camping, exploring, hiking
April-October: Mud Bay, hiking and hunting April-October: Brents Beach, hiking July: Shelikof, camping April-October: Freds Creek, hiking
April-Sept., subsistence fishing; March-Sept., berries
July, beach asparagus
April-June, Shelikof and North Beach; Feb., Shelikof and North Beach
May-September: Camping/Fishing
Year Round- All kinds of activities.
March-June, fishing; Sept.-Nov, hunting.
June-July: Magouns- beach asparagus, bull kelp, Kasiana- bull kelp
October-January, 2 hr radius boat ride from Sitka for deer hunting; July, Sockeye subsistence harvesting at Redoubt Falls.
May-Nov, Sitka Sound for halibut; Oct-Dec, False Island deer hunt
August-October: berry picking, deer hunting, subsistence halibut
Varies
March-October, fishing, hunting, firewood in all areas
June-August, Shell collection and driftwood
August-January: Entire Island (hunting deer)
Don't personally visit, but others bring me seaweed and Salmon
All over Kruzof year-round.
October-November: Deer Hunt
May-August, hiking and nature study
Spring and Fall: Seawood/Herring Spawn for garden Spring and Summer: Fishing for Salmon and Halibut (near Sitka) Fall: Hunting for Deer
November- Deer hunting
June: Hayward, Seaweed July-August: Shelikof Bay, Coho
Fall - Sitka area for mushroom gathering and berry picking; Spring - Sitka area for spruce tip and daily fishing clams; Fall - Sitka area deer hunts
Prefer not to say.
August-November, Sinitsin Ridge-hunting; Outer Kruzof - hunting
November-December: Noah Beach, hunting (deer) November-December: Shelikoff, hunting (deer)
May-June, spruce tips at Shelikof Bay; August, Beach asparagus at Peril Strait; September, berries, seaweed and deer hunting at Peril Strait
July, Mud Bay road system and Brent's Beach
November-March: Shelikoff Bay, Trapping August: Shelikof Bay River System, Coho August-January: Whole island, Hunting Deer June-July: Whole island, Berry Harvesting Summer, Fall, Winter: Beaches of whole island, Shellfish Harvesting
Built logging road at Eagle Creek, northern Kruzof, in 1960s.
March-October, Dry Pass (North End) for deer, fish
March-June: Fishing
May-Sept, camping
March-April: wherever there is roe on kelp May-September: Sitka Sound, Salmon August-September: Hoonah Sound, Shrimp/Halibut August-January: Sitka Sound/Hoonah Sound/West Chichagof, Deer Hunting
August Redoubt (ops not Kruzof) August-September: Harbor Mountain, Blueberries
March/April, herring eggs on the eastern shoreline; April-June, Seaweed at North (Kalinin Bay); May-July, Subsistence fishing (Kalinin Bay)
June-August: Camping, Hiking
April-June, offshore and in bay fishing and crabbing
August-October: East Side, deer hunting
Nov-December, deer hunting
October-December, Kruzof for deer; May-September, Kruzof cabins for camping; January-December, visit Kruzof if there?
September-November, Shoals Pt., Inner Pt. for deer harvest
All year and most weekend (weather permitting): Range throughout Sitka Ranger District all over beyond Necker-Bay South and throughout North areas including Hoonah Sound. Fishing for all species, shrimp, salmon, halibut, octopus, ling cod, snapper, clams, kelp, seaweed, mushroom picking, berry picking, beach asparagus, etc. and hunting. (All is only subsistence).
July - Climb Mt. Edgecumbe; October- Mud Bay to hunt
May-June, inner coast for seaweed; May-August, beach flats for greens; August-December, trails for deerhunting
May-August: Halibut Point, Recreational Picnics
Shelikof is great for sports fishing
April-June: Hike yearly
April-September: Shelikof North Beach, camping April-September: Fred's Creek, camping December-January: Fred's Creek, hunting September-May: Shoal's Point, Surfing
October-December: Whale Bay, Deer Hunting
October-November, hunt ; June, beachcomb
All year: hiking, fishing, camping, hunting, beach combing, harvesting plants, etc.
September-December, Port Krestoff for duck hunting; October-December, East and North side for deer hunting
Fall: Mud Bay, Trail to Shelikof, Berry gathering Fall: Everywhere, hunting
April-June: Spruce Roots July-September: Berries June-August: Fish March: Hiking
Year round: Fishing June-July: Beach asparagus Year-round: Eastern Channel, scallops March-April: Sitka Sound, Herring eggs Summer: Krestoo Sound, Bull kelp September: Silver Bay, Mushrooms Summer: Everywhere, berries
January, East side of the Kruzof for hunting
AUGUST - JANUARY, HUNTING, EASTERN SHORES

Statistic	Value
Total Responses	75

12. If possible, please estimate the annual value of goods your household obtains through subsistence hunting and harvesting (in dollars).

Text Response
??
100
$350 I subsistence fish, but not on the island, so I'm not sure if you want that value or not.
$500
$2,000-3,000
This question feels offensive, and I am not sure why. In order for my family to live here we Must harvest, it has become too expensive to live in Sitka without hunting and fishing. The price it cost, or what it's worth are so difficult to quantify... With the cost of gas, amo, boat maintenance: cost $2,500 per year. Value about $1,200 per year
$20,000 ? I've never thought to put a dollar value on the venison, halibut, all species of salmon, shellfish, seal oil, herring roe on both kelp and branches, berries, beach asparagus, and much more.
1000
$3000.00
$200 in deer, $2000 in fish, $300 in berries
10000
5-deer $?
0
1000
Priceless
$5000 mostly fish
Not sure
Hundreds of dollars
1200
$2,000
0
$5,000
2000, at least in seafood
$500 (includes gifted fish)
$200
15-20,000
2000
$2,000 (from all areas, not just Kruzof)
$3,500
Enough to feed a family of 4 that eats 99% fish and wild game
Unknown need to make some things and sell them before I know
$2,000 ($1,000 deer mean; $1,000 halibut and king salmon)
2,000
1000 plus seaweed and clamshells for garden
500-1000
$75/year- Fertilizer Savings; $200/year meat; $400/year Fish
500
$500
2,000
$500
750-1000
$500
0
$30
2,000
$500
400
$300
At least 5,000
$2,000
5000
$500
0
$7,100
1,000
$1,000 (between fish and berries)
60 per month?
1000 - fish, berries, beach asparagus, etc.
Salmon and Halibut - 1,500; Crab - 150
100
$3,000
#1,320
About 100, through others' subsistence fishing
Unknown $ value- most of our diet is gathered or hunted, so we buy very little meats, no jams, no seafood. Eat garden greens and make dog food for our dog.
200
$150
Priceless
30-60 from sport king fishery
0
$400
4000
$5,000
The value is our health and use of Natural resources. Can't put a price on no GMO, preservatives, hormones, etc.
2000- priceless
Priceless
200
Priceless: economics is a poor management tool.
Given to us by others maybe as much as 5000 (fish, animals, meat, skins/furs)
$3,000
500
750
$3000

Statistic	Value
Total Responses	82

13. Which of the following activities do you think brings the most economic benefit to the communities surrounding Kruzof Island? (Please select one).

#	Answer	Bar	Response	%
1	Logging and timber sales		5	5%
2	Commercial and charter salmon fishing		50	49%
3	Tourism and recreational activities undertaken by area residents (e.g. ORV-riding; hunting and fishing excursions)		23	23%
4	Subsistence Activities (e.g. hunting, fishing, and gathering for household consumption)		21	21%
5	Other - Please write		3	3%
	Total		102	

Other - Please write
Were Logging still allowed on a major level Logging it would be. Commercial fishing keeps the most dollars in town. Tourism probably generates the most gross revenue, but with the number of businesses which only show up in the summer and in many cases import employes the income generated is simply "pass-thru."
Not sure
Nothing going on here any longer.

Statistic	Value
Min Value	1
Max Value	5
Mean	2.68
Variance	0.91
Standard Deviation	0.96
Total Responses	102

14. Which of the following activities do you think brings the most economic benefit to the communities within the Sitka Ranger District? (Please select one).

#	Answer	Bar	Response	%
1	Logging and timber sales		4	4%
2	Commercial and charter salmon fishing		52	55%
3	Tourism and recreational activities undertaken by area residents (e.g. ORV-riding; hunting and fishing excursions)		18	19%
4	Subsistence Activities (e.g. hunting, fishing, and gathering for household consumption)		19	20%
5	Other - Please write		1	1%
	Total		94	

Other - Please write
Were Logging still allowed on a major level Logging it would be. Commercial fishing keeps the most dollars in town. Tourism probably generates the most gross revenue, but with the number of businesses which only show up in the summer and in many cases import employes the income generated is simply "pass-thru."

Statistic	Value
Min Value	1
Max Value	5
Mean	2.59
Variance	0.80
Standard Deviation	0.90
Total Responses	94

15. Please select any of the following types of timber harvest you would like to see on Kruzof Island.

#	Answer	Bar	Response	%
1	Clear-cut old growth commercial harvest		7	6%
2	Selective old growth commercial harvest		23	20%
3	Clear-cut young growth commercial harvest		7	6%
4	Selective young-growth commercial harvest		41	36%
5	Selective harvest for commercial biomass		17	15%
6	Utilization of thinning byproducts for commercial and/or personal timber products (e.g. firewood)		51	45%
7	Would not support any kind of timber harvest		41	36%
8	Other - Please Write		15	13%

Other - Please Write
Thinning for wildlife habitat improvement
Management state plans partial harvest
I hope you people understant SE Alaska
I would support habitat restoration
biased question - education that in some areas clear cutting only way to make sure that replanted areas grow back
Not sure - would depend
No commercial timber sales; area overharvested by pulp mill
No timber harvest on Kruzof; selective harvest in other areas
Driftwood logging for firewood
Restoration of previously harvested areas (may include personal use firewood)
Use best science to save our forests
Selective cutting
I leave that decision to the experts as to how to do it
clearcut on small scale
Don't know enough

Statistic	Value
Min Value	1
Max Value	8
Total Responses	114

16. How intense do you think the timber harvesting activity(ies) you selected above should be?

#	Answer	Bar	Response	%
1	Logging as the dominant activity on the island		1	1%
2	Logging at levels compatible to a multiple-use management plan		31	28%
3	Logging as a limited activity on the island		29	26%
4	No logging		44	39%
5	Other - Please Write		7	6%
	Total		112	

Other - Please Write
I did not select any type of timber harvest
Logging that helps local economy and helps keep the forest accessible to all - again very biased questioning
Others bring me wood
Would need more info
Selective logging for the health of the forest
Limited to beach harvest
Save our forests!

Statistic	Value
Min Value	1
Max Value	5
Mean	3.22
Variance	0.91
Standard Deviation	0.96
Total Responses	112

17. Do you collect firewood for your personal use?

#	Answer	Bar	Response	%
1	Yes		54	47%
2	No		61	53%
	Total		115	

Statistic	Value
Min Value	1
Max Value	2
Mean	1.53
Variance	0.25
Standard Deviation	0.50
Total Responses	115

18. If the U.S Forest Service allowed the collection of thinning byproducts from Kruzof Island for personal use, would you be interested in taking advantage of this opportunity?

#	Answer	Bar	Response	%
1	Yes		28	54%
2	No		24	46%
	Total		52	

Statistic	Value
Min Value	1
Max Value	2
Mean	1.46
Variance	0.25
Standard Deviation	0.50
Total Responses	52

19. If not, please describe why:

Text Response
Too far from home.
Too far to travel personally. However, I would patronize a local business which made a biomass product for home heating fuel.
We just use firewood for bonfires.
Use for commercial
Moving any amount of firewood even on a personal versus take special equipment impossible for most residents.
Easier to get to Baranof Island
It's too expensive to get it to Sitka from Kruzof when firewood can be found in town.
Elsewhere!
I will be 80 in February. Others may gather wood for me there.
I can collect my own. Do not need commercial logging on Kruzof.
Have our own sources
Do not have a boat.
Logistics - would need a big boat; hard to get to
Kruzof is special- and it's too far from Sitka- personal use wood could come from places closer to town.
There exist firewood opportunities closer to Sitka
I don't have a boat large enough to bring wood back. I would be interested in purchasing wood or cutting lots on Barnof Island.
Cost of transportation
Kruzof Island is too far away and access is by boat.
Too much work
Too far to transport economically
We collect very little firewood
Too far away- please make firewood available near town
too far

Statistic	Value
Total Responses	23

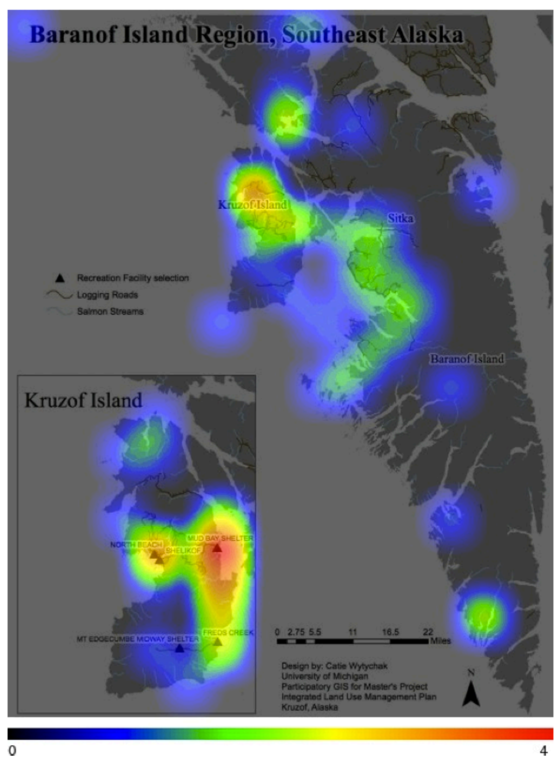
20. What is your race? Please mark one or more options below.

#	Answer	Bar	Response	%
1	White		92	81%
2	Black or African American		0	0%
3	Alaska Native - Please print name of Tribe or Tribal Group		12	11%
4	American Indian		4	4%
5	Asian Indian		0	0%
6	Chinese		0	0%
7	Filipino		0	0%
8	Japanese		1	1%
9	Korean		0	0%
10	Vietnamese		0	0%
11	Other - Please print race		3	3%
12	Choose not to disclose race		8	7%

Alaska Native - Please print name of Tribe or Tribal Group	Other - Please print race
Tlingit	
Tlingit Haida Inupiaq	
Tlingit	
Tlingit	
Kliuket	
Born in Cordooa, AK	
Tlingit	
Tlingit	
Sealaska	
	Spanish
	American
	Metis

Statistic	Value
Min Value	1
Max Value	12
Total Responses	113

21. We ask that you please click on any areas of the map that are of special importance to you. Such areas might include locations used for recreation, subsistence use, or for cultural or sentimental reasons. If you also currently harvest wood from Kruzof Island or other locations around Sitka, please indicate those areas as well. This information will be used to identify locations of future management priority.



Statistic	Value
Total Responses	11

22. Please briefly describe any reasons why a particular area that you indicated above is important to you. If possible, please provide the name of the location/area.

Text Response
Starrigavan Recreation Area - for day use picnicking, birding, wildlife viewing, hiking. South Baranof wilderness - for the importance of maintaining wild areas and intact wildlife/fish habitat; and the opportunity to enjoy primitive, wild recreation experiences away from day-to-day civilization. Sitka area trails - extremely important to keep up on maintenance of the high quality trail system in Sitka; with a limited road system, these nearby hiking opportunities are critical for allowing local residents to get out and be active, especially if you don't have a boat.
Hmmm. This is way too hard. You state at the beginning that the survey was about Kruzoff and then you throw most of Baranof Island on the map? Whoa! Slow down. There are way too many places on the whole island that I use for hiking, camping, fishing, etc.!!! I've marked the ones on Kruzoff: the Mud Bay and South Cabin corridor, Kalinin and Sea Lion Cove, Brent's Beach, and the Fred's Creek/Edgecumbe hike corridor.
Sport or subsistance fishing: Nakwasina Sound, Cape Edgecumbe, Vitskari Rocks, Starrigavin Bay, Salmon Lake, Redoubt Recreation: Nakwasina, Starrigavin, Salmon Lake/Creek, Blue Lake, Rodman Creek, Mud Bay, Iris Meadows, Shelikof Bay, Cross Trail
Gilmer Bay, fishing Mud Bay area, beach asparagus Freds Creek, spruce roots Plus I have highlighted areas of importance to Historic Sites I hope these areas of harvest are not published for all to go to...
Good deer hunting. Great camping.
Best hiking. Best hunting, best diving, best scenery
Fish from Redoubt, Silver Bay, Katlian Bay, Hiking on Kruzof, Goddard hot springs
It is home. All of it.
I hope you received lots of surveys, but it would have been nice to have a link from SCS and have the envelope preaddressed.
The cabin rental system is a unique and priceless gift to Sitkans. For those of us families with four-wheelers, it would be delightful to see more trails available to ride. We are very constricted here on our little island and families value play time and adventures with their kids.
Our family like Mud Bay-Shelikof and stays at the Shelikof cabin -> very peaceful/beautiful beach. Fred's Creek FS cabin is a good place to stay and hike up Mount Edgecombe or go hunting. Hiking Sea Lion cove trail is a fun day trip. Hunting Beaches around Inner Point are great.
We need to keep this area wild and only the addition of remote cabins could this area be better utilized by low-impact activities.
Most of my use is commercial fishing on outside of Kruzof. Hunting in starred area. Anchoring outside Kruzof.
I and my family use the Forest Service cabins at Fred's Creek, Brent's Beach, Shelikof Cabin, Sea Lion Cove also.
Use FS cabin that supports subsistence hunting activities. Hiking trails of exceptional value.
Camping, subsistence fishing, wildlife observation, seaweed gathering, beach picnics, hot springs
Sentimental, subsistence, recreation, hiking, boating, fishing, camping!! I use the cabins and shelters at least 2 times per year. Beachcombing, collecting beach asparagus, skiing, hunting, birdwatching on starred locations.
I am not being funny putting a star over the entire region: ALL is of importance, whether or not I or mine use or it simply exists in the world. Chaos theory -> micro events can lead to macro consequences.
Subsistence Use- Hunting
Mud Bay to North Beach and Shelikoff used primarily to deer hunt, trap, and for recreational ATV riding. Fred's Creek to camp out and walk trail up Mt. Edgecombe. Great trout fishing in creek next to Fred's cabin. Other starred areas to harvest fish and deer hunt. Brant's beach cabin to harvest clams and deer hunt.
The starred areas are important fishing or hunting areas for our family.
It would be nice to have a place to tie up a boat (float, dock).
I starred fishing and hunting places. We NEED firewood in Sitka.
We use and enjoy every navigable waterway (and hunt, fish, gather as appropriate) from Sitka to Still Harbor, through Salizbury Sound, West Chichagod Island, Hannah Sound, Rodman Bay, and everywhere in between. There are way too many special places we use and love to provide details.
Recreation or subsistence.
Best use economics based on sound ecological considerations. Promote Aldo Leopold's conservation ethics philosophy.
Hiking, hunting, skiing, biking
Brent's Beach, annual camping Schoal's Point, Annual beachcombing Trail up Mount Edgecombe, annual Hike to Sea Lion cove
It's pretty darn special, to be honest.
Sea lion cove for camping. Mud Bay roads for mountain biking. East and southeast beaches for camping and exploring.

Statistic	Value
Total Responses	30

1B. Full Supplementary ATV Survey Results

Survey Number	Where are you from?	How often do you visit Kruzof for recreational activities?	How long do you typically stay?	What activities attracted you to the island? (If multiple, please rank from 1-4)	What are the areas of Kruzof you most often visit while doing these activities?	How did you get to Kruzof Island?	What was your access point?	How many people are in your group?	Do you know who manages Kruzof Island?	How did you first hear about Kruzof Island?
1	Sitka or Southeast Alaska (a)	5-10 times per year (d)	one day (a)	Hiking, ATV riding, hunting (a,b,c,)	More east-side than west-side	On my own boat (c)	Mud Bay	2	Forest Service	Found on own (d)
2	Sitka or Southeast Alaska (a)	5-10 times per year (d)	one day (a); a weekend (b)	Hiking, hunting	Sea Lion Cove, South Kruzof	On my own boat (c)	Mud Bay	2	USFS and State of AK	A HS friend had a job logging on Kruzof with a company back in 1973
3	Sitka or Southeast Alaska (a)	1-5 times per year (c)	A weekend (b)	Hiking, wildlife viewing/birdwatching	Shelikof, South Kruzof, Freds Creek	On my own boat (c)	Mud Bay, Fred's Creek, South Kruzof	6	USFS	Grew up here
4	Sitka or Southeast Alaska (a)	1-5 times per year (c)	3-7 days (c)	Hiking, Atv riding, camping	N/A	On my own boat (c)	Mud Bay	3	USFS	N/A
5	Sitka or Southeast Alaska (a)	1-5 times per year (c)	A weekend (b)	All	Iris Meadows, North Beach	On a charter or tour boat (a)	Mud Bay	1	Forest Service	A friend or family member (a)
6	Sitka or Southeast Alaska (a)	1-5 times per year (c)	A weekend (b)	Hiking, Hunting, Camping	Shelikof	On your own boat (c)	Mud Bay	4	Forest Service	Because she lives here?
7	Sitka or Southeast Alaska (a)	1-2 weeks (e)	A weekend (b)	Atv riding	North Beach & pits	On your own boat (c)	Mud Bay	2	Forest Service	A friend or family member (a)
8	Sitka or Southeast Alaska (a)	1 every 2 years	One day (a)	Atv riding, wildlife viewing	North Beach	On your own boat (c)	Mud Bay	5	F.Service	A friend or family member (a)
9	Sitka or Southeast Alaska (a)	1-5 times per year (c)	3-7 days (c)	Atv riding, hunting	N/A	On your own boat (c)	Mud Bay	2	F.S.	Found on own (d)
10	Sitka or Southeast Alaska (a)	2x per year	One day (a)	Hiking, Atv riding	Shelikof	On your own boat (c)	Mud Bay	7	F.S.	Always (e)
11	Sitka or Southeast Alaska (a)	10X per year	A weekend (b)	Atv riding	North Beach	On your own boat (c)	Mud Bay	2	Don't know	Have been going since young
12	Sitka or Southeast Alaska (a)	10x	3-7 days (C)	Atv riding	North Beach, the pits	On your own boat (c)	Mud Bay	2	Forest Service	Has been going here since young
13	Sitka or Southeast Alaska (a)	1-5 times per year (c)	A weekend (b)	Hiking, Atv riding	Shelikof, Fred's Creek, Brutz Creek	On your own boat (c)		3	Forest Service	Work and razor clam digging

What do you perceive to be the most important mission of the USFS?	Do/have you had any interactions with the USFS while on Kruzof Island?	What do you think should be the management priority while on Kruzof Island?	Which of the below activities do you think brings in the greatest amount of revenue on Kruzof Island?	What do you see as the greatest risk to the sustained health of Kruzof Island's Ecosystem, if any?	Would you like to see any of the following changes to Kruzof Island? If yes, number in order or write in	In what areas or at what points on Kruzof would you most like to see these changes?	Have you ever harvested timber? YES/NO please circle one:	If yes, for what purpose? Please circle one: commercial use/subsistence use/other:	From where in Sitka area did you/do you harvest?	Would you support some level of timber harvest on Kruzof Island?	If yes, what type of timber harvest would you support on Kruzof Island? Place an X by all that apply	What intensity of timber harvest would you support on Kruzof Island?
Manage federal lands for multiple uses. Restore logging-damaged areas.	General information (d) (met stream restoration group this trip)	a-d	annual salmon harvesting (b)	N/A	1 - better habitat or restoration	N/A	Yes	Personal subsistence timber use	Lower Baranof Island	Yes	selective young-growth commercial harvest	Logging as a limited activity (c)
Recreational, multi-use, subsistence, and small-scale commercial logging	No, not recently	N/A	recreation activities (c)	4-wheelers and global warming	Other - maintain trail to Shelikof Cabin (trail brushing)	N/A	Yes, not on Kruzof	Subsistence use	N/A	Yes	Subsistence harvest; other: alder firewood/biomass	Logging as a limited activity (c)
Maintaining the boundaries of ATV use and hikers	helped do maintenance (e)	Providing and maitaning multiple-use trails (b)	recreation activities (c)	If they were to log it again	Better signage (trail to Shelikof); better habitat restoration or preservation	Shelikof sign, mile markers, preservation of North Beach	No			No, has not gone well historically	Subsistence on occasion	No logging
Maintaining for recreation	Yes (did not describe)	Scenic hiking trails and multiple use trails (a,b)	recreation activities (c)	No risj	1- Improved trail system; 2- Additional visitor amenities (bathroom)	N/A	No	N/A	N/A	No	N/A	Logging as a limited activity (c), No logging (d)
Forest Management	Yes, while working	Protecting fish and wildlife, restoring.maintaing habitat (c)	Recreation activities (c)	Logging	Better habitat restoration or preservation	North Beach	No	N/A	N/A	Yes	Subsistence harvest	No logging
Management for multiple uses, recreation, steam restoration (moving from timber sales, thinning)	Yes, worked for them (friends also worked for them)	Protecting fish and wildlife, restoring.maintaing habitat (c), integrating human use	annual salmon harvesting (b)	Tourism (ATV and hunting bears), logging	Better intepretaive signage and trail maps/markers	N/A	No	N/A	N/A	Yes	Young growth (thinning left over)	No logging
"Close off all the fun places"	Yes	Providing and maitaning multiple-use trails (b)	Logging and timber sales (a) PAST/Recreation activities (c) CURRENT	Trash	Improved trail system (and more ATV trails); Better interpretative signage	(maps at trail heads)	Yes	Subsistence us	North Beach	Yes	Subsistence harvest	No logging
Maintaining trails	No	Managed timber harvest (d)	Recreation activities (c)	N/A	Better landing	Mud Bay	No	N/A	N/A	Yes	Selective harvest for commercial biomass; clear cut in some areas	Logging at levels compatible with a multiple-use plan
To allow access and keep resources and in good shape	Yes, just spoke with them	scenic hiking trails and multiple use trails (a,b)	recreation activities (c)	No risk (little impact from ATVs)	No water bars/a dock	Mudbay - dock	No	N/a	N/A	Yes	selective old-growth and young-growth commercial harvesting	Logging at levels compatible with a multiple-use plan
Keep things open for recreation and logging someday	No	scenic hiking trails and multiple use trails (a,b)	Logging and timber sales (a) PAST	Volcano	Dock	Mud Bay	No	N/A	N/A	Yes	selective old-growth and young-growth commercial harvesting, along with selective harvest for commercial biomass	Logging at levels compatible with a multiple-use plan
Protection	Yes, seen doing stream surveys	Multiple use-trails (b)	Recreation activities (c)	None	Improved trail system (and more ATV trails); Better interpretative signage	A trail down Shelikof would be cool	No	N/A	N/A	Yes	Selective old-growth commercial and subsistence harvest	Logging as a limited activity (c)
Keep Kruzof open	Yes, general infomation	Multiple use-trails (b)	Recreation activities (c)	None	Improved trail system	Old logging roads	No	N/A	N/A	Yes	Old-growth clear-cut commercial harvest	Logging at levels compatible with a multiple-use plan
Multiple use	Yes	Multiple use-trails (b)	Recreation activities (c)	Past logging methods; ATV in areas	Maintain trails & cabins	N/A	No	N/A	N/A	Yes	selective harvest for commercial biomass	multiple use and limited activity

1C. Detailed Subsistence Calendar

Location & Timing of Subsistence Activities		Baranof Island & Surrounding Areas											Kruzof Island & Surrounding Areas												
Month	Activity	Shoals Point	False Island	Peril Strait	Kasiana Islands	Silver Bay	Indian River	Nakwasina Sound	Krestoff Sound	Sitka Sound	Redoubt Cove	Redoubt Falls	Southern shoreline of Kruzof	Eastern Half of Kruzof	Kalinin Bay	Magoun Islands	Hayward Point	Sinitsin Cove	Sea Lion Cove	Shelikof Beach	Shelikof Bay	Fred's Creek	Brent's Beach	North Beach	Mud Bay
January	Mushroom Gathering																								
January	Berry Picking																								
January	Deer hunting									✓				✓											
January	Trapping																			✓	✓				
January	Beachcombing																								
January	Camping																								
January	Fishing																								
January	Kelp, Beach Asparagus, Seaweed Gathering																								
February	Mushroom Gathering																								
February	Berry Picking																								
February	Hunting									✓															
February	Kelp, Beach Asparagus, Seaweed Gathering																								
February	Trapping																			✓	✓				
February	Camping																								
March	Kelp, Beach Asparagus, Seaweed Gathering																								
March	Gathering Spruce Roots																								
March	Camping																								
March	Hiking																								
March	Firewood Gathering																								
March	Trapping																			✓	✓				
March	Shellfish gathering Clams, Scallops)																							✓	
March	Collecting Roe									✓				✓											
March	Fishing																							✓	
March	Hunting									✓														✓	
April	Kelp, Beach Asparagus, Seaweed Gathering														✓										
April	Camping																								✓
April	Hiking																					✓	✓		✓
April	Hunting									✓														✓	✓
April	Gathering Spruce Roots and Tips																								
April	Collecting Shellfish (scallops)																							✓	
April	Berry Picking																								
April	Mushrom Gathering																								
April	Firewood Collection																								
April	Collecting Roe									✓				✓											
May	Kelp, Beach Asparagus, Seaweed Gatherings								✓						✓										
May	Gathering Spruce Roots and Tips																				✓				
May	Shellfish Gathering (clams, scallops)																							✓	
May	Camping																								✓
May	Hiking																					✓	✓		✓
May	Hunting									✓														✓	✓
May	Fishing									✓					✓									✓	
May	Beachcombing																								
May	Collecting Roe													✓											

Location & Timing of Subsistence Activities

June

Area	Location	Kelp, Beach Asparagus, Seaweed Gathering	Camping	Hiking	Berry Picking	Fishing (Halibut, Sockeye Salmon)	Beachcombing	Hunting	Crabbing	Gathering Spruce Tips
Kruzof Island & Surrounding Areas	Mud Bay		✔	✔				✔		
	North Beach					✔		✔		
	Brent's Beach			✔						
	Fred's Creek			✔						
	Shelikof Bay									✔
	Shelikof Beach		✔							
	Sea Lion Cove			✔						
	Sinitsin Cove									
	Hayward Point	✔								
	Magoun Islands	✔								
	Kalinin Bay	✔				✔				
	Eastern Half of Kruzof									
	Southern shoreline of Kruzof									
Baranof Island & Surrounding Areas	Redoubt Falls					✔				
	Redoubt Cove									
	Sitka Sound					✔				
	Krestoff Sound	✔								
	Nakwasina Sound									
	Indian River									
	Silver Bay									
	Kasiana Islands	✔								
	Peril Strait									
	False Island									
	Shoals Point									

July

Area	Location	Berry Picking	Mushroom Gathering	Camping	Hiking	Kelp, Beach Asparagus, Seaweed Gathering	Fishing (Coho & Sockeye Salmon, Halibut)	Beachcombing	Hunting
Kruzof Island & Surrounding Areas	Mud Bay			✔	✔				✔
	North Beach						✔		✔
	Brent's Beach				✔				
	Fred's Creek				✔				
	Shelikof Bay			✔			✔		
	Shelikof Beach			✔					
	Sea Lion Cove				✔				
	Sinitsin Cove								
	Hayward Point								
	Magoun Islands					✔			
	Kalinin Bay						✔		
	Eastern Half of Kruzof								
	Southern shoreline of Kruzof								
Baranof Island & Surrounding Areas	Redoubt Falls								
	Redoubt Cove								
	Sitka Sound						✔		
	Krestoff Sound	✔	✔			✔			
	Nakwasina Sound	✔	✔						
	Indian River	✔	✔						
	Silver Bay								
	Kasiana Islands					✔			
	Peril Strait								
	False Island								
	Shoals Point								

August

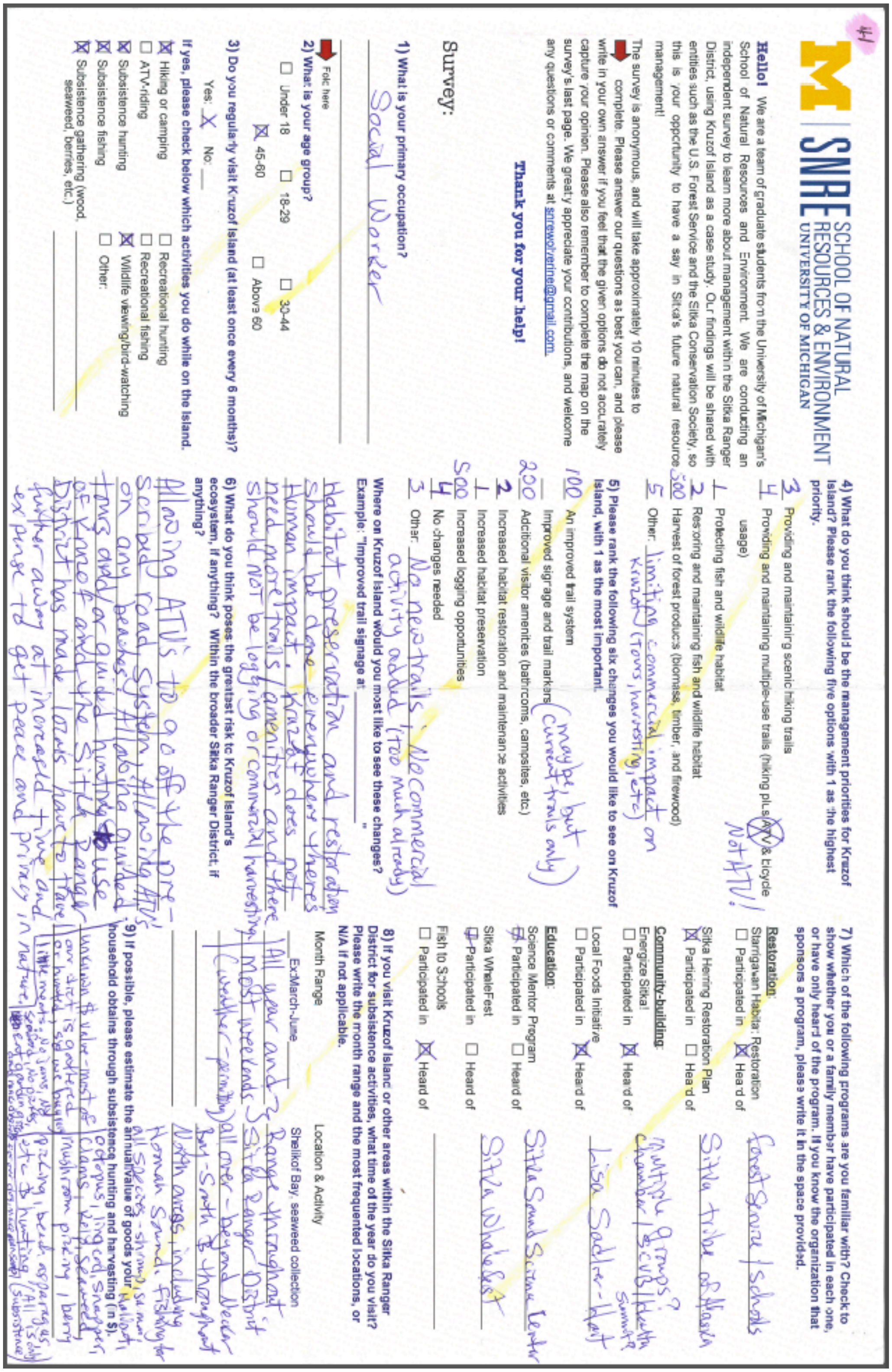
Area	Location	Mushroom Gathering	Berry Picking	Kelp, Beach Asparagus, Seaweed Gathering	Hiking	Camping	Hunting	Fishing (Halibut & Coho Salmon)	Hunting	Beachocmbing
Kruzof Island & Surrounding Areas	Mud Bay				✔	✔			✔	
	North Beach						✔	✔		
	Brent's Beach				✔					
	Fred's Creek				✔					
	Shelikof Bay							✔		
	Shelikof Beach					✔				
	Sea Lion Cove				✔					
	Sinitsin Cove								✔	
	Hayward Point									
	Magoun Islands									
	Kalinin Bay									
	Eastern Half of Kruzof						✔		✔	
	Southern shoreline of Kruzof									
Baranof Island & Surrounding Areas	Redoubt Falls									
	Redoubt Cove									
	Sitka Sound							✔	✔	
	Krestoff Sound	✔	✔	✔						
	Nakwasina Sound	✔	✔							
	Indian River	✔	✔							
	Silver Bay									
	Kasiana Islands									
	Peril Strait			✔						
	False Island									
	Shoals Point									

September

Area	Location	Kelp, Beach Asparagus, Seaweed Gathering	Gathering Spruce Roots	Deer Hunting	Duck Hunting	Fishing (Halibut, Salmon, Shrimp)	Camping	Hiking	Mushroom Gathering	Berry Picking
Kruzof Island & Surrounding Areas	Mud Bay			✔			✔	✔		
	North Beach			✔		✔				
	Brent's Beach							✔		
	Fred's Creek							✔		
	Shelikof Bay									
	Shelikof Beach									
	Sea Lion Cove									
	Sinitsin Cove			✔	✔					
	Hayward Point									
	Magoun Islands									
	Kalinin Bay			✔						
	Eastern Half of Kruzof			✔	✔					
	Southern shoreline of Kruzof									
Baranof Island & Surrounding Areas	Redoubt Falls									
	Redoubt Cove									
	Sitka Sound			✔		✔				
	Krestoff Sound			✔	✔				✔	✔
	Nakwasina Sound								✔	✔
	Indian River								✔	✔
	Silver Bay								✔	
	Kasiana Islands									
	Peril Strait	✔		✔						✔
	False Island									
	Shoals Point			✔						

Location & Timing of Subsistence Activities		October								November							December				
		Berry Picking	Mushroom Gathering	Fishing (Halibut, Salmon)	Deer Hunting	Duck Hunting	Hiking	Camping	Beachcombing	Deer Hunting	Hiking	Camping	Trapping	Duck Hunting	Berry Picking	Fishing (Halibut, Salmon)	Deer Hunting	Duck Hunting	Shellfish Gathering	Hiking	Beachcombing
Kruzof Island & Surrounding Areas	Mud Bay				✔		✔	✔													
	North Beach			✔	✔																
	Brent's Beach						✔														
	Fred's Creek						✔														
	Shelikof Bay									✔			✔	✔			✔	✔			
	Shelikof Beach												✔								
	Sea Lion Cove																				
	Sinitsin Cove				✔					✔				✔							
	Hayward Point																				
	Magoun Islands																				
	Kalinin Bay																				
	Eastern Half of Kruzof				✔					✔											
	Southern shoreline of Kruzof																				
Baranof Island & Surrounding Areas	Redoubt Falls																				
	Redoubt Cove																				
	Sitka Sound			✔	✔					✔						✔	✔				
	Krestoff Sound	✔	✔			✔								✔				✔			
	Nakwasina Sound	✔	✔																		
	Indian River	✔	✔																		
	Silver Bay																				
	Kasiana Islands																				
	Peril Strait																				
	False Island				✔					✔							✔				
	Shoals Point				✔					✔											

1D. Image of Primary Survey



Chapter 2 | Assessment of Habitat Restoration

Shelikof and Starrigavan Creek

Kruzof Island & Baranof Island, Southeast Alaska

Restoration Team Members: Sisimac Duchicela, Nathan Jacobson, Gwen Oster, Catherine Wytychak

I. Introduction

After clear-cut harvesting occurred in 1968 throughout regions of the Tongass National Forest in Southeast Alaska, the forest began its natural succession. Forests in Southeast Alaska are characterized by having high frequency, low magnitude disturbances that lead to very complex, uneven aged stands. In this case, because the forest was allowed to regrow naturally, it resulted in an even aged stand in the stem-exclusion phase (Brady & Hanley, 1984). The disturbance caused by clear-cut harvest practices had high ecological impacts, not only to the forest but also to the stream. Streams were physically harmed during the clear-cut harvest because they were used to transport the timber from the forest. These impacts continued to be observed long after harvesting was completed due to a loss of large woody debris and increased channel instability and erosion. The combined ecological damage and social pressure motivated the USFS to begin restoration practices in the 1980s. Our study aims to assess the long term impacts of clear-cut harvesting practices and evaluate the success of restoration projects.

Research Questions

1. *Are there lasting impacts from the clear-cut harvest of 1968?*
2. *Can we see measurable improvements from the 1980 restoration projects?*
3. *What restoration protocols should be changed, added, or enhanced?*

From the community engagement portion of our report, we found that there is widespread support for restoration practices to improve the overall ecosystem health. Overall ecosystem health is critical to support subsistence hunting, fishing, and firewood harvesting. Sitka black tailed deer, *Odocoileus hemionus sitkensis*, are widely hunted and constitute a large portion of survey respondent's livelihood (see the participatory GIS map in Appendix 2A). Additionally, the Sitka black tailed deer populations are considered an important ecological indicator (Hanley, 1993). For this region, deer are not considered a threat like they are in many other states.

Removal or disturbance of riparian vegetation, which has occurred during clear-cut timber harvest at many sites on Kruzof and Baranof Islands, has the potential to alter various aspects of the riparian zone and adjacent stream. Possible impacts on the riparian zone include a decrease in plant and animal diversity, loss of food and habitat, change in forest composition and age structure, disruption of nutrient cycling, increase in soil instability, and an overall decline in forest health. Possible impacts to the health and functioning of the stream can include changes in the amount of shading, water temperature, stream bank instability, allochthonous inputs, groundwater/surface water interactions, water quality, and habitat conditions. Potential habitat condition changes can include loss of large woody debris, increase in fine sediment, changes in the ratio of pools and riffles, and alterations in the width and depth of the channel. Large wood is beneficial in that it provides habitat and cover for fish and macroinvertebrates, adds complexity (pools, riffles, etc.) to the channel, alters channel morphology, and traps sediment (Washington Department of Fish and Wildlife, 2009). Overall, disturbances in the riparian zone have the potential to cause a wide array of negative consequences to the overall health of a stream and its riparian zone, focusing in this particular study on the effects of timber harvests.

In order to scientifically determine the impacts of timber harvest on riparian and stream health, and assess the success of subsequent ecological restoration efforts, quantitative monitoring is needed. Unfortunately, due to a lack of time and money, adequate monitoring data is normally scarce or nonexistent. Additionally, when projects do monitor restoration or disturbance events, they tend to only assess the areas after these events have occurred by collecting post-restoration data. Pre-restoration data is a crucial element of monitoring restoration success, yet is not available for most projects. It sets a baseline to compare to post-restoration data, which allows goals and objectives to be quantitatively determined, provides information about the potential for the site, informs what type of restoration work should be conducted, and can be used to assess success by determining the degree of change in specific metrics or overall quality after restoration efforts (Borgmann et al., 2007). Pre-restoration data collection also provides a template for monitoring that can be reproduced using the same methods of data collection and analysis after restoration, ensuring that the values can be truthfully compared. Overall, it is important to understand that ecological monitoring data, both before and after restoration work or disturbance, is a powerful tool for determining past impacts, assessing restoration success, and advising future work and management.

In order to monitor restoration success and the impact of past timber harvest we utilized a rapid bioassessment approach to monitoring. This can be defined as a quick, inexpensive, and integrated method for assessing the quality of an area based on the collection of habitat, water quality, and biological samples (Barbour et al., 1998). Measuring biological health is a valuable aspect of monitoring because the biology of an area is impacted by many variables/stressors and thus displays the aggregate impacts. Thus, bioassessments integrate multiple stressors, including pollutants, nutrients, temperature, and sedimentation, to generate a direct measure of biological health over time (Rinella et al., 2005). The results of rapid bioassessments can be utilized in a variety of ways, including setting baseline conditions, identifying stressors, prioritizing areas for future testing, assisting in management decisions, and detecting areas in need of restoration or protection (ENRI, 2004). Rapid bioassessment protocols were developed due to the need for cost-effective biological surveys in the 1980's due to diminishing monitoring resources, massive amounts of unassessed stream miles, and the need to rapidly collect and analyze data in order to inform management decisions (Barbour et al., 1998). They have since become a valuable component of the ecological toolkit.

To ensure that monitoring continues to be conducted around Sitka in the future, it is important that the methods that are chosen utilize fairly simple yet effective techniques. This is crucial because it allows the monitoring to be carried out by students, volunteers, or entry level scientists, which greatly increases the chances of the monitoring being conducted multiple times for each site. Until greater amounts of funding are allocated for monitoring for all restoration projects, utilizing volunteers and students to monitor sites is one of the best ways to obtain data. Additionally, incorporating students and volunteers in projects provides them with a sense of worth, is a great teaching tool, allows hands-on experience in science, teaches about local and regional ecological issues, and increases their involvement in protecting the local environment, which hopefully leads to them being better stewards of nature (ENRI, 2004).

Indicator Metrics

Width to Depth Ratio: The width to depth ratio determines the cross sectional channel shape of a stream. This, in turn, determines the maximum cross sectional flow that can be transported through a system. In general, width to depth ratio provides an indicator of habitat quality, as the width and depth of a channel influences fish spawning and rearing. The width to depth ratio can also be used to indicate if erosion or aggravation is occurring in the channel, which is important since channel form, pattern, and fine sediment are key factors affecting fish habitat. Width to depth ratio measured as the ratio of the width of the wetted channel to depth of water at the determined riffle cross-section.

Woody Debris: In small streams, LWD is a major factor influencing pool formation in plane–bed and step–pool channels. The main role of key wood in a stream includes stabilizing the stream channel and strongly influencing the deposition and transport of other pieces of large woody debris, thereby creating a debris jam. All of the types of woody debris in the bankfull width of the stream, within the designated reach, were noted. The types are fallen log, log complex, brush, and/or overhanging vegetation. It did not matter the quantity of each of these types, just whether they are present.

Benthic macroinvertebrates: An increasingly important aspect of aquatic rapid bioassessments and biological monitoring is the collection of benthic macroinvertebrate data. Benthic macroinvertebrates are the small animals, large enough to be seen with the naked eye but without a backbone, that live amid the substrate, debris, and aquatic plants on the bottom of streams, rivers, and lakes. They are great indicators of stream health and water quality since they show the cumulative impacts of contaminants and habitat alterations over a relatively long time frame. In comparison, other standard measures of water quality, such as samples measuring temperature or dissolved oxygen concentrations, tend to be snapshots of what is currently occurring in the stream at the second the sample is collected, which can be deceiving. Additionally, macroinvertebrates are used as indicators due to the fact that they are plentiful in most streams, are easily and inexpensively collected and analyzed, have a range of tolerances, tend to be relatively sedentary, and reflect the health of both primary producers and fish due to the linkage in the food chain.

The focus of many macroinvertebrate analyses is the number and proportion of EPT orders. EPT refers to the three macroinvertebrate orders that are generally intolerant of pollution and thus indicators of good stream health: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). While a lot of focus is put on identifying EPT orders, it is still important to identify and consider other orders that aren't EPT because they tend to indicate poorer water quality due to their general tolerance of pollution (ENRI, 2004). There are many benthic macroinvertebrate metrics that can be chosen to assess habitat quality, which is why benthic macroinvertebrate multimetric indices have been created and calibrated in many places across the United States. These indices provide scientifically rigorous and quantifiable methods for analyzing macroinvertebrate data (Rinella et al., 2005). Based on these reasons, macroinvertebrate collection and analysis is one of the main methods that was utilized in this study to assess and compare the water quality of different sites.

Substrate size: The size of the substrate/sediment in a stream plays a vital role in determining the quality of habitat for fish and other stream biota by affecting water quality, cover, refuge from high velocity water, prey habitat, and spawning and rearing surfaces (Daniels & McCusker, 2010). The fact that salmon spawn on the substrate and macroinvertebrate prey live in the substrate means that fish habitat quality is directly tied to the size of substrate particles. Two of the most relevant measures of substrate size for fish quality include overall size (mean and median) and percentage of fine particles. Overall size is useful for describing the availability of particles large enough for successful spawning. Additionally, substrate size has been experimentally shown to be correlated to the size of fish (Keeley & Slaney, 1996). Scientifically collected data and expert opinion support the conclusion that a conservative estimate of the preferred substrate size for salmonid spawning is between 13 and 128 mm, and that greater than 50% of particles should fall within this range to provide suitable spawning habitat for salmonids (Klein et al., 2007).

Fine sediment, which are the smallest particles (<2 mm or <6 mm wide), also play a crucial role in the quality of habitat for fish. Many studies have supported the conclusion that the presence of excessive amounts of fine sediment harms fish habitat by negatively impacting prey and egg health (Chapman, 1988; Keeley & Slaney, 1996; Kondolf, 2000). Fine sediment clogs the interstitial spaces between larger substrate particles, decreasing habitat available to macroinvertebrate prey and preventing adequate flow of water and oxygen from reaching buried fish eggs. Additionally, fine sediment has been shown to increase in areas impacted by erosion, timber harvest, and road construction, further justifying the use of this metric in assessing the impact of timber harvest and subsequent restoration work (Kondolf, 2000). These land uses increase the amount of fine sediment in streams by disrupting soils, removing vegetation that holds soil in place, increasing the amount of overland water flow and runoff, and causing erosion and possibly landslides (USDA Forest Service, 2006). Data suggests that less than 14% of substrate at a specific site should be smaller than 2 mm in size and less than 20% should be smaller than 6 mm in order to provide adequate oxygen availability for salmonid incubation and emergence (Klein et al., 2007). All of the above metrics of substrate size can be fairly easily collected and calculated by students and professionals using Wolman pebble count methods (Wolman, 1954), providing valuable quantitative data that can be used to assess the impacts of disturbances and the success of restoration efforts for stream biota.

Forest Structure: Old growth forests are distinguishable by their complex, heterogeneous structure, otherwise known as uneven aged stands. Forests that have experienced large scale disturbances, like clear-cut harvesting, often regrow a homogenous, even aged stand. To assess if there are long term impacts of the past harvesting methods, we measured the size and abundance of understory and overstory trees in the riparian zone. An uneven aged stand has many more sapling and understory species than the next size classes. An even aged stand has less saplings and understory species than mid-sized trees. Forest structure is important in determining if a stand is an even aged stand and in the stem exclusion phase. The stem exclusion phase occurs when the overstory is so dense that the understory doesn't receive enough light to grow sufficiently. Without a strong understory, a forest's long term health is jeopardized. Additionally, if a dense shrub population can't grow because the forest is in stem exclusion, then there is insufficient food for deer during the winter months. Subsequently, when deer populations suffer, subsistence hunters are similarly impacted.

Forest Composition: Species found in a forest can be indicators of elevation, soil nutrient richness, water availability and/or disturbance. We are interested in using species composition as an indicator of lasting impacts from disturbances. An early successional species, alder is often found where disturbances have occurred (Malcom, 2001). All alder species are nitrogen fixers and are considered to increase understory regeneration through soil enrichment (Batzli & McCray, 1998). To assess if there are long term impacts of the timber clear-cut harvest, we quantified the abundance of species in the understory and overstory of the riparian zone.

Standing and Fallen Dead Wood: Snags and fallen deadwood are considered important factors that contribute to the functioning of a forest. Because of its direct contributions to wildlife habitat, it is also used as an indicator of biodiversity. For example, snags are particularly important for nesting habitat for birds (Zarnoch et al. 2014). Additionally, saproxylic organisms use fallen deadwood in some part of their life-cycle. It also plays a key role in nutrient cycling and ecosystem functioning (Laussauce et al. 2011).

For this reason deadwood volume has been used by some authors as an appropriate indicator for biodiversity in a forest and for forest management suitability (Rondeux & Sanchez, 2010).
In terms of their role in the structure of the forest, it is often a way to measure habitat quality and to characterize old-growth forests (DeLong et al. 2008). When the successional process of a forest is free of silvicultural activities, natural disturbances drive the forest to develop complex stand structures (Lombardi et al. 2012). Therefore deadwood in this case, functions as an indicator to characterize an old-growth forest (Peterken, 1996) and is recognized to be one of the most common components of an old-growth forest (Siitonen et al. 2000).

These indicators were used to characterize the overall quality and health of the riparian and aquatic zones of the two sites, Shelikof Creek and Starrigavan Creek. To answer the research questions proposed in this study different sections of each creek were assessed. Because restoration in Shelikof Creek has recently begun, the goal for this site was to obtain baseline data for the monitoring plan. For this site, data from a disturbed section of the stream was obtained, which would provide information on the starting point of the forest without restoration, and from a non-disturbed section of the stream, which would provide data on the reference characteristics of an old-growth forest in this area. In Starrigavan Creek, because there was an area that had been disturbed and then restored, obtaining data on the indicators for this site as well as a disturbed not restored and a non-disturbed site would provide information on the effects of the restoration. This approach describes the trajectory of the succession of a forest system after it has been clear-cut.

II. Background

A. Study Site: Shelikof Creek on Kruzof Island, Alaska

Shelikof Creek is located on Kruzof Island, 15 miles northwest of Sitka within the Tongass National Forest of Southeast Alaska. Ninety eight percent (98%) of Kruzof Island's 89,221 acres is managed by the Sitka Ranger District of the Tongass Forest Service with the remaining portion designated as a State Marine Park. The eight miles of Shelikof Creek are primarily located within the Iris Meadows watershed and drain west to the Pacific Ocean. Throughout Iris Meadows and the surrounding watersheds, 6,473 acres were clear-cut harvested by the United States Forest Service in 1968 (USDA Forest Service, 2013). Timber harvest efforts were concentrated around logging roads and creeks for ease of transportation *(see Appendix 2A)*. The majority of riparian land to the north and south of Shelikof Creek was clear-cut harvested, however, two stretches of land were not disturbed due to the presence of a mire that would have hindered transportation between the stream and road *(see Appendix A)*.

The Iris Meadows watershed has been identified by the Forest Service as a priority for protection and restoration in the Kruzof Island Inventory and Watershed Action Plan (USDA Forest Service, 2013). Through a survey of public perceptions, the Sitka Conservation Society identified Iris Meadows as the third prioritized location for restoration in the Sitka Community Use Area (Harris, 2013). The area is identified as a restoration priority by both the surveyed public and the Forest Service because of the ecological degradation caused by clear-cut harvesting.

Clear-cut harvesting caused vegetation to grow at the same rate until the stem exclusion phase. The stem exclusion phase occurs when a large scale disturbance forces all species, in this case Hemlock, Spruce, Alder and Oak, to grow simultaneously until their canopies become so dense that no sunlight can penetrate to the understory. Since the forest canopy is closed to light penetration, the understory and groundcover is nearly nonexistent in the most extreme cases. Additionally, the high density of even-aged stands causes enough competition for light, nutrients and space that very few of the adult trees reach their largest size class (Lieffers et al., 1999).

Without persistent understory and groundcover vegetation throughout the winter, the available food source for deer is reduced. A secondary effect in riparian zones experiencing the stem exclusion phase includes the lack of large old growth that falls into streams, creating pools and meanders. Without meanders, a stream will flow at a faster rate and without pools, there are fewer slow moving zones. Each of these factors negatively affect fish habitat by altering sediment size and position in the stream, changing nutrient deposition and increasing turbidity (Martin & Grotefendt, 2007).

In an ecosystem where large-scale disturbances like clear-cut harvesting haven't occurred, small disturbances such as windfall will create small gaps in the canopy to allow for understory growth and a varied forest canopy structure. This varied forest canopy will allow for species like *Vaccinium* to persist throughout the winter, creating healthy habitats for wildlife. Without the density that occurs during stem exclusion phase, adult trees have enough resources to grow to their largest size class. These large trees provide ecosystem services such as habitat for wildlife.

In undisturbed habitat, aquatic characteristics are affected because large woody debris naturally falls into the stream, providing needed pools, riffles and in some cases, meanders. Pools are important habitat for juvenile fish and meanders help slow down a stream. A slow stream causes less bank erosion, is better wildlife habitat and allows for deposition of sediments into substrate (Martin & Grotefendt, 2007).

Varied forest structure and resulting ecosystem services are important for those who practice subsistence fishing, hunting and timber harvesting. The Iris Meadows watershed and Shelikof Creek are recognized as valuable ecological locations to sustain these subsistence practices. To improve ecological integrity, the Forest Service plans to restore Shelikof Creek by improving wildlife habitat characteristics through the addition of large woody debris and meanders to the stream. Forest gaps are added to areas where the forest has reached the stem exclusion phase and thinning is practiced to open the riparian canopy alongside Shelikof Creek.

Field research conducted in June of 2014 by the University of Michigan Master's team gathered baseline data comparing the undisturbed riparian and stream stretch to the disturbed riparian and stream stretch. Our analysis compares the two locations in terms of forest structure, species composition, spatial arrangement, stream structure, water quality and habitat quality. To scientifically monitor the impact of the planned restoration, our data will provide a reference condition that the restored stretches should eventually replicate. To ensure that restoration efforts are monitored and evaluated for success and opportunities for improvement, a monitoring plan is proposed by the Master's team.

B. Study Site: Starrigavan Creek on Baranof Island, Alaska

The Starrigavan Creek watershed encompasses approximately 4,097 acres of the northern portion of Sitka Sound, about 7 miles north of downtown Sitka on the northern end of the city's road system. This 3,644 acre watershed Analysis Area is federally owned and managed by the Sitka Ranger District of the Tongass National Forest while the remaining 453 acres is managed under jurisdiction by the State of Alaska. Dating back as far as 5,000 years ago, this area was used for subsistence by the first native people. In the late 1700's, Russians established their first settlement near the mouth of Starrigavan Creek. At the start of the 1970's, the Forest Service managed timber production within the Analysis Area (USDA Forest Service, 2007). Today, residents likewise use the watershed for subsistence use and provision of natural resources.

Approximately 739 acres within the Analysis Area have been harvested for timber. As a result of clear-cut harvesting occurring over 30 years ago, the forest has reached a stem exclusion phase. The stem exclusion phase is characterized by a dense overstory that shades out understory growth. To open the canopy, thinning activities on a small portion of the Analysis Area have taken place. In 1995, 20 acres of dense, alder dominated, second-growth riparian stands were thinned to allow the development of spruce and hemlock trees to improve bank stabilization and inputs of large woody debris (LWD). 10 years later, in 2005-2007, an additional 10 acres of dense, second-growth riparian stands dominated by red alder were thinned to provide additional LWD deposits and improvements to bank stabilization (USDA Forest Service, 2007).

Wildlife depend heavily on thinning and gaps in the forest canopy for survival. Today, around 18% of the Analysis Area is comprised of second-growth, even aged forest structure previously serving as ideal deer winter habitat. Ideal deer winter habitat consists of a complex uneven aged stand with a dense overstory. A dense overstory reduces the amount of snow that reaches the ground and allows for easier movement. A complex uneven aged stand is also important because a dense shrub layer can form and provide a much needed food source for deer during the winter. *Vaccinium* species are the most important food source to deer during the winter months. In a USFS analysis, thinning to create uneven aged stands and enhance upland deer and bear habitat are recommended, more specifically 233 acres of the total 589 acres of upland harvest are considered high priority areas recommended for thinning (USDA Forest Service, 2007).

Due to successful regeneration measures stated in the National Forest Management Act (NFMA), all harvested areas within the analysis zone have been certified as regenerated. Timber production in the Analysis Area has not occurred in over 30 years. The land now falls under a semi-remote Recreation Land Use Designation (LUD) status, allowing for very limited forms of commercial timber harvest. Since the Starrigavan Valley falls under the Public Facilities-Retain (Pr) and Public Recreation & Tourism-Undeveloped (Ru) land designations, the area can now only be used for public recreation purposes (USDA Forest Service, 2007).

The Starrigavan watershed contains around 19.3 miles of significant streams, classified using the Alaska Regional Channel Type Classification System. Storm events and other natural disturbances naturally introduce large wood (LW) into these streams, forming debris jams which dissipate stream energy and create pools for fish spawning habitat. The Starrigavan Creek watershed supports three species of anadromous salmon: pink (*Oncorhynchus gorbuscha*), chum (*Oncorhynchus keta*), and coho (*Oncorhynchus kisutch*), as well as rainbow/steelhead trout (*Oncorhynchus mykiss*) and Dolly Varden char (*Salvelinus malma*) (USDA Forest Service, 2007). The recent conversion of old-growth to second-growth forests and harvesting along riparian zones, however, has altered summer and winter peak stream flows and impacted salmon survival and reproduction. Flooding during winter peak flow events reshapes and redistributes gravel bars and large woody debris within the stream bed, crushing or burying salmon eggs spawned in these areas. Restoration activities in 1995 added large woody debris structures to 2+ miles of stable stream, aimed to provide key fish habitat in a debris deficient area (USDA Forest Service, 2007).

The US Forest Service devised an interdisciplinary team of biologists, planners, and staff officers to provide recommendations to directly enhance recreational and commercial opportunities and provide recommendations to the management of the watershed. To restore fish habitat and aquatic ecosystem functioning damaged by riparian harvest and converted to red-alder dominated ecosystems, 96 areas of riparian habitat along class 1 and 2 streams have been recommended for thinning. Additionally, 0.5 mile reaches of stream were recommended to undergo in-stream rehabilitation of fisheries habitat (USDA Forest Service, 2007).

Field research conducted in June of 2014 by the University of Michigan Master's team gathered baseline data to analyze the success of thinning and LWD introduction restoration efforts of the USFS in comparison to undisturbed and disturbed-unrestored sites. Our analysis compares the three locations in terms of forest structure, species composition, spatial arrangement, stream structure, water quality and habitat quality. To scientifically monitor the impact of the implemented restoration, our data will provide baseline measurements for a reference condition that the restored stretches should eventually replicate. To ensure that restoration efforts are monitored and evaluated for success and opportunities for improvement, a monitoring plan is proposed by the Master's team. The overall objective is to analyze the success of restoration and find parameters for future goals.

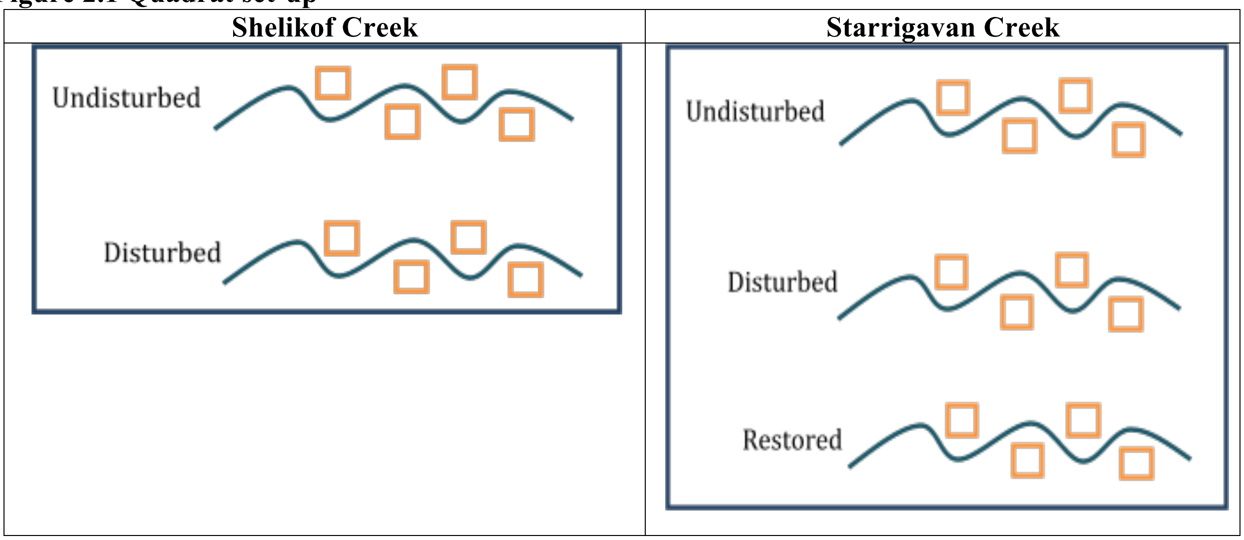
III. Methodology

To answer our research questions, the following methods were used. Baseline data that was collected during this project can be furthered by future replication of our methods. By replicating our procedure post restoration, SCS can analyze the long term success of restoration projects. The methodology used in this study was also developed into environmental education lessons, detailed in chapter three of this report. All lessons were developed to monitor restoration projects and engage the community.

A. Study Area

This study focused on the ecology of the stream and riparian zones of two creeks, Starrigavan and Shelikof. Both creeks have reaches that have been clear-cut, which were designated in this study as disturbed areas. To develop an appropriate protocol for monitoring the restoration of these two creeks, reference sites were selected along the same creek. In the case of Starrigavan, there is a section where restoration has been done. Therefore, for Shelikof the study included a disturbed and undisturbed reach and for Starrigavan it included a disturbed, undisturbed and restored reach (Figure 2.1).

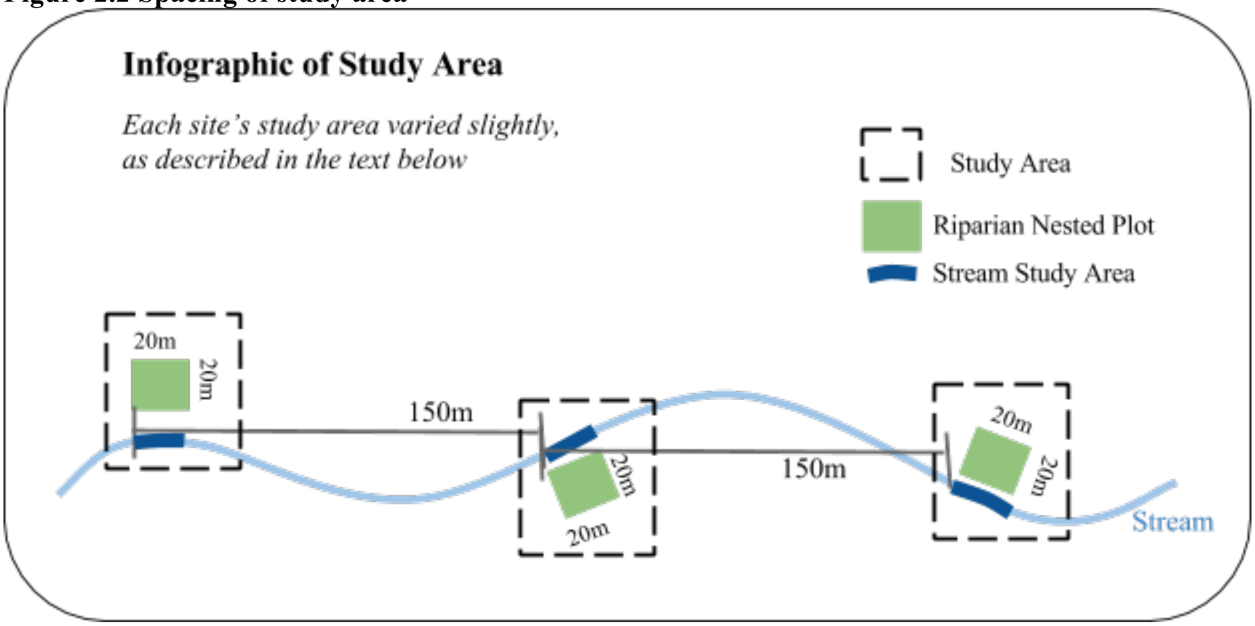
Figure 2.1 Quadrat set-up



Shelikof Creek has a total length of 6.73 kilometers of which about 5.35 kilometers is in areas where there has been disturbance. For the undisturbed reach our study sites alternated every bank of the stream starting with the right bank looking upstream and continued working upstream. For the disturbed our study sites were all on the left side of the stream looking upstream and worked downstream. We were unable to cross the stream to alternate study sites because of safety reasons on some parts of the stream. For both reaches the study sites had a spacing of 150 meters between them (Figure 2).

Starrigavan Creek has a total anadromous creek length of 8.25 kilometers of which about 6.24 kilometers is in areas where there has been disturbance. For the undisturbed reach the study sites were done alternating each bank starting with the right bank looking upstream and continued working upstream. For the undisturbed the spacing was of 100 meters between study sites. For the disturbed reach we started with the right bank looking upstream and worked downstream. Here the spacing between study sites was of 75 meters. For the restored site we started with the right bank looking upstream and worked downstream. The study sites had a spacing of 50 m between them. The difference in the spacing between the sites for Starrigavan occurred in order to maximize the amount of plots that were placed because the length of the stream and of each reach was a limitation to the amount of plots we could set up.

Figure 2.2 Spacing of study area



B. Aquatic Methodology

The stream portion of the field methodology has three components:

1. Pre-existing Stream Team Methods
2. Stream Structure
3. Substrate Particle Size Sampling

The first part of the aquatic methodology, hereafter referred to as "Stream Team," was composed of the stream survey methods from the University of Alaska Anchorage's Environment and Natural Resources Institute (ENRI) publication of "Alaska Stream Team Educational Level Water Quality Monitoring Field Guide" (ENRI, 2004). The Stream Team methodology had already been utilized throughout southeast Alaska and had even been previously employed at the Starrigavan Creek site by school kids. Due to time constraints and the similarity between sites within each segment, one Stream Team survey was completed for each type/segment of stream that was monitored. Thus, for Shelikof Creek, one Stream Team survey was conducted for the undisturbed site and one for the disturbed site. For Starrigavan Creek, one Stream team survey was conducted for each of the three types of sites: undisturbed, restored, and disturbed.

The full Stream Team methods, along with data sheets, can be found in the "Alaska Stream Team Educational Level Water Quality Monitoring Field Guide" in Appendix 2B. (ENRI, 2004). In order to ensure reproducibility and compatibility with past and future monitoring work, the manual was followed while conducting our monitoring of Shelikof and Starrigavan Creeks. The manual contained instructions for a stream habitat walk, water quality observations (qualitative and quantitative), and a rapid bioassessment using macroinvertebrates. The stream habitat walk resulted in recording of the date and time of observations, location of the site, and general observations. Location information included stream name, reach name, site name, latitude, longitude, and driving/hiking directions.

The second section of the Stream Team manual was composed of qualitative and quantitative water quality observations. By following the Stream Team manual we were able to qualitatively determine the predominant habitat types in the stream reach, appearance of the water, color of the streambed, and any noticeable odor. The possible habitat types included: undercut bank, aquatic vegetation, riffles/cobbles, and snag. We also quantitatively determined the dissolved oxygen content (mg/L) of a riffle within the reach using a dissolved oxygen kit, pH using either a kit or electronic meter, and air and water temperature (^{0}C) using a thermometer. Each of these variables was measured three times and averaged in order to ensure an accurate representation of the site. A chart, provided in the manual, was utilized along with the water temperature and dissolved oxygen results to calculate the dissolved oxygen saturation percentage. Lastly, the discharge was calculated from the measured average depth, average width, and flow rate of a fairly straight reach of the stream. The flow rate was measured by determining how much time it took for an empty bottle to travel 20 feet down a straight stretch of the stream. The width of a representative section of the reach was measured as the average width. Average depth was calculated from depth measurements taken every 1-3 feet, if possible, along a representative cross-section of the stream.

The third section of the Stream Team manual describes how to complete a rapid bioassessment using macroinvertebrates. A representative sample of the macroinvertebrate community at each sampled reach was collected and analyzed on-site. The composite sample for the reach was composed of a total of 5 sub-samples. The locations and habitat types to be sampled were based on the predominant habitat types of the reach, as determined in the qualitative water quality section. Each habitat type required a specific technique of sampling, which was described in depth in the Stream Team manual. The on-site analysis included separation of macroinvertebrates from the composite sample, sorting based on appearance, identification of the order and family (type) of each macroinvertebrate, and counting the total number of organisms of each order and family. A thorough sampling event took a minimum of 15 minutes and did not require that every macroinvertebrate in the composite sample was collected, but rather that most of the macroinvertebrates were collected and every order or family in the composite sample was recorded. After all individuals were recorded, the completed data sheet included the following information: number of types/families of each order, number of individuals of each order, EPT richness (types and total), non-EPT richness (types and total), taxa richness, and total number of organisms collected. The completed data sheets were then ready to be analyzed via our statistical methodology and entered online into the ENRI Stream Team database (http://astdatabase.uaa.alaska.edu/). This database allows the data to be accessed by other researchers, teachers, and students.

The second part of the aquatic methodology (Stream Structure) was composed of additional monitoring methods that were chosen and adapted specifically for the monitoring of Shelikof and Starrigavan Creeks in order to complement the Stream Team methodology. We decided to add the additional methods to better monitor the impact of timber harvest and large woody debris additions on habitat features and substrate quality. With that being said, these methods were still designed in order to be applicable to, and utilized in, future monitoring of other streams and for other types of restoration work. Whereas Stream Team surveys were done for only one reach within each stream segment, the second part of the methodology was conducted at every reach that we monitored, including the same reaches as the Stream Team surveys. For example, we collected data for this survey at eight reaches within the Shelikof Creek undisturbed area and eight within the Shelikof Creek disturbed area.

The first step at each site was to observe and record general descriptions of the reach in the notes section. Once the site was described, general information for each site was recorded using the data collection sheet in Appendix 2B. General information for each site included stream name, stream type, transect number, date, person conducting survey/writing, elevation (if possible), GPS coordinates, weather conditions, air and water temperatures, and photographs taken. The photographs were taken from within the stream, whenever possible, in an attempt to get the entire reach in the photo. Notable aspects of the reach were photographed as well.

After general information was filled in, qualitative and quantitative data was recorded in an attempt to understand the reach and concretely compare sites. Qualitative data included general bank condition, types of woody debris present, dominant substrate types, presence of fish, presence of wildlife, and any additional notes or comments to better describe the reach. Quantitative data included number of large wood pieces, number of key wood pieces, average water depth, average stream channel width, and the wetted width-to-depth ratio. Further descriptions of each of these variables can be found in Appendix 2C.

The third, and final, part of the aquatic methodology (Substrate Particle Size Sampling) was the implementation of the Wolman pebble count in order to quantify the surface particle size distribution of each site. The pebble count procedure was conducted at the same sites as the Stream Team methods, as described earlier. Our pebble count procedure followed the general methods described by Wolman (1954). This process involved measuring the diameter of 100 randomly selected substrate samples/particles at each site. Five cross-sections, perpendicular to the stream bank, were evenly spaced out (about 5 m between each cross-section) within the 20 meter reach. Twenty samples were taken at each of the five cross-sections, totaling 100 particles per site. Each particle was selected by randomly moving along the whole length of the stream cross-section, looking up while picking up particles, and selecting the first submerged particle the sampler touched with their index finger. In order to standardize this process even further, the sampler always picked up the substrate particle that was at the tip of his/her boot.

One common method for measuring the size of each particle is to use a ruler to measure the length of the intermediate axis of each pebble. In our surveys, we utilized a gravelometer, which provides a hand-held template with square holes of different size classes to classify particles, acting like a sieve to sort particles (Stream Systems Technology Center, 1994). Rather than measure the intermediate axis of every particle with a ruler, we classified each particle based on the size (mm) of the smallest hole in the gravelometer that the particle was able to fit through, which corresponded to the length of the intermediate axis. Using a gravelometer minimized potential operator/sampler error by standardizing the measurement and preventing the sampler from measuring the wrong axis (Daniels & McCusker, 2010). In the end, the methods described above combined to provide data for each site that could then be analyzed to assess different facets of stream habitat and water quality.

C. Riparian Methodology

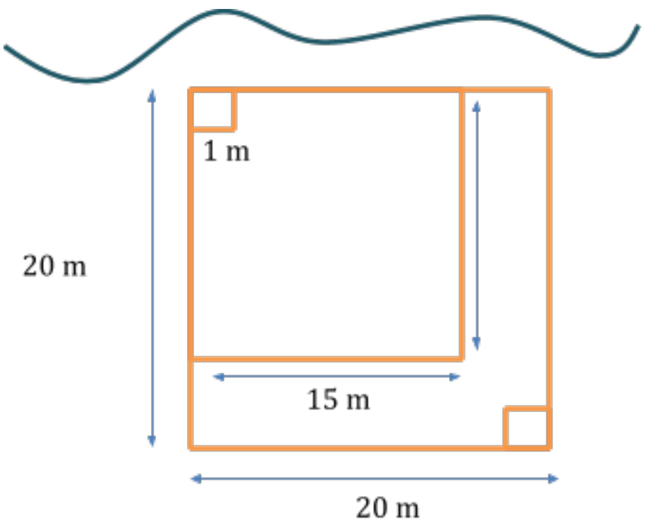
The sample unit used to determine the forest structure of the riparian zone of the two creeks was a modification of the nested quadrat technique frequently used in forestry inventories (Barbour et al. 1980). In the case of the two streams studied, Shelikof and Starrigavan, additional variables were considered to ensure an accurate representation of the riparian zone. In order to assess the maximum area of the riparian zone, which is defined functionally as the "zone of direct interaction between aquatic and terrestrial environments" according to Swanson et al. 1982, the proximity of the quadrat to the stream was one of the major factors for quadrat placing. Likewise, for this reason, the quadrats were placed on alternating sides of the stream and at a standardized distance from each other.

The standardized size of the sampling unit was established as 20 x 20 m (0.02 ha) plots. For Shelikof, eight plots, for each site, disturbed or undisturbed, were placed at 150 m from each other along the stream (Figure 2). For Starrigavan, four quadrats were placed for each one of the study sites, disturbed, undisturbed and restored. As mentioned previously, the difference in the quantity of quadrats between the two creeks was determined due to the length of the stream and the total distance of the stream within the disturbed, undisturbed or restored areas.

The distance of the plots to the stream was not standardized for all the quadrats because the stream's meander caused the edge of the riparian zone to be irregular. In this case, the plots were placed as close as possible to the stream where a straight 20 m line completely over forest ground could be formed. Tributaries from the stream ran internally through some of the plots, because they represent the composition of the riparian zone they were still included in the study.

The design of the nested 20 x 20 m plots consisted of two additional sub-quadrants to ensure that co-occurrence of species would be estimated at smaller spatial scales. The design of the stream as seen in Figure 2.3. shows a 15 x 15 m sub-quadrat with a starting point in the lower right corner. Two 1 x 1 m sub-quadrats were placed at opposing corners of the 20 x 20 m plot, with one of them sharing the same starting point as the other two quadrats and the other in the opposing corner (Figure 2.3).

Figure 2.3 Nested grid set-up



The sub-quadrats were used to assess the smaller size classes that are better represented at a smaller spatial scale, and this would allow the analysis of the age structure of the forest. In the 20 x 20 m plots the Diameter at Breast Height (DBH) was recorded for each tree with a diameter equal to or greater than 20 cm. Along with measuring the DBH, the adult trees were identified and spatially located using a handheld GPS, in order to determine the forest's spatial structure.

The 15 x 15 m plots were used for the identification and frequency count of saplings and understory species. Within these plots stems were counted for plants that were about knee height (50 cm) and up to 20 cm DBH. The 1 x 1 m plots were used to determine the percent vegetation cover, percent bare ground, percent moss cover, and presence or absence of lichen. Additionally, we also counted the number of individual plants found in each 1 x 1 m quadrat. The objective was for each sub-quadrat to provide information on a specific age class that would allow the analysis of the age structure of the forest. Lichen and specific understory plants, like *Vaccinium* sp., were used as indicators for adequate deer habitat.

Incorporating deadwood analysis in forest inventories have been used to find the floristic and structural determinants of old-growth forests (Burrascano et al. 2008), which would be useful in the characterization of the reference data for monitoring the restoration. In this case, the distinction between lying and standing deadwood was made. Similarly to live trees, DBH measurements were also taken for the snags found in the 20 x 20 m plots. For the lying deadwood the amount of logs found along one of the edges of the 20 x 20 m plot (Figure 2.3) was determined. Additionally, there were three decay classes, sound, partial and decomposed. Using a knife to perforate the logs, they were tested in their degree of decomposition (Table 2.1).

Table 2.1 Description of decay classes

Decay Class	*Description*	*Knife Test*
Sound	Logs seem intact.	Knife bounces off the log.
Partial	Logs are partially soft with stubs still attached to them.	Knife enters the log with difficulty and is easily removed.
Decomposed	Logs are soft and moist.	Knife enters and exits the log easily.

(Adapted from Rondeux & Sanchez, 2010)

All of the previously stated data were written into a data sheet on site and later entered into an Excel spreadsheet for further analysis (Appendix 2B).

D. Statistical Methodology

Aquatic Statistical Methods

Width to Depth Ratio: The goal of the width to depth statistical analysis was to determine the overall structure of the different sections of Shelikof and Starrigavan Creeks, specifically in terms of cross sectional channel shape and structure. The width to depth ratio data was collected from measurements of both the average width and depth of sites in Shelikof and Starrigavan Creeks. We aimed to use this data to compare various stream reaches (undisturbed, disturbed, and/or restored) to determine quantitative differences.

In order to statistically analyze our data, the raw width to depth ratio data was entered into R statistical software (R Core Team, 2014) in order compare the sample sites for both streams. For each site, we plotted the data as a box plot, which displayed the minimum, first quartile (25th percentile), median, third quartile (75th percentile), whisker (maximum within 1.5*IQR from the third quartile), and extreme outlier values. An ANOVA analysis of variance test was used to compare mean width to depth ratio of each Shelikof and Starrigavan Creek site, undisturbed/disturbed and undisturbed/disturbed/restored, respectively. The test compared the mean ratios between groups and determined the extent to which the means were significantly different from each other. A resulting p-value greater than 0.05 indicated that the mean width to depth ratios were not significantly different between the sites at a 5% level of significance (95% confidence level) and that the null hypothesis was not rejected.

Large and Key Woody Debris: The goal of the woody debris statistical analysis was to quantify the presence of both large and key woody debris within the sampled stream channels. Woody debris is important in that it influences water flow, nutrient and sediment transport, pool formation, and provides habitat and shelter for fish and macroinvertebrates. The large and key woody debris data was collected from counts of logs, which were classified based on channel width, wood diameter, and wood length, for both Shelikof and Starrigavan Creeks. In addition, we aimed to compare various stream reaches (undisturbed, disturbed, and/or restored) to determine quantitative differences. For Shelikof Creek, we were interested in determining the extent to which the disturbed and undisturbed sites differed in terms of the amount of large and key wood, which influence fish habitat availability and quality. For the Starrigavan Creek sites, we aimed to determine the extent to which the disturbed and restored sites differed from the undisturbed site and if restoration efforts were positively or negatively influencing habitat quality.

In order to statistically analyze the data, the raw large and key woody debris data was entered into R statistical software (R Core Team, 2014) in order compare the sample sites for both streams. For each site, we plotted the data as a box plot, which displayed the minimum, first quartile (25th percentile), median, third quartile (75th percentile), whisker (maximum within 1.5*IQR from the third quartile), and extreme outlier site values. An ANOVA analysis of variance test was used to compare mean large and key wood amounts per stream sample site of Shelikof and Starrigavan Creeks, undisturbed/disturbed and undisturbed/disturbed/restored, respectively. The test compared the mean ratios between groups and determined the extent to which the means were significantly different from each other. A resulting p-value greater than 0.05 indicated that the mean width to depth ratios were not significantly different between the sites at a 5% level of significance (95% confidence level) and that the null hypothesis was not rejected.

Substrate: Overall, the goal of the substrate statistical analysis was to determine the overall quality of the stream substrate, particularly in regards to the impact on salmonid health and abundance. The quality was determined from collected data on the substrate size and proportion of fine sediment in Shelikof and Starrigavan Creeks. We also wanted to compare the different stream areas (undisturbed, disturbed, and restored) and determine how they were different. For Shelikof Creek, we were mainly trying to determine whether the disturbed and undisturbed sites differed in fish habitat quality based on substrate size and percent fine sediment. For the Starrigavan Creek sites, we were also trying to determine whether the disturbed and restored sites were different from the undisturbed site, how they differed, and whether the restoration efforts were impacting (positively or negatively) the quality of the habitat.

For our analysis, the following metrics were computed from the raw Wolman pebble count data (100 particles) for each site: mean substrate size, median substrate size (D50), coarse substrate size (D84), percent fine sediment (<2 mm and <6 mm), percent of substrate in the preferred range (13-128 mm), and dominant substrate size class. Each metric was assessed for a variety of reasons. Multiple metrics were considered due to the fact that "there is no reason to expect that any single statistic can fully represent the attributes of the gravel size distribution relevant to the distinct functions of redd construction, embryo incubation, and fry emergence. Gravel size plays a different role in each life stage, and thus the relevant size attributes differ" (Kondolf, 2000). The first three metrics of central tendency (mean, median, and coarse) are all different measures of overall substrate size that are easy to read from distributions and able to be unambiguously interpreted (Kondolf, 2000). The mean particle size is a standard calculation that sums up the average sized particle at each site into a single number. The median particle diameter, or D50, is the size that 50% of the sample is finer than. It is commonly used in hydrology, geomorphology, and engineering to measure the middle value of a distribution and is not skewed by outliers (Kondolf, 2000). The size of coarse particles, or D84, is the size that 84% of the sample is finer than. (Kondolf & Wolman, 1993). It is a less well known measure used to help understand what the substrate in an area is like by understanding the size of larger particles in the area.

Other than measures of central tendency, measures of proportion and dominant size class are also helpful in analyzing the substrate of a site. Target values for proportion of fine sediment and preferred substrate size were based off of targets set for the Lower Red River Meadow restoration project in Idaho, which utilized ecological principles, scientific research, biological and hydrologic data, modeling, and expert judgment in target value determinations (Klein et al., 2007). Percent fine sediment describes the percentage of the particles in the sample that were either less than 2 or 6 mm in size. The presence of fine sediment plays a major role in the functioning of a stream and can be indicative of further problems (Kondolf, 2000). For example, fine sediment less than 2 mm clogs interstitial spaces and decreases oxygen availability for salmonid eggs during incubation. The target value of less than 14% fine sediment <2 mm was therefore used as an indicator of oxygen availability during salmonid incubation. Since larger fine sediment (<6 mm) can still impact the ability of hatched salmonids during emergence, the target value of less than 20% fine sediment <6 mm was used as an indicator of oxygen availability during salmonid emergence. Based on the literature, it was determined that a safe estimate of the preferred substrate size for salmonid spawning was between 13 and 128 mm. Therefore, the percentage of particles in the sample that were between 13 and 128 mm in size was calculated as the percent of substrate in the preferred range. The target goal was set at greater than 50% in order to provide suitable spawning habitat for salmonids (Klein et al., 2007). Finally, the substrate size class that had the highest proportion of particles per site was also recorded in order to determine which substrate type/size was most common and, thus, would tend to impact salmon the most. All of these metrics/variables indicate something different about the type of substrate at a site and the impact it has on the biota of the stream, which is why we made sure to consider all of them when analyzing the Wolman pebble count data.

We began our statistical analysis by inputting the 100 substrate samples from each site into the "Analyzing Pebble Count Data Collected by Size Classes" spreadsheet, (Potyondy & Bunte, 2002), located online and previously created to help with analyzing Wolman pebble count data. Since the spreadsheet allowed us to compare two sites, we created multiple workbooks in order to compare all of the sites. In the "Data Input" sheet we entered the number of particles in each size class for each site. The attached sheets of the Excel workbook then automatically produced a number of outputs, including the following: the number and percentage of pebbles counted that were less than and greater than a designated particle size criterion/bin (2, 4, and 8 mm), a statistical analysis of the data, a table and graph of the cumulative particle size distribution of each site, and a histogram of the data for each site. The statistical analysis of the data provided a p-value for each bin to determine at what confidence level it could be said that the proportion of particles less than the specific criterion was statistically different between the two sites. Additionally, the workbook was able to assist us by providing background information on pebble counts, instructions on how to conduct pebble counts and use the workbook, estimates of required sample sizes, and case studies to help understand the results. A p-value less than 0.05 indicated that the proportion of particles less than the specific criterion (2 mm, 4 mm, or 8 mm) was significantly different between the two sites at a 5% level of significance (95% confidence level), which is what we set as the standard for our analysis.

We entered the raw substrate data into R statistical software (R Core Team, 2014) in order to compare the sites and better statistically analyze our data. For each site, we plotted the data as a box plot, which displayed the minimum, first quartile (25th percentile), median, third quartile (75th percentile), whisker (maximum within 1.5*IQR from the third quartile), and extreme outlier substrate size values. We then conducted an analysis of variance (ANOVA) for each of the streams, Shelikof Creek and Starrigavan Creek, to determine whether the means of the sites within each creek were statistically different from each other. In order to corroborate these results in a more specific manner, we also conducted multiple Student's t-tests with the data to compare the sites within Shelikof and Starrigavan. Again, this was done in order to determine whether the mean substrate size was statistically different between sites. A resulting p-value less than 0.05 indicated that the mean substrate size was significantly different between the sites at a 5% level of significance (95% confidence level).

Macroinvertebrates: The overall goal of the macroinvertebrate statistical analysis was to determine the overall water quality of each site based on the types and number of macroinvertebrates present within the stream. We utilized multiple methods for analyzing the macroinvertebrate data. A multimetric index was one method that was used to combine a lot of data into one number that could easily be compared between sites. The macroinvertebrate multimetric index we utilized in our analysis was created by the University of Alaska Anchorage Environment and Natural Resources Institute (ENRI) and Tetra Tech, Inc. in order to assess the biological quality of wadeable, non-glacial streams in the Alexander Archipelago of Southeast Alaska. The model was formulated by collecting macroinvertebrate, physio-chemical, and habitat data in 123 streams of varying quality (undisturbed, urbanized, landfill runoff, timber harvest, etc.) for three consecutive years from 2002-2004. The six metrics selected for the final index included insect taxa richness, percent non-insect taxa, percent EPT (Ephemeroptera, Plecoptera, and Trichoptera), percent intolerant taxa, clinger taxa richness, and scraper taxa richness. The index was calibrated using undisturbed and stressed/urbanized sites in order to select these six metrics as the best explanation of the data and create scoring formulas in order to adequately weight each metric within the overall index score (Rinella, Bogan, Kishaba, & Jessup, 2005).

We were then able to apply the scoring formula for the above mentioned six metrics to our collected data, which resulted in an overall index score for each of our sites. A higher score for the multimetric index indicated a stream of overall higher quality in regards to the macroinvertebrate community that was sampled. The 25th and 75th percentile values of sampled sites in Southeast Alaska, from the study that formulated the index, ranged from about 70-85 for undisturbed sites and 20-60 for stressed sites (Rinella et al., 2005). Thus, for our analysis, we determined that any score greater than 70 indicated a high quality site, between 60 and 70 a site of average quality, and below 60 designated a poor/stressed site.

In addition to the multimetric index, we also utilized common individual macroinvertebrate metrics in our analysis of the data. The six metrics we utilized were percentage EPT, percentage dominant taxa, percentage Chironomidae (midges), taxa richness, EPT richness, and non-EPT richness. EPT refers to the following three insect orders: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). The EPT orders are known for being sensitive to pollution and thus indicators of good stream quality. The percentage of individuals sampled that were classified as EPT (percentage EPT) and the number of EPT types/taxa in the sample (EPT richness) are macroinvertebrate metrics that were expected to increase with decreasing disturbance. On the other hand, non-EPT taxa tend to be less sensitive to pollution, so larger non-EPT richness was indicative of poorer water quality and increased perturbation. Since the percentage of the dominant taxa is a measure of redundancy and diversity, a high proportion normally indicates low diversity and dominance of pollution tolerant organisms (Barbour et al., 1998). Individuals of the order Chironomidae (midges) are tolerant of pollution, low dissolved oxygen, and warm water. Therefore, higher percentages of midges indicated increased disturbance and poor water quality. Finally, the total number of taxa (taxa richness) is a measure of the overall variety of macroinvertebrates in a sample. It is believed that an increased richness was correlated with greater overall health which implied that niche space, habitat, and food sources were suitable enough to support many species (Barbour et al., 1998). These metrics were calculated from the raw data at each site and compared using bar plots. Concrete conclusions cannot realistically be made from one metric alone. Instead, all of these metrics were considered in order to compare the quality of the sites within Shelikof Creek and Starrigavan Creek.

Riparian Statistical Methods

Forest Structure and Composition: A free source statistical program, R Console 2014 (R Core Team, 2014), was used to graphically show the forest structure by size class. A t-test was used to determine if there is a significant difference between the undisturbed, restored and disturbed sites.

Understory Density and Composition: T-tests and ANOVA tests were used to determine significance between test sites. In Shelikof, only t-tests were used to compare the difference between the undisturbed sites and the disturbed sites in terms of adult tree size, measuring in DBH, and basal area. In Starrigavan, t-tests between the undisturbed, restored and disturbed were used in each combination to determine if there is a significant difference and the degree of difference between test sites. ANOVA tests were also used for all three sites but didn't allow for the same level of detail as the t-tests for each site. R was used to graphically show a box and whisker plot of results.

Adult Tree Size (DBH) and Basal Area: R was used to graphically show the forest structure by size class. A t-test was used to determine if there is a significant difference between the undisturbed, restored and disturbed sites in terms of total density, edible vegetation density and regenerative vegetation density.

Snags: T-tests were used to determine significant differences between the amount of snags between the sites (disturbed, undisturbed, and restored in the case of Starrigavan) for the two creeks in the study. Snag counts were converted to basal area in order to assess the effect of forest density on the occurrence of snags within each site. For Shelikof the t-test compared the disturbed versus undisturbed sites and for Starrigavan the t-tests compared Disturbed versus Undisturbed and Restored versus Disturbed and Undisturbed.

Deadwood: For deadwood, a similar approach as the snags was used. Because we did not obtain a density measurement for deadwood found we used count instead of basal area for the fallen logs that were in each of the decomposition stages (solid, partial and decomposed). Therefore, t-tests were done to determine the difference between the sites of the two creeks and the total amount of deadwood in all of the stages and in each one of the stages. All t-tests for snags and deadwood were done in R Core Team 2014.

IV. Results

A. Study Site: Shelikof Creek

Shelikof Creek has not undergone restoration so we compared two sites, one undisturbed and one disturbed from the clear-cut harvest.

Aquatic Results by Indicators

All summary results can be found within a table in Appendix 2D. Results for each indicator are detailed for the aquatic and riparian portion of our study.

Width to Depth Ratio

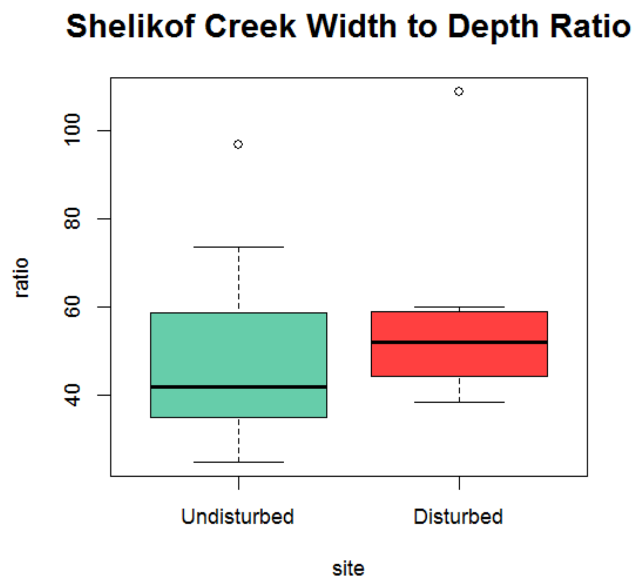


Figure 2.4 Box plot of the Shelikof Creek width to depth ratio data for the disturbed and undisturbed sites. A total of eight reaches were sampled for each site (n=8).

The Shelikof Creek wetted width to depth ratio box plot displays a way to view the relationship between stream width and depth among the two sampled sites for Shelikof Creek (Figure 2.4). The undisturbed site had a lower mean ratio at around 40, whereas the disturbed site had a mean ratio greater than 50. The undisturbed site had a much larger range (48.66) of values compared to the disturbed (21.51), not accounting for outliers. The higher width to depth ratio of the disturbed site suggests that the disturbed sites were either wider, shallower, or both in comparison to the undisturbed. No significant difference was found at the 0.05 alpha level in means for the width to depth ratio between the disturbed and undisturbed site of Shelikof Creek (P=0.486).

Large and Key Woody Debris

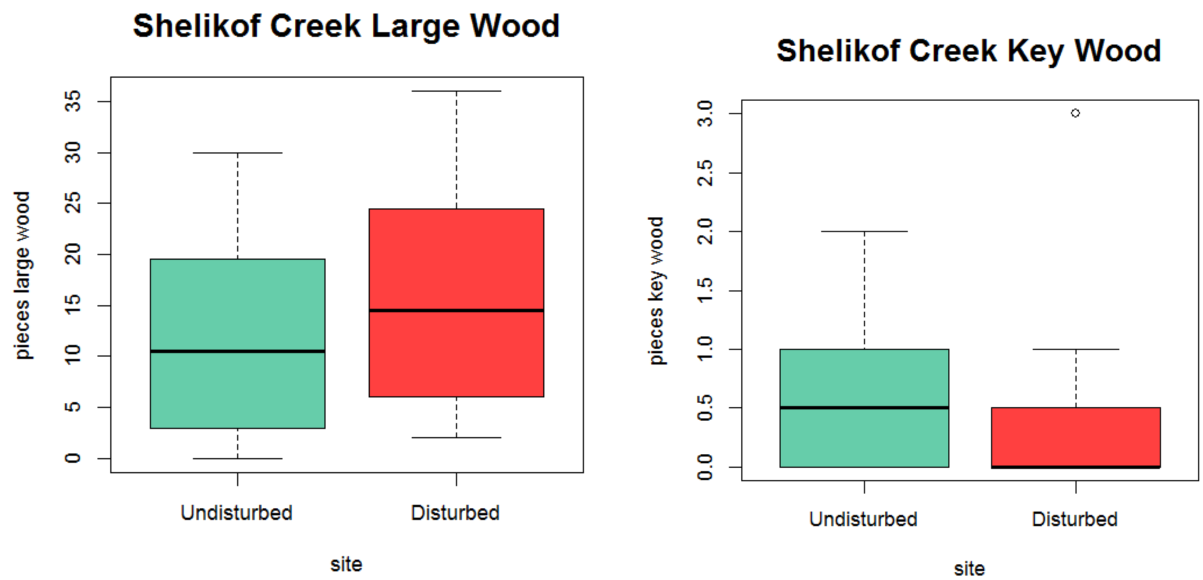


Figure 2.5 Box plot of the amount of large woody debris (LWD) and key woody debris (KWD) in Shelikof Creek. The sample size for each site was eight 20 meter long stream reaches (n=8).

There was no significant difference at the 0.05 alpha level in mean numbers of large wood (P=0.50) and key wood (P=0.79) between the disturbed and undisturbed sites of Shelikof Creek. In terms of large woody debris present in Shelikof Creek, the disturbed site contained a mean of 16 pieces of large wood per 20 m transect, whereas the undisturbed site contained a mean of 12 pieces. Less large woody debris was found in the undisturbed site compared to the disturbed. In terms of key woody debris present in Shelikof Creek, the disturbed site contained a mean of 0.143 pieces of key wood per 20 m transect (disregarding outlier of 3 pieces), whereas the undisturbed site contained a mean of 0.5 pieces. Less key woody debris was found in disturbed site (Figure 2.5). For both large wood and key wood values, however, none were found to be statistically significantly different.

Substrate

Variable	Target Value (Klein et al., 2007)	Undisturbed	Disturbed
Mean Substrate Size		10.446 mm	12.718
Median Substrate Size (D50)		4.12 mm	6.49 mm
Coarse Substrate Size (D84)		12.99 mm	21.51 mm
Percent Fine Sediment (<2 mm)	<14%	27%	17%
Percent Fine Sediment (<6 mm)	<20%	63%	47%
Percent Substrate in the Preferred Range (13-128 mm)	>50%	19%	32%
Dominant Substrate Size Class		<2 mm	<2 mm

Table 2.2 The variables were summarized from data collected using the Wolman pebble count method and have a sample size of 100 substrate pebbles/particles per site (Wolman, 1954). The target ecological values for percent fine sediment and percent of substrate, from Klein et al., are also listed (2007).

For all three overall substrate size variables (mean, median, and coarse), the disturbed site had a larger substrate size compared to the undisturbed site. The t-test performed from the data suggests that the mean substrate size between the two Shelikof sites was not significantly different. It is uncertain, however, whether the values for median and coarse were statistically significant. The Shelikof disturbed site had a lower proportion of fine sediment for both measures of fine sediment (<2 mm and <6 mm) and had a higher proportion of samples in the preferred range of substrate sizes for salmonid spawning. Neither site met the target values of less than 14% fine sediment <2 mm, less than 20% fine sediment <6 mm, or greater than 50% of substrate in the preferred range (Klein et al., 2007). Finally, the dominant substrate size class was less than 2 mm for both Shelikof Creek sites (Table 2.2).

Shelikof Creek Substrate Size Significance Tests	
Size Class	**Disturbed vs. Undisturbed**
< 2 mm	0.0622
< 4 mm	0.0071*
< 8 mm	0.0526
Mean	0.341

Table 2.3 P-values of the Shelikof Creek t-tests of different size criterion for the disturbed site compared to the undisturbed site. An asterisk (*) next to the value indicates that the proportion of particles less than the specific criterion or mean are significantly different (statistically) between the undisturbed and disturbed sites at a 5% level of significance (95% confidence level). Sample size for each site is 100 substrate particles (n=100). Sites were replicated 8 times within the undisturbed and 8 times within the disturbed reaches.

The tests revealed that the only substrate size criterion that was significantly different (95% confidence level) between the disturbed and undisturbed reaches was for substrate less than 4 mm (Table 2.3). When using the mean substrate size or the proportion of particles less than 2 mm or 8 mm to compare the sites, the Shelikof disturbed site was not significantly different from the Shelikof undisturbed site.

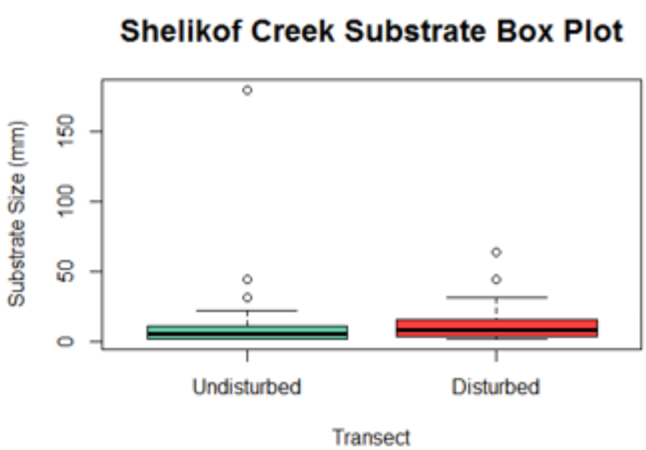
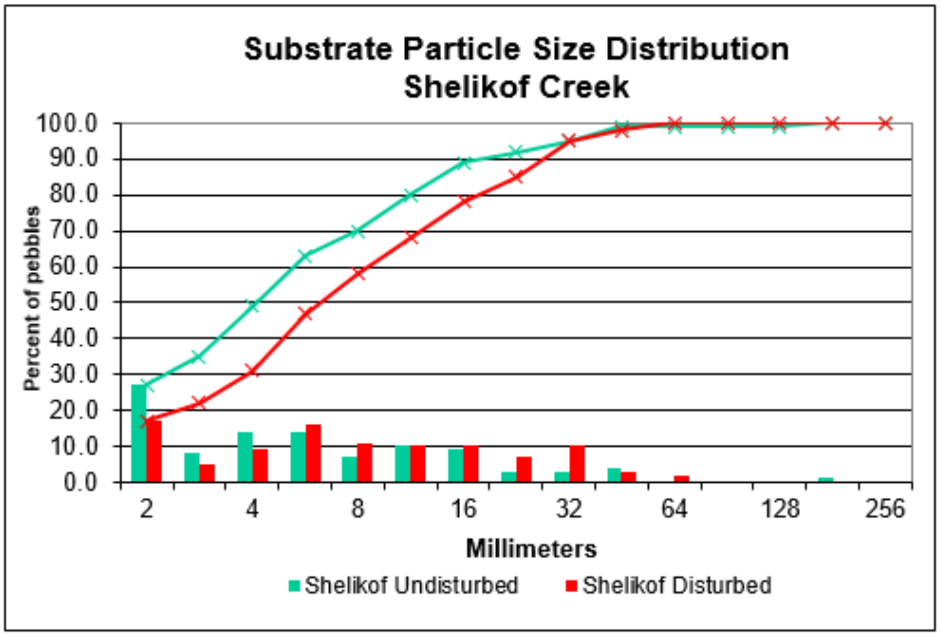


Figure 2.6 Box plot of the Shelikof Creek substrate data for the disturbed and undisturbed sites. The sample size for each site was 100 substrate particles (n=100). Sites were replicated 8 times within the undisturbed and 8 times within the disturbed reaches.

The box plot displays another way to compare the study site to the undisturbed site (Figure 2.6). The values between the disturbed and undisturbed sites appear to be fairly similar, which corroborates the lack of significant difference between the two sites. The undisturbed site appears to have had slightly smaller values, disregarding outliers, which might have skewed the mean value, resulting in non-significance. Overall, this graph supports the conclusion that the substrate size data for the Shelikof disturbed and undisturbed sites were not significantly different from each other.



The substrate size histogram and cumulative particle size distributions for the two Shelikof sites appear to be fairly similar (Figure 2.7). They both follow a comparable trend, except that the undisturbed site had slightly higher proportions of smaller particles (<4 mm), whereas the disturbed site had slightly more of the moderate size particles (8-32 mm).

Figure 2.7 Substrate size histogram and cumulative particle size distributions for the Shelikof Creek undisturbed and disturbed sites. The sample size for each site was 100 substrate particles (n=100). Sites were replicated 8 times within the undisturbed and 8 times within the disturbed reaches.

Macroinvertebrates

Regarding the Shelikof sites, the disturbed site (84.9) had a higher index score compared to the undisturbed site (60.5). The Shelikof disturbed site was designated as high quality whereas the disturbed site was designated as average quality (Figure 2.8).

For the Shelikof sites, the disturbed site had a higher percent EPT and slightly lower percent dominant taxa and percent midges. These metrics suggest that the Shelikof disturbed site is of higher quality compared to the Shelikof undisturbed site (Figure 2.9).

The disturbed site had more EPT taxa and less non-EPT taxa, even though both sites had the same number of total taxa. These metrics indicate that the Shelikof disturbed site is of considerably higher water quality than the undisturbed site (Figure 2.10).

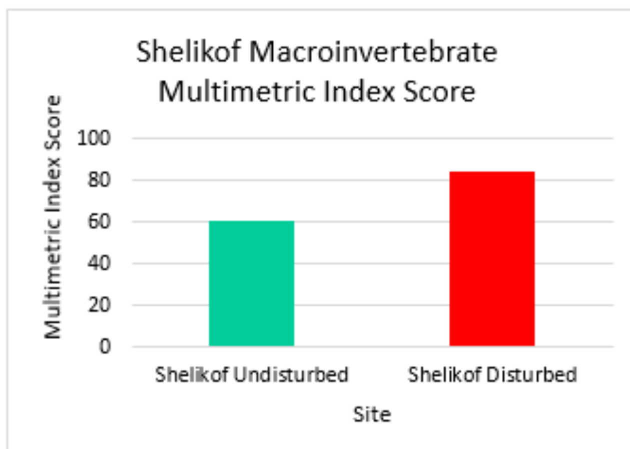


Figure 2.8 Chart presenting the results of applying the Macroinvertebrate Multimetric Assessment Index (Rinella et al., 2005) to the macroinvertebrate data collected for the Shelikof undisturbed and disturbed sites. The data was collected by sampling one 25 meter long stream section for each site (n=1). Thus, a total stream area of about 282 m² was sampled for the undisturbed site and 414 m² was sampled for the disturbed site.

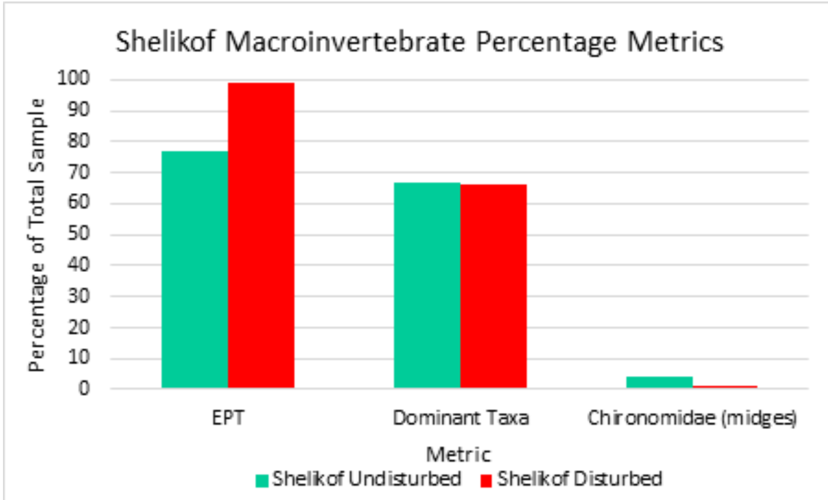


Figure 2.9 Chart displaying the percentage of macroinvertebrates sampled at each Shelikof Creek site that were of the EPT group (orders Ephemeroptera, Plecoptera, and Trichoptera), the dominant taxa of the site, and the family Chironomidae (midges). The data was collected by sampling one 25 meter long stream section for each site. Thus, a total stream area of about 282 m² was sampled for the Shelikof undisturbed site and 414 m² was sampled for the Shelikof disturbed site. A total of 100 macroinvertebrates were collected for the Shelikof undisturbed site and 226 macroinvertebrates for the Shelikof disturbed site.

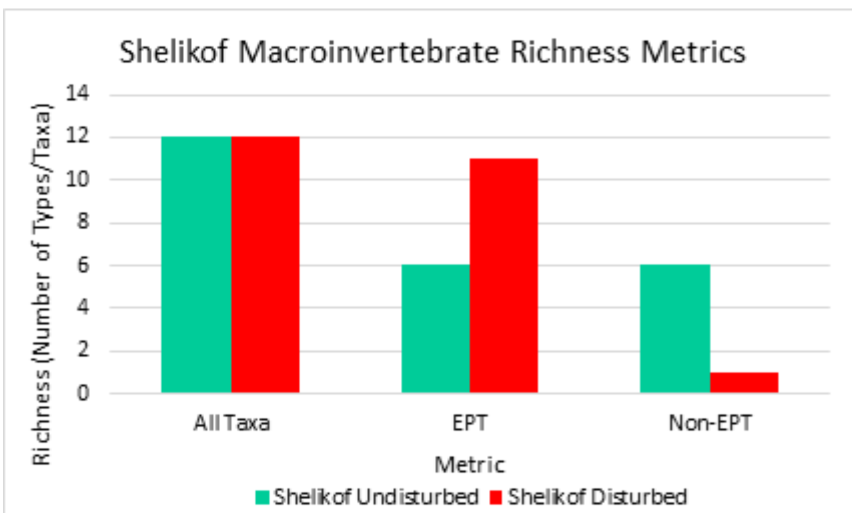


Figure 2.10 Chart of the number of overall taxa, EPT taxa (orders Ephemeroptera, Plecoptera, and Trichoptera), and non-EPT taxa sampled at each Shelikof Creek site. The data was collected by sampling one 25 meter long stream section for each site. Thus, a total stream area of about 282 m² was sampled for the Shelikof undisturbed site and 414 m² was sampled for the Shelikof disturbed site. A total of 100 macroinvertebrates were collected for the Shelikof undisturbed site and 226 macroinvertebrates for the Shelikof disturbed site.

Riparian Results by Indicators

All summary results can be found within a table in Appendix 2D.

Forest Composition

Riparian forests in southeast Alaska are primarily composed of Western hemlock, *Tsuga heterophylla* and Sitka spruce, P*icea sitchenses.* Red alder, *Alnus rubra* is common where large scale disturbances have occurred.

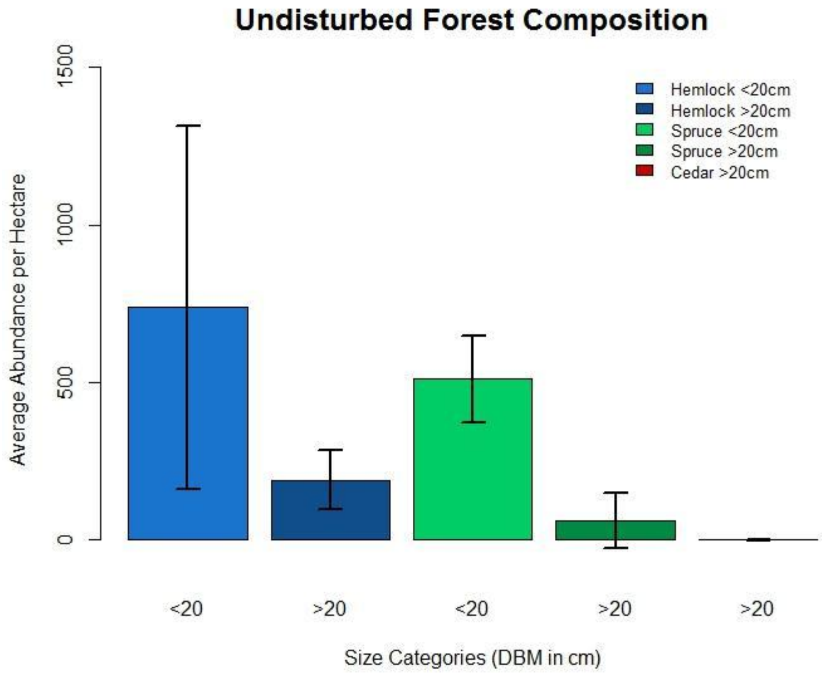


Figure 2.11 Species in the first size class for each species are taller than knee height and less than 20 cm DBH. Species in the second size class are larger than 20 cm DBH. Sample size is 8 transects of 400 square meters for trees larger than 20 cm DBH and 225 square meters for trees less than 20 cm DBH.

The undisturbed forest data shows a higher average abundance per hectare in sapling populations (less than 20 cm DBH) than in larger species (greater than 20 cm DBH for both Western hemlock and Sitka spruce. Hemlock is more abundant than spruce as a sapling but there are more spruce in the larger size class than hemlock. Large error bars show a high amount of variability found between transects (Figure 2.11). For example, one transect within Shelikof Creek contained a root ball with spruce saplings growing densely.

The disturbed forest composition is distinctly different than the undisturbed site in that alder is present within Shelikof Creek.

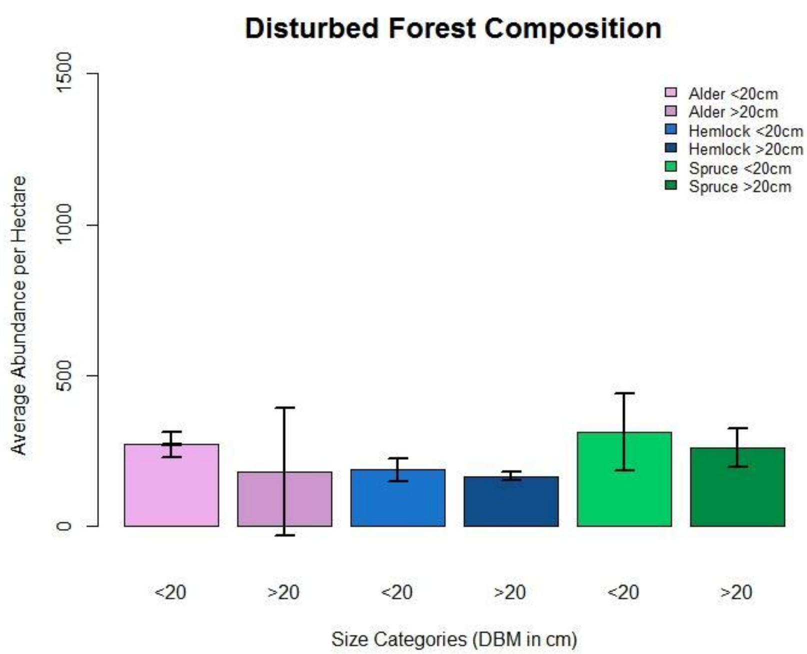


Figure 2.12 Trees in the first size class for each species are taller than knee height and less than 20 cm DBH. Species in the second size class are larger than 20 cm DBH. Sample size is 8 transects of 400 square meters for trees larger than 20 cm DBH and 225 square meters for trees less than 20 cm DBH.

Hemlock saplings are in higher abundance than the larger size class (greater than 20 cm DBH). Both alder and spruce have lower sapling densities than their larger size class (Figure 2.12). A t-test found no statistical significance between the undisturbed and disturbed sites in their forest composition.

Forest Structure

Within Shelikof Creek, the undisturbed forest structure shows an age structure of an uneven aged forest where there are more saplings and small trees than large ones. The disturbed forest shows a similarly distributed, uneven age structure with more saplings than trees in the 20-40cm size class. Overall, there are less large trees in the disturbed forest (Figure 2.13).

According to a t-test, there is a significant difference ($p < 0.05$) between undisturbed and disturbed sites in regards to the size (DBH) distribution. The undisturbed site has larger trees than the disturbed site. According to a Basal Area t-test, there is no significant difference between undisturbed and disturbed sites. Although there are more large trees in the undisturbed forest, the large number of smaller trees allows for similar basal areas between the disturbed and undisturbed forests.

Understory Composition and Density

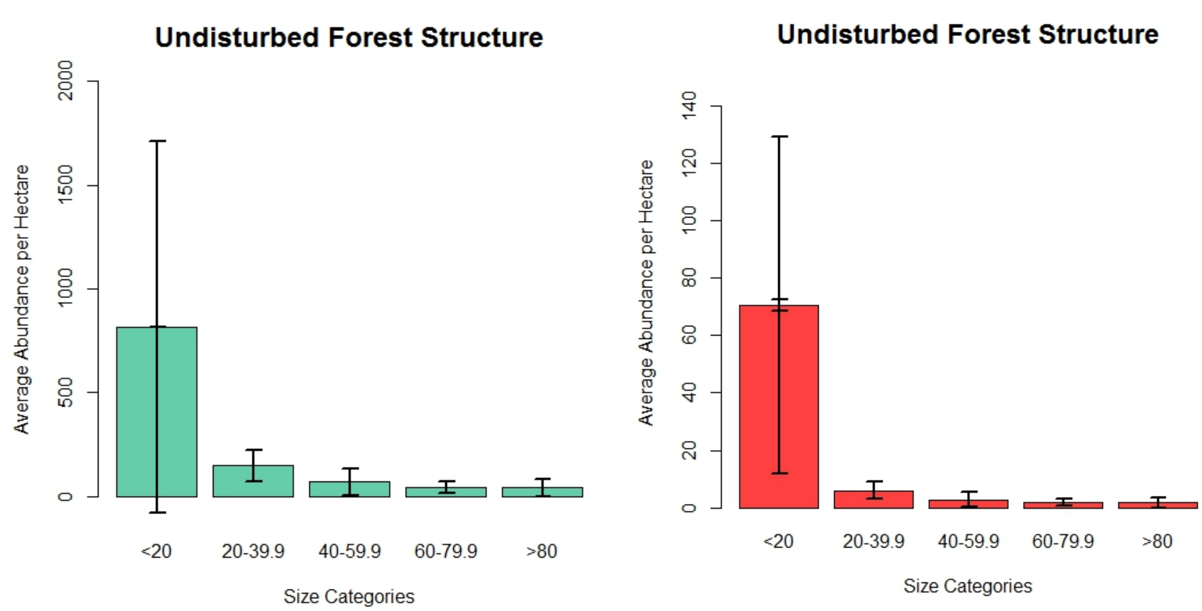


Figure 2.13 Size class is determined by diameter at breast height. Woody plants less than 20 cm were above knee height. Only regenerative species; Alder, Spruce and Hemlock were included. Sample size is 16 transects (8 undisturbed and 8 disturbed) of 400 square meters each.

Results show a significantly ($p<0.01$) higher average abundance per hectare of all woody understory species in the undisturbed site as compared to the disturbed site of Shelikof Creek. Similarly, there is a higher density of regenerative vegetation in the undisturbed sites. There is a significant difference ($p<0.05$) in the average abundance per hectare of regenerative species in the undisturbed and disturbed sites (Figure 2.14).

There is no significant difference between the undisturbed and disturbed sites in respect to the average abundance per hectare of understory species that are edible to deer in the winter for Shelikof Creek. There appears to be more available edible species in the undisturbed sites (Figure 2.15). Similarly, there is no significant difference in the amount of shrub species found in the two sites. The undisturbed site appears to have more shrub species but there is a large amount of variability.

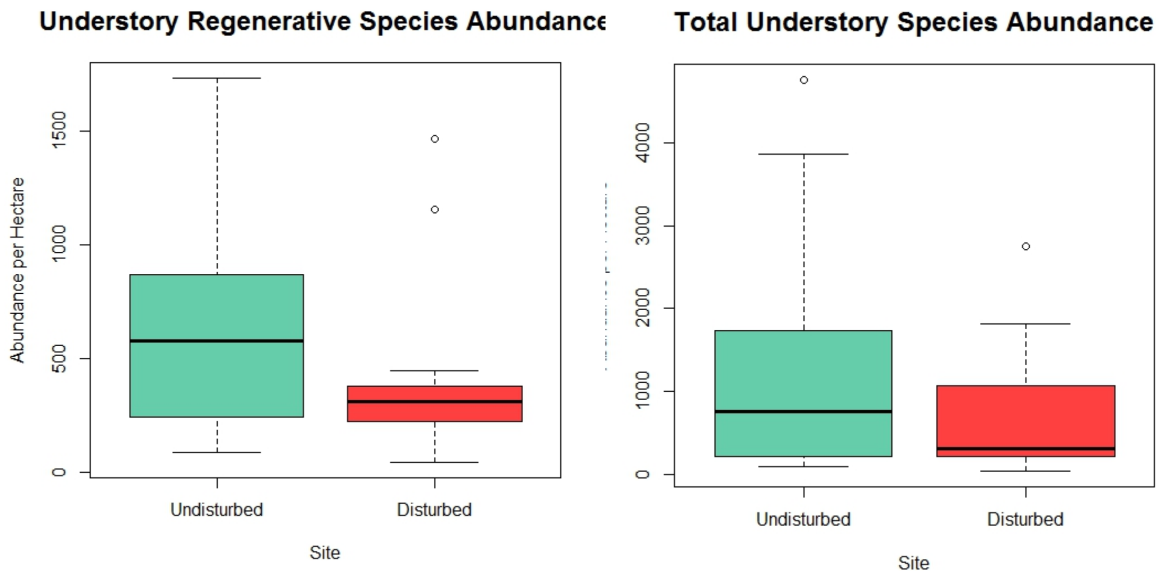


Figure 2.14 The overall abundance per hectare between the disturbed and undisturbed sites show understory density of all woody species. Regenerative vegetation can grow into overstory species and consists of alder, spruce and hemlock. Sample size is 16 transects (8 undisturbed and 8 disturbed) of 225 square meters each.

Figure 2.15 The edible vegetation abundance figure shows only understory species that act as a winter food source for deer, and include blueberry, hemlock and spruce. Woody vegetation is considered a shrub when less than 20 cm DBH and will not grow into the overstory. These species include salmonberry, elderberry, blueberry, menziesia or devil's club. Sample size is 16 transects (8 undisturbed and 8 disturbed) of 225 square meters each.

Snags

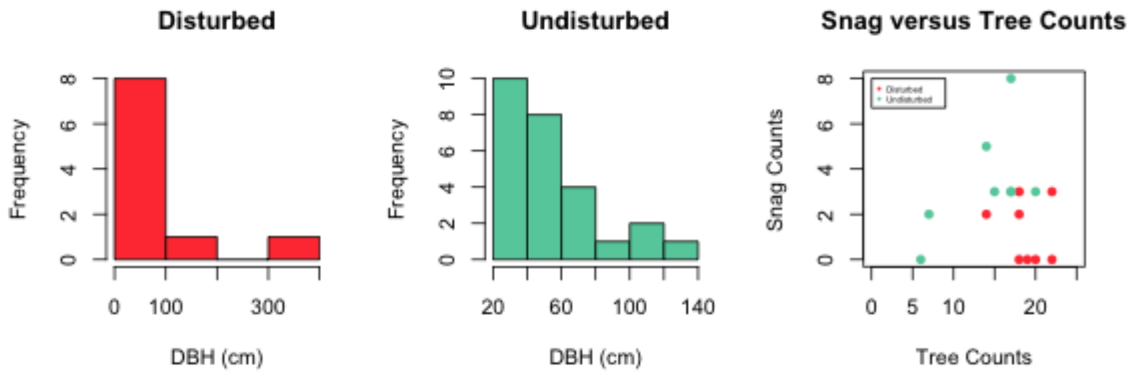


Figure 2.16 Plots of the frequency of snags per DBH ranges and scatterplot of tree counts versus snag counts.

A t-test of DBH showed no significant differences between the disturbed and undisturbed sites of Shelikof Creek. The histogram for the disturbed dataset shows a separation in the distribution of values. On the other hand, the undisturbed dataset is asymmetrical, skewing towards smaller DBH values (Figure 2.16).

A t-test comparing snag versus tree ratios found that there were significant differences between in the snag to tree ratio between disturbed and undisturbed ($p<0.05$). The plot shows that areas with more trees had higher snag counts in the undisturbed site while there was a smaller amount of snags in the disturbed site.

Deadwood

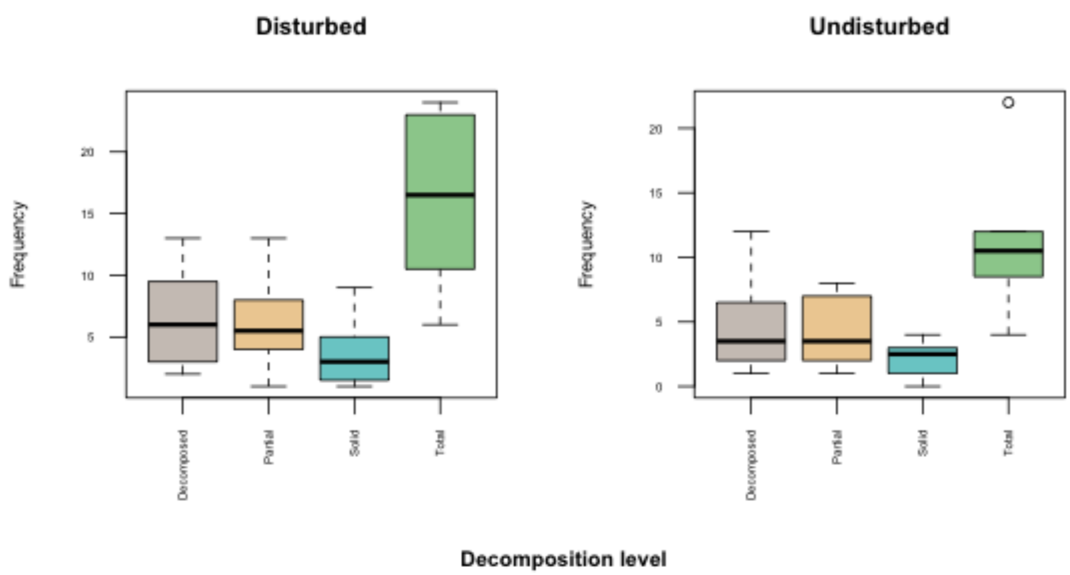


Figure 2.17 Box plot of dead wood, categorized by level of decay, for disturbed and undisturbed sites. The levels of decay, from left to right are: decomposed, partially decomposed, solid and then the total abundance of deadwood is represented by the green bar on the far right.

A t-tests found no significant differences between the stages of decomposition in the two sites of Shelikof Creek. The boxplot indicates that the solid stage may be the least found in both disturbed and undisturbed sites (Figure 2.17).

B. Study Site: Starrigavan Creek

Starrigavan Creek differs from our previous study site in that restoration practices began in the 1980s. Consequently, we compared three sites; 1) undisturbed, 2) restored and 3) disturbed.

Aquatic Indicators
Width to Depth Ratio

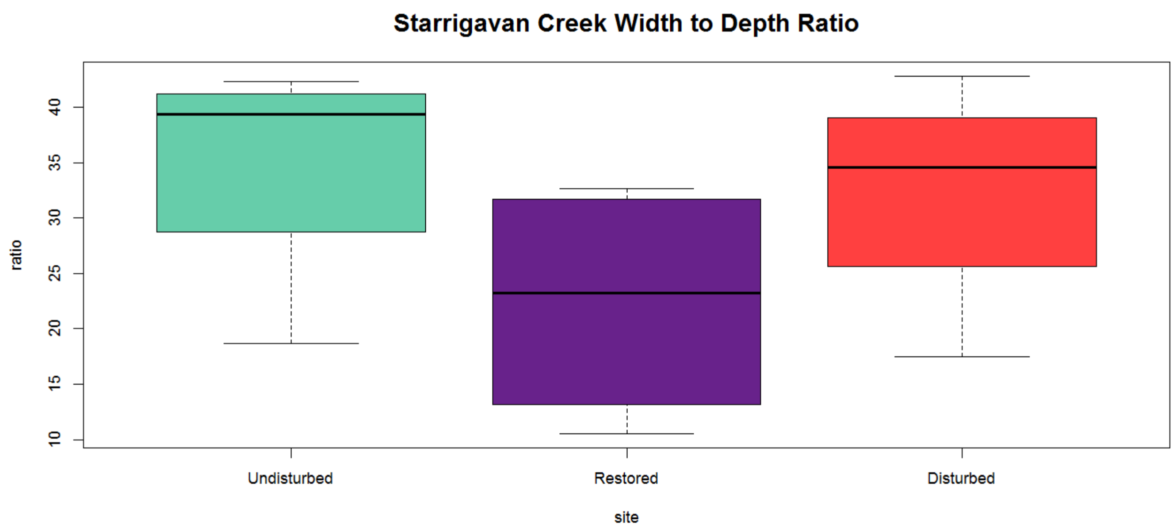


Figure 2.18 Box plot of the Starrigavan Creek width to depth ratios for the undisturbed, restored, and disturbed sites. A total of four reaches were sampled for each site (n=4).

The box plot displays a way to view the relationship between stream width and depth among the three sample sites for Starrigavan Creek (Figure 2.18). The undisturbed site had the highest mean ratio at around 40, whereas the disturbed had a slightly lower mean at 35. The mean width to depth ratio for the restored site was even lower at 20-25. Based on the box plot, it appears that the restored site displays the lowest ratio whereas the undisturbed and disturbed are fairly similar with the undisturbed having a slightly higher ratio. No significant difference at the 0.05 alpha level in means for the width to depth ratio between the disturbed, reference, and restored sites of Starrigavan Creek (P=0.27) were found. These results suggest that there is an analogous/comparable stream structure between the undisturbed, restored, and disturbed sites and that the channel shapes are similar.

Large and Key Woody Debris

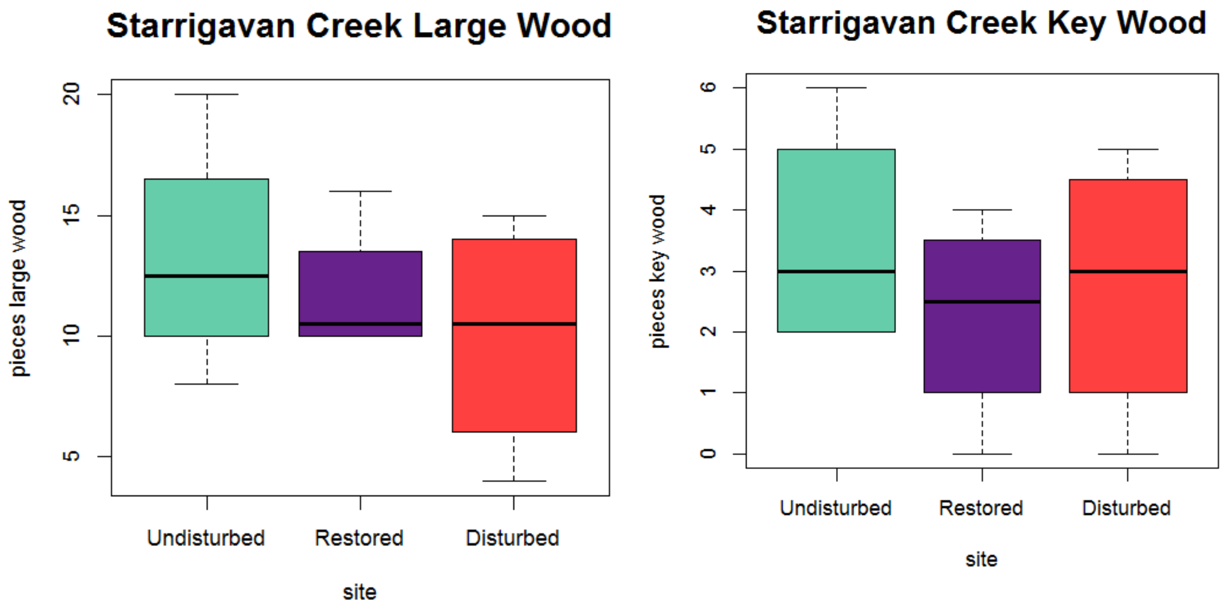


Figure 2.19 Box plot of the amount of large woody debris (LWD) and key woody debris (KWD) in Starrigavan Creek. The sample size for each site was four 20 meter long stream reaches (n=4).

No significant difference was found at the 0.05 alpha level in mean number of large wood (P=0.596) and key wood (P=0.674) between the disturbed, undisturbed, and restored sites of Starrigavan Creek. In terms of large woody debris present in Starrigavan Creek, the disturbed site contained a mean of 10 pieces of large wood per 20m transect, whereas the undisturbed site contained a mean of 13.25 and the restored site a mean of 11.75. The least amount of large woody debris was found in the disturbed site. In terms of key woody debris present in Starrigavan Creek, the disturbed site contained a mean of 2.75 pieces of key wood per 20m transect, whereas the reference site contained a mean of 3.5 and the restored site a mean of 2.25. The least amount of key woody debris was found in the restored site (Figure 2.19). For both large wood and key wood values, however, none were found to be statistically significantly different.

Substrate

Variable	Target Value (Klein et al., 2007)	Undisturbed	Restored	Disturbed
Mean Substrate Size		65.744 mm	20.354 mm	28.566
Median Substrate Size (D50)		32 mm	13.46 mm	18.7 mm
Coarse Substrate Size (D84)		130.59 mm	38.46 mm	38.07 mm
Percent Fine Sediment (<2 mm)	<14%	4%	1%	1%
Percent Fine Sediment (<6 mm)	<20%	7%	22%	9%
Percent Substrate in the Preferred Range (13-128 mm)	>50%	63%	57%	80%
Dominant Substrate Size Class		128-181 mm	16-22.6 mm	16-22.6 mm

Table 2.4 The variables were summarized from data collected using the Wolman pebble count method and have a sample size of 100 substrate pebbles/particles per site (Wolman, 1954). The target ecological values for percent fine sediment and percent of substrate, from Klein et al., are also listed (2007).

For Starrigavan Creek, all three overall substrate size metrics (mean, median, and coarse) showed the same trend; the undisturbed site had the largest substrate size while the restored had the smallest size (Table 2.4). For all three metrics, the undisturbed site appeared to have much larger values, whereas the disturbed and restored sites were more similar to each other. The t-tests showed that the differences in mean substrate size between all three sites were significantly different (95% confidence level). The Starrigavan restored site had the highest percentage of fine sediment for both categories (<2 mm and <6 mm) and the lowest proportion of substrate in the preferred salmonid spawning range. The disturbed site had the highest proportion of substrate in the preferred range and the lowest percentage of fine sediment less than 2 mm. The undisturbed site had the lowest percentage of fine sediment less than 6 mm and the middle amount of fine sediment less than 2 mm and substrate in the preferred range. All three Starrigavan sites met the target of less than 14% fine sediment <2 mm and greater than 50% of substrate in the preferred range. The Starrigavan restored site was the only site that did not meet the target of less than 20% fine sediment <6 mm (Klein et al., 2007). The dominant substrate size class was much larger for the undisturbed site (128-181 mm) compared to the disturbed and restored sites (16-22.6 mm).

Shelikof Creek Substrate Size Significance Tests			
Size Class	**Disturbed vs. Undisturbed**	**Restored vs. Undisturbed**	**Disturbed vs. Restored**
< 2 mm	0.1825	0.1256	0.0116*
< 4 mm	0.6272	0.0169*	0.0169*
< 8 mm	0.5861	0.0006*	0.0006*
Mean	1.11e-07*	1.03e-10*	0.005087*

Table 2.5 P-values of the Starrigavan Creek t-tests of different substrate size criterion between sites. An asterisk next to the value indicates that the proportion of particles less than the specific criterion or the mean are significantly different (statistically) between the sites at a 5% level of significance (95% confidence level). The sample size for each site was 100 substrate particles (n=100).

The significance tests revealed that substrate less than 4 mm and 8 mm for the Starrigavan restored site were significantly different (95% confidence level) from both the undisturbed and disturbed sites (Table 2.5). The proportion of substrate less than each of the three size classes were not statistically different between the Starrigavan disturbed and undisturbed sites. All three of the substrate size classes (< 2, 4, and 8 mm) were significantly different between the Starrigavan disturbed and restored sites. When using the mean substrate size to compare the sites, both of the Starrigavan study sites (disturbed and restored) were significantly different from the undisturbed site and from each other. Additionally, an ANOVA that was carried out for the mean substrate values between all three sites indicated that they were significantly different at a greater than 95% confidence level (p-value of 2.19e-15).

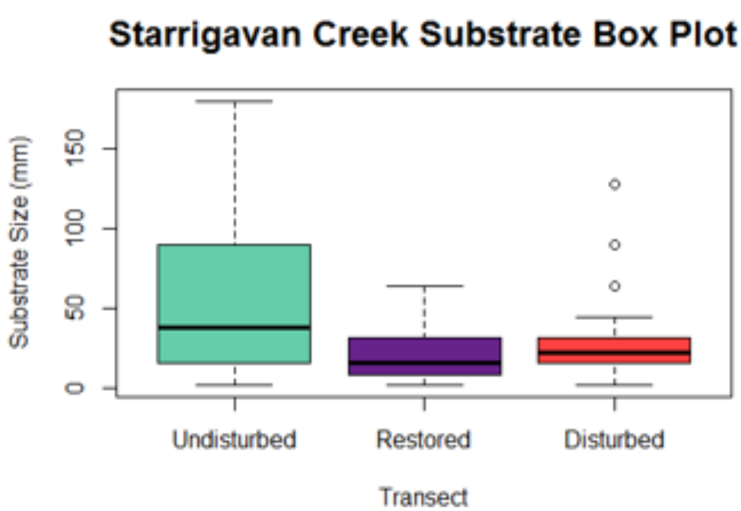


Figure 2.20 Box plot of the Starrigavan Creek substrate size data for the undisturbed, restored, and disturbed sites. The sample size for each site was 100 substrate particles (n=100).

The Starrigavan Creek substrate size box plot (Figure 2.20) displays another way to compare the Starrigavan study sites to the undisturbed site. The sites all had very different maximum, whisker, third quartile, and median values. The undisturbed site had the largest median substrate size and also the largest range of sizes of the three sites. The disturbed and restored sites were more similar to each other, with the median size being slightly smaller for the restored site.

The Starrigavan Creek substrate size histogram and cumulative particle size distributions (Figure 2.21) display the differences between the substrate of the three sites. The undisturbed site followed either a slightly exponential or linear cumulative distribution, had the largest proportion of large particles (>64 mm), and had fairly few small particles. The restored site followed a slightly logistic cumulative distribution, had fairly uniform numbers of most size categories, and was composed of higher proportions of smaller sized particles than the other sites. The disturbed site followed a logistic cumulative distribution with a high slope, had relatively low proportions of small (<16 mm) and large (>64 mm) particles, and was mostly composed of mid-sized particles (the 22.6 mm size class, in particular).

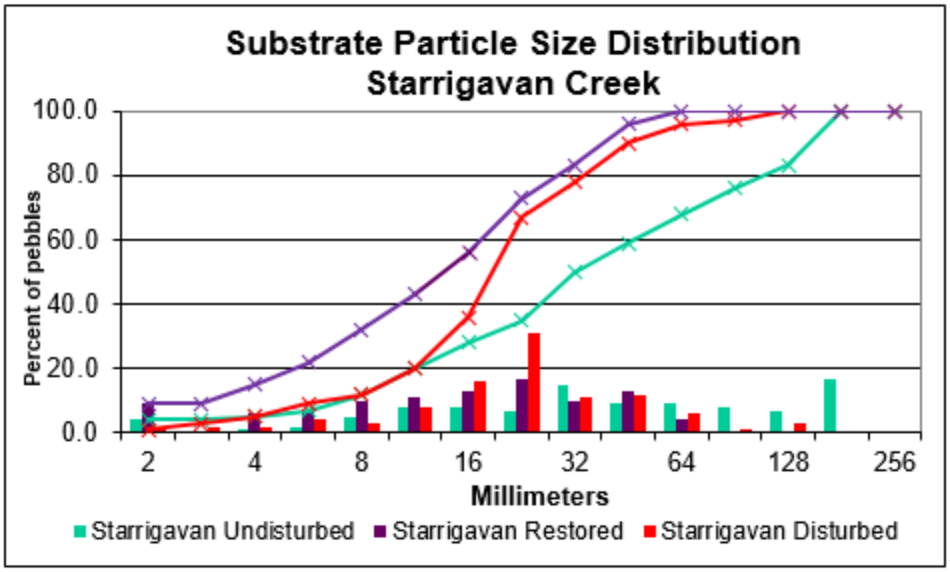
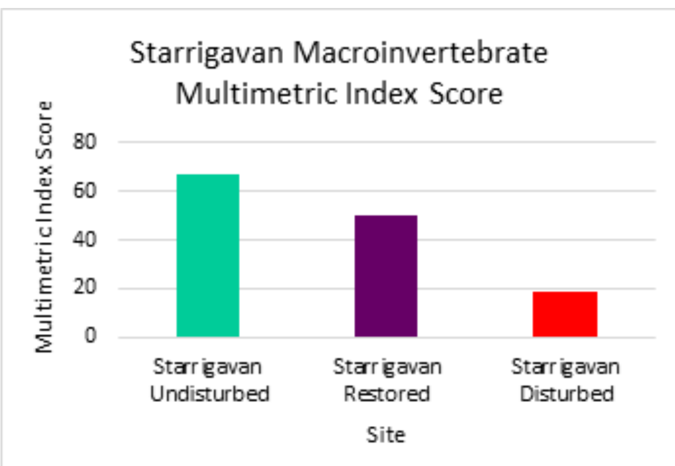


Figure 2.21 Substrate size histogram and cumulative particle size distributions for Starrigavan Creek's undisturbed, disturbed, and restored sites. The sample size for each site was 100 substrate particles (n=100).

Macroinvertebrates



For the Starrigavan sites, the undisturbed site (67.1) had the highest macroinvertebrate multimetric index score while the disturbed (18.5) had the lowest score (Figure 2.22). The Starrigavan restored site (50.4) had a higher score than the disturbed site, but a lower score than the undisturbed site. Based on these index scores, the Starrigavan undisturbed site was categorized as average quality whereas the restored and disturbed sites were categorized as poor quality.

Figure 2.22 Bar graph showing the results of applying the Macroinvertebrate Multimetric Assessment Index (Rinella et al., 2005) to the macroinvertebrate data collected for the Starrigavan undisturbed, restored, and disturbed sites. The data was collected by sampling one 25 meter long stream section for each site (n=1). Thus, a total stream area of about 53 m² was sampled for the Starrigavan undisturbed site, 50 m² for the Starrigavan restored site, and 50 m² for the Starrigavan disturbed site.

For the Starrigavan sites, the undisturbed site had the highest proportion of EPT and dominant taxa, but the lowest proportion of midges (Figure 2.23). The Starrigavan disturbed site had the highest proportion of midges, but the lowest proportion of EPT and the dominant taxa. These metrics indicate that the Starrigavan undisturbed site had the highest relative water quality while the disturbed had the lowest relative water quality. The undisturbed site had more total taxa and EPT taxa than the other sites (Figure 2.24). All three sites had the same number of non-EPT taxa. The Starrigavan disturbed site had the lowest number of total taxa and EPT taxa. These metrics indicate that for the Starrigavan sites, the undisturbed site had the highest relative water quality while the disturbed had the lowest relative water quality.

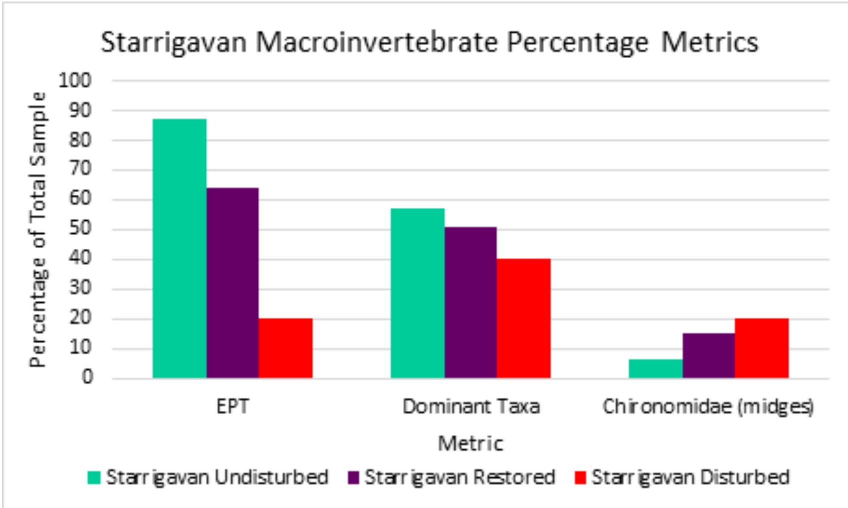


Figure 2.23 Bar graph displaying the percentage of macroinvertebrates sampled at each Starrigavan Creek site that were of the EPT group (orders Ephemeroptera, Plecoptera, and Trichoptera), dominant taxa of the site, or family Chironomidae (midges). The data was collected by sampling one 25 meter long stream section for each site (n=1). A total stream area of about 53 m² was sampled for the Starrigavan undisturbed site, 50 m² for the Starrigavan restored site, and 50 m² for the Starrigavan disturbed site. A total of 175 macroinvertebrates were collected for the Starrigavan undisturbed site, 78 macroinvertebrates for the Starrigavan restored site, and 10 macroinvertebrates for the Starrigavan disturbed site.

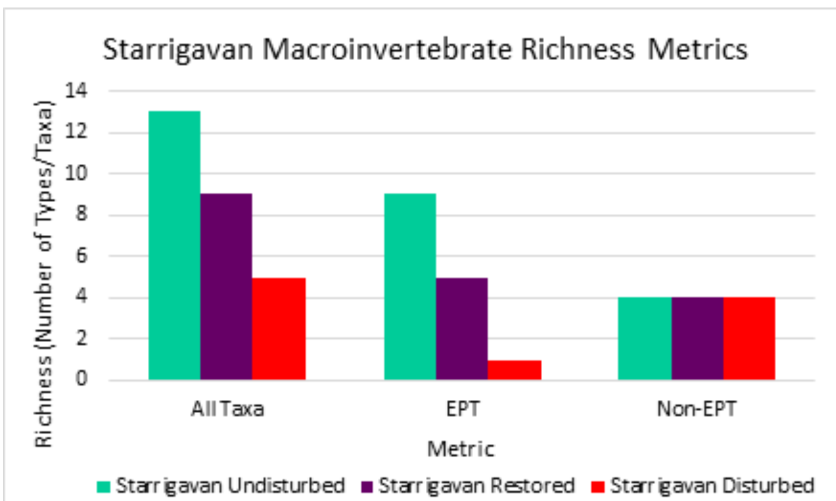


Figure 2.24 Chart presenting the number of overall taxa, EPT taxa (orders Ephemeroptera, Plecoptera, and Trichoptera), and non-EPT taxa sampled at each Starrigavan Creek site. Thus, a total stream area of about 53 m² was sampled for the undisturbed site, 50 m² for the restored site, and 50 m² for the disturbed site. A total of 175 macroinvertebrates were collected for the undisturbed site, 78 macroinvertebrates for the restored site, and 10 macroinvertebrates for the Starrigavan disturbed site.

Riparian Results by Indicators

Forest Composition

Data in the restored stands differ from the undisturbed in that alder is present. The data shows that hemlock is less abundant than spruce for both the smaller and larger size classes (Figure 2.25). Also, Figure 2.25 supports the conclusion that the regeneration of alder appears to be slowing in the restored stands due to the relatively small average abundance of alder saplings.

The undisturbed site shows a higher abundance of hemlock saplings than spruce saplings, but there are more spruce than hemlock in the larger size class (Figure 2.26).

Similar to the Starrigavan restored forest composition, alder is present in the disturbed sites, but the regeneration appears to be slow, with fewer saplings than adults (Figure 2.27). There are less hemlock than spruce in the disturbed sites, but spruce populations are larger in the disturbed sites compared to the restored. Sapling abundances of hemlock are also greater in the disturbed sites compared to the restored sites.

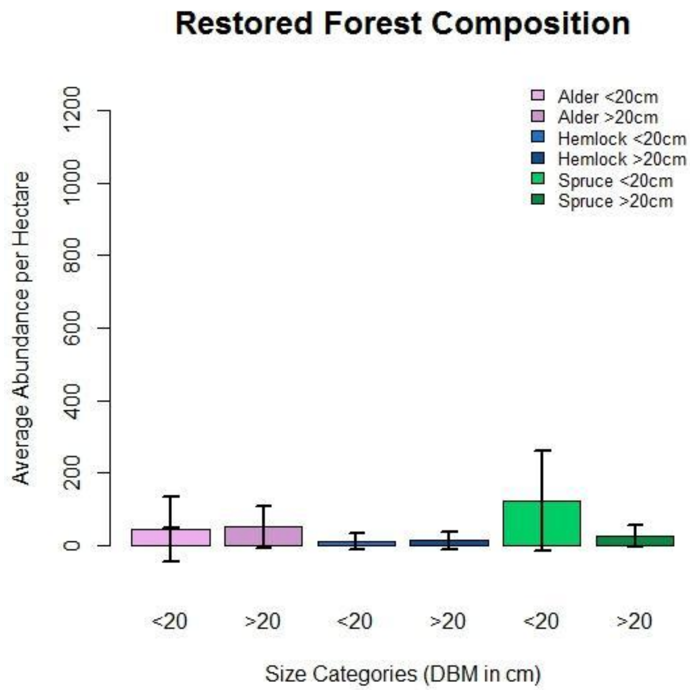
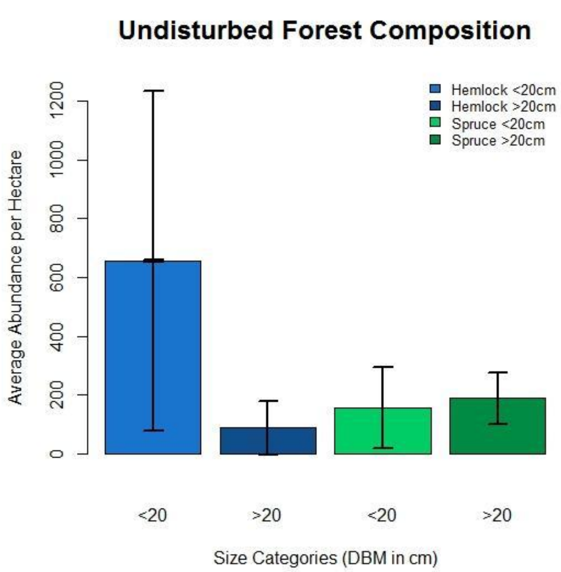


Figure 2.25 The abundance of different size classes of alder, hemlock, and spruce trees per hectare in the Starrigavan restored area. Individuals in the first size class for each species are taller than knee height and less than 20 cm DBH. Species in the second size class for each species are larger than 20 cm DBH. N=12 transects of 20x20 meters and a total of 4,800 square meters.



Forest Structure

Based on Figure 2.28, results indicate that the Starrigavan undisturbed and restored sites are of an uneven age structure whereas the disturbed site has an even age structure. An uneven aged structure is distinguishable by a large sapling size class (DBH <20 cm) and then less and less of each subsequent size class. Both the undisturbed and restored sites have higher average sapling densities than larger size classes.

In contrast, the disturbed site appears to have an even age structure because there is the same average abundance in the first two size classes. The disturbed site is likely in a stem exclusion phase where little light is reaching the understory because of the dense, even aged overstory. There are also less large trees and fewer saplings in the disturbed sites compared to the other two. The restored site's age structure indicates that there are less large trees, as exemplified by the lack of trees in the 60 to 70 cm DBH size class.

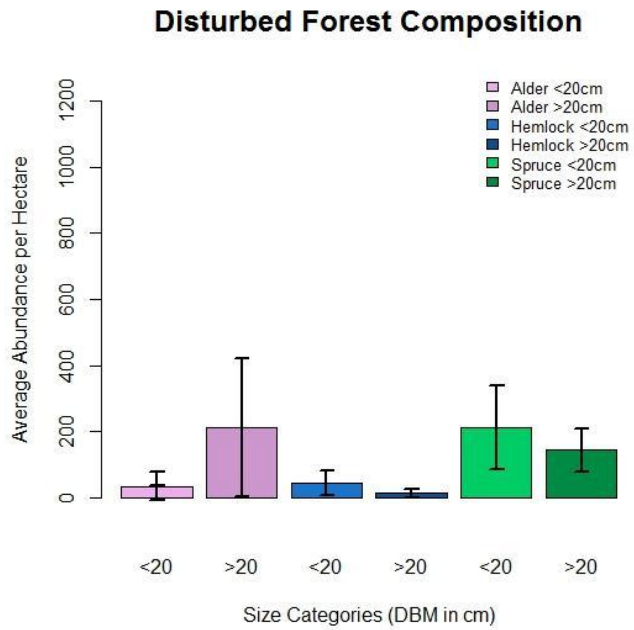


Figure 2.26 The abundance of different size classes of hemlock and spruce trees per hectare in the Starrigavan undisturbed stand. Individuals in the first size class for each species are taller than knee height and less than 20 cm DBH. Individuals in the second, third and fourth age class for each species are categorized in the larger than 20 cm DBH class. Size classes are in bins of 30 cm difference to simplify the graph but show forest structure.

Additionally, an ANOVA test of the overall size distribution (DBH) showed that there was no significant difference between the adult tree size of all three sites; disturbed, restored and undisturbed sites (p>0.05). T-Tests showed a significant difference between undisturbed and disturbed sites as well as between undisturbed and restored sites. No significant difference was found between the restored and disturbed sites, indicating that the restored site is more similar to the disturbed site than the undisturbed site. The undisturbed site has the largest amount of trees per hectare.

A Basal Area ANOVA showed no significant difference between the adult tree size of all three sites; the disturbed, restored and undisturbed sites. T-tests showed significant difference (alpha =.05) between undisturbed and disturbed sites as well as between undisturbed and restored sites. No significant difference was found between the restored and disturbed sites, again indicating that the restored site is more similar to the disturbed site than the undisturbed site. The undisturbed site has the highest basal area per hectare.

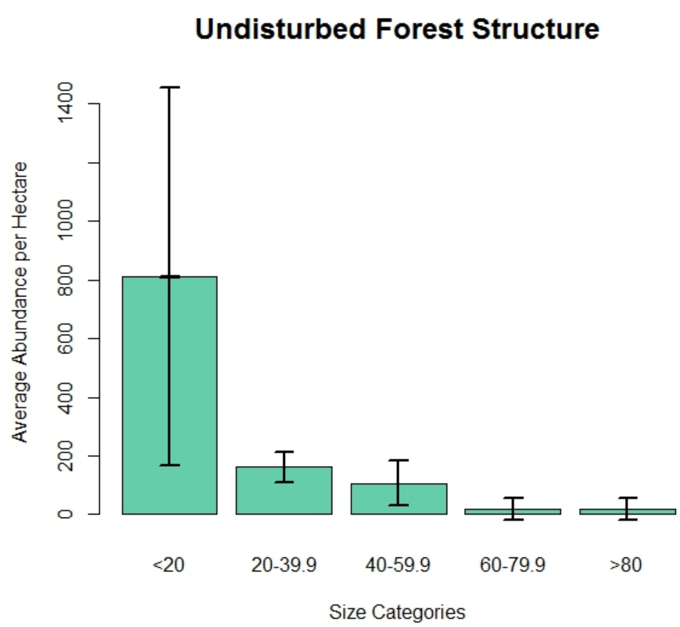


Figure 2.27 The abundance of different size classes of alder, hemlock, and spruce trees per hectare in the Starrigavan disturbed stand. Individuals in the first size class for each species are taller than knee height and less than 20 cm DBH. Individuals in the second, third and fourth age class for each species are larger than 20 cm DBH. Size classes are in bins of 30 cm difference to simplify the graph but show forest structure.

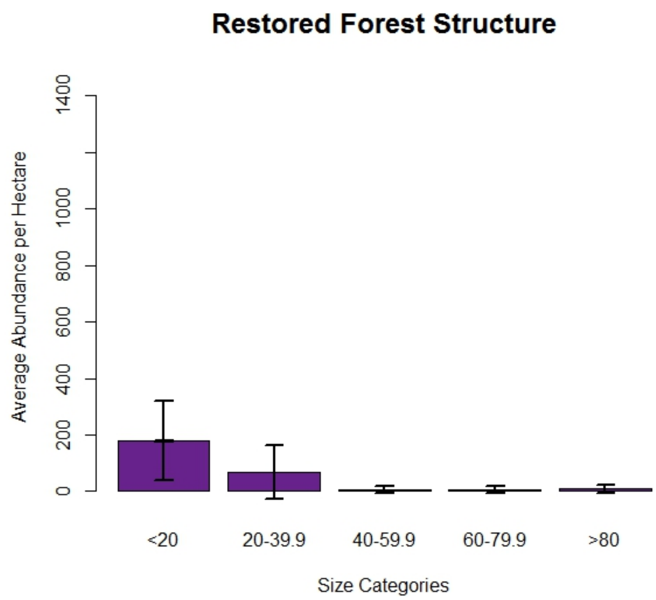
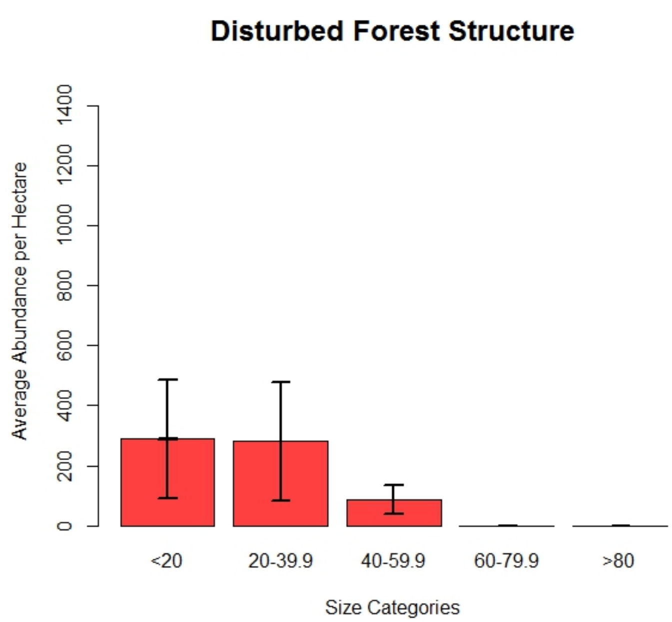


Figure 2.28 Bar graphs show forest structure by dividing trees abundance per hectare into size class bins. Size class is determined by diameter at breast height. Woody plants less than 20 cm were above knee height. Regenerative species; Alder, Spruce and Hemlock, are the species included. Each bin is the average abundance per hectare of trees. N=12 transects of 20x20 meters and a total of 4,800 square meters.



Understory Composition and Density

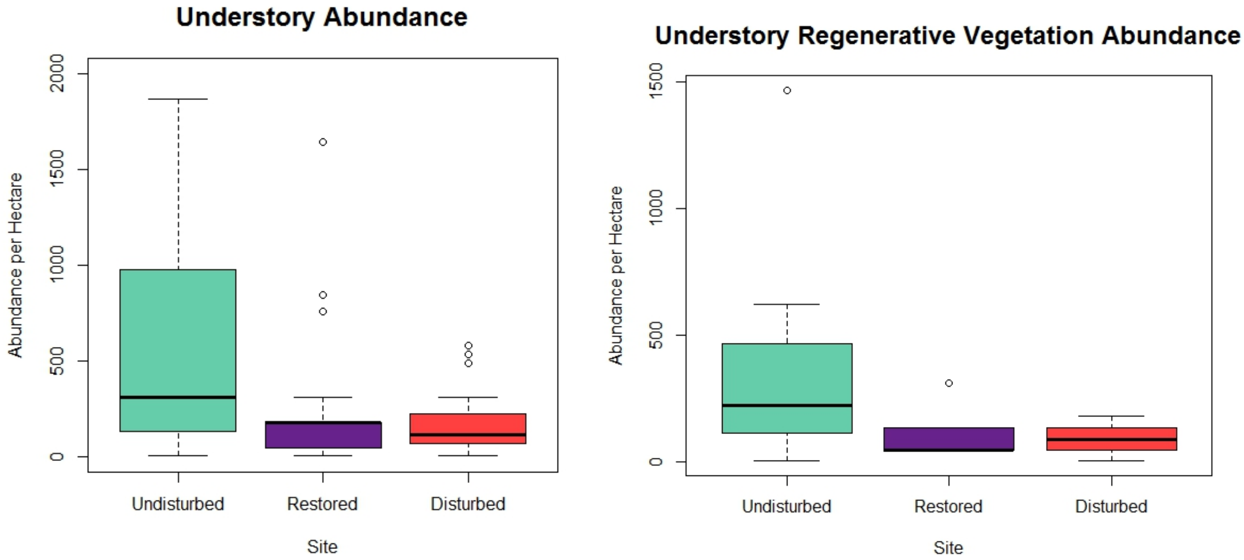


Figure 2.29 Comparison of the sapling density (abundance per hectare) of Starrigavan disturbed, restored and undisturbed sites. The total understory abundance of species less than 20 cm DBH and above knee height is shown. The regenerative vegetation is the density of juvenile woody trees (Elder, Sitka Spruce, and Western Hemlock). N=12 transects of 20x20 meters and a total of 4,800 square meters.

There are significantly ($p<0.05$) more understory species in the undisturbed site than measured in the restored or disturbed sites (Figure 2.29). Total understory species found in the restored site is not significantly different than found in the disturbed site. No significant difference was found between the abundance of regenerative species measured in the understory of each site. With that being said, there appears to be a higher average abundance of species that will regenerate the overstory in the undisturbed site than in the disturbed or restored sites (Figure 2.29).

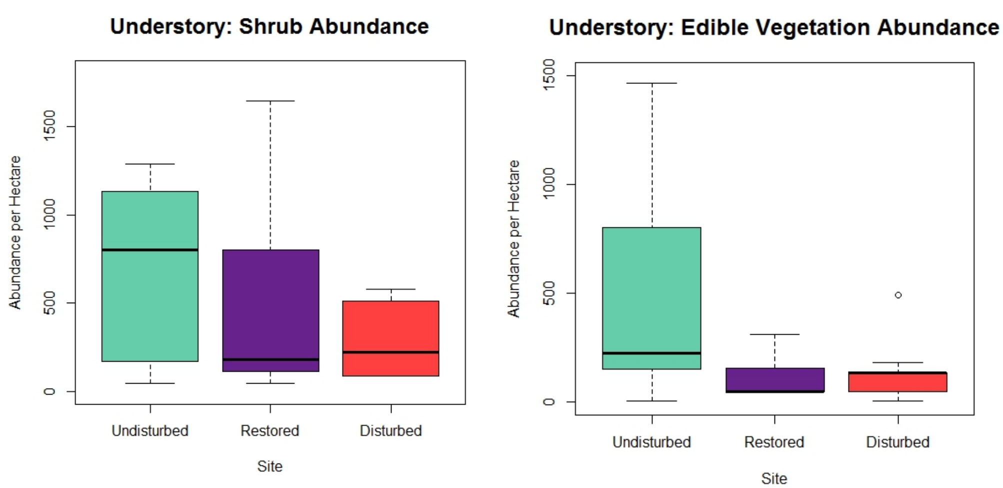


Figure 2.30 The abundance per hectare, in all three Starrigavan sites, of species that supply a food source for deer during the winter months are depicted in the edible vegetation graph and include Blueberry, Hemlock, and Spruce. Shrub abundance is the density of species that are less than 20 cm DBH and will never grow into the overstory (Salmonberry, Blueberry, Devil's Club, and Elderberry). N=12 transects of 20x20 meters and a total of 4,800 square meters.

An ANOVA test and individual t-tests show that there is no significant difference at the alpha ($p<0.05$) level between the understory total density of all three sites; the disturbed, restored and undisturbed sites. Still, the undisturbed site appears to have a much larger average abundance of edible vegetation than the other two sites (Figure 2.30). There is no significant difference in the average abundance of shrub species between the restored and the other two sites but a significant difference at the 90% confidence level was found between the undisturbed and the disturbed sites. The restored site is similar to both sites and has a large variability (Figure 2.30).

Snags

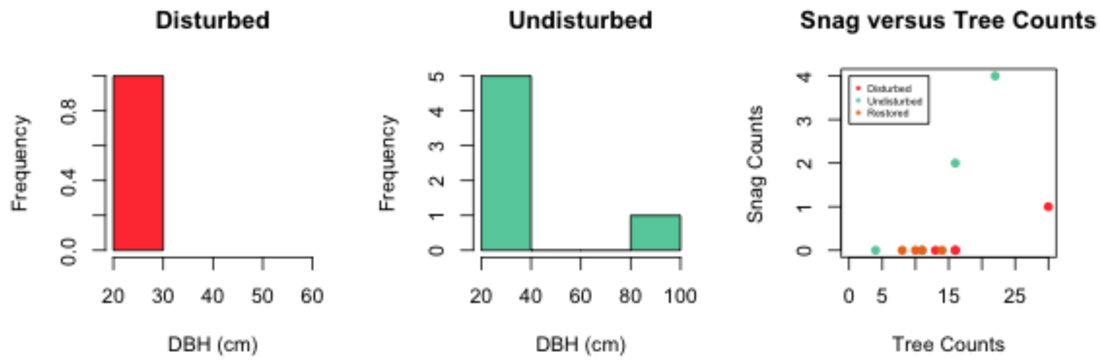


Figure 2.31 Plots of the frequency of snags per DBH ranges in the Starrigavan undisturbed and disturbed sites. The scatterplot compares tree counts and snag counts for the Starrigavan sites.

Since there was only one snag in the disturbed site and no snags found in the restored site, a t-test to compare the DBH measurements was not elaborated. Based on the results of snag vs. tree ratio t-tests, there were no significant differences in the snag to tree ratios of the three sites. In Figure 2.31, the number of snags and total trees for the undisturbed site have a positive linear relationship, in which more trees result in a higher snag count. On the other hand, the disturbed and undisturbed sites are similar in having little to no occurrence of snags no matter the number of trees.

Deadwood

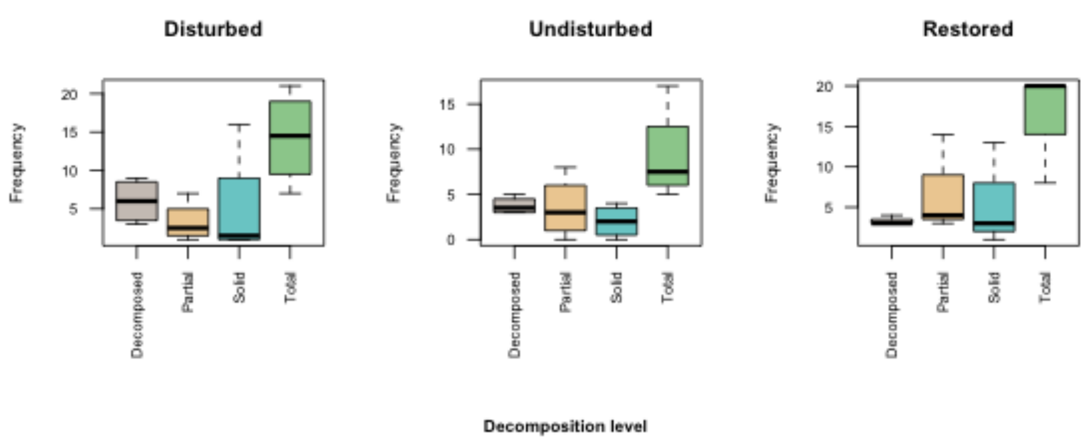


Figure 2.32 Boxplots for all three Starrigavan sites of the frequency of deadwood for each decomposition level that was assessed. Levels of decomposition assess, from left to right are: decomposed, partially decomposed, solid and then the total number of deadwood.

T-tests showed that there were no significant differences between the frequencies of deadwood within the riparian zones of the three sites. The plot for the disturbed site (Figure 2.32) shows that the amount of deadwood in the solid stage of decomposition varied more than in the other two sites. Additionally, for the restored site, the amount of deadwood in the decomposed phase had a smaller variability than in the other sites.

V. Discussion

A. Study Site: Shelikof Creek

Aquatic Discussion by Indicator

Overall, stream quality and channel structure depend upon a number of ecological variables. The wetted width to depth ratio determines the cross sectional channel shape of a stream. This, in turn, determines the maximum cross sectional flow that can be transported through a system (Brierley et al., 1996). In general, width to depth ratio provides an indicator of habitat quality, as the width and depth of a channel influences fish spawning and rearing. As found in the literature, the Rosgen delineation criteria assigns low width to depth ratio values at <12, moderate to high between 12 and 40, and very high at >40 (Flosi et al., 1998). Wide, shallow channels have high width/depth ratios; bank erosion tends to be high in these channels. A lower width todepth ratio indicates a more stable channel. Additionally, shade from riparian vegetation, cover from undercut banks, water velocity, and water temperature are all affected by the width to depth ratio.

According to the box plot for Shelikof Creek, the undisturbed site had a slightly lower mean ratio (around 40) compared to the disturbed site (around 50). The similarity in mean ratio values and the fact that the mean values were not statistically significant suggests an analogous/comparable stream structure between the undisturbed and disturbed sites, which may be due to similarities in stream location, slope, and elevation.

The width to depth ratio can also be used to indicate if erosion or aggravation is occurring in the channel, which is important since channel form, pattern, and fine sediment are key factors affecting fish habitat. Even though the results aren't significant, the fact that the disturbed site had a larger ratio (wider and shallower) suggests that it may be encountering some erosion of the banks or aggradation/accumulation of soils in the channel. Increased sediment yield to streams, if not scoured by seasonal flows, can result in streambed aggradation and the development of severe streambank instability. As sediments become deposited, the stream channel is forced to widen as the substrate surface level rises. When the channel width increases, the stream shallows and the surface area exposed to the sun increases in relation to the volume of water. This leads to potentially higher water temperatures and alterations in habitat suitability, species composition, and aquatic biomass (Flosi et al., 1998). Reductions in the presence of undercut banks, which are associated with higher width to depth ratios, minimize the amount of critical cover preferred by many salmonids as well (Foster et al., 2001). The higher width to depth ratio of the disturbed site suggests a relatively poorer habitat quality for salmonids compared to the undisturbed site. Overall, the width to depth data suggests that the undisturbed stream supports a slightly higher habitat quality for wildlife in terms of fish spawning habitat in comparison to the disturbed site and, thus, illustrates the need for additional management efforts to reduce the impacts of disturbances. Still, based on a lack of significance in the ratio between sites, it appears that the impacts of timber harvesting are no longer being observed on Shelikof, suggesting that the management of the land has been successful. Due to the nature of the disturbed site and need to prevent potential stream bank erosion, recommendations for management include the introduction of large woody debris into the stream to create the pools required for fish spawning and/or measures to prevent erosion and stream bank instability from propelling fine sediment into the stream and decreasing channel depth (Rinella et al., 2009).

Large and Key Woody Debris

When a large piece of wood enters and remains in a stream, it alters the flow of water in the channel, affects nutrient and sediment transport, and scours out pools which provide shelter for fish. In this regard, it can generally be said that a healthier stretch of stream should contain a greater amount of large wood. Large wood also provides habitat for fish and invertebrates, increases channel complexity, and provides food and allochthonous inputs for stream biota. Juvenile salmonid abundance in rivers, particularly juvenile coho salmon, is positively correlated to the abundance of LWD (Hicks et al. 1991). In small streams, LWD is a major factor influencing pool formation in plane–bed and step–pool channels. Bilby (1984) and Sedell et al. (1985) found that approximately 80 percent of pools within several small streams were associated with wood. The hydraulic complexity created by LWD encourages the capture and sequestration of other allochthonous inputs, making these materials more available to the food chain through both grazing and decomposition (Washington Department of Fish and Wildlife, 2009). In our results, however, the disturbed site exhibited a greater amount of large wood and, thus, exhibited the opposite result as was expected in terms of stream quality. The disturbed site contained a mean of 16 pieces of large wood per 20 m transect, whereas the undisturbed site contained a mean of 12. With that being said, there was no significant difference at the 0.05 alpha level in mean numbers of large wood between the sites.

The presence of greater amounts of large wood within the disturbed site could be attributed to the composition of the surrounding riparian vegetation. Approximately 70 percent of structural diversity is derived from root wads, trees, and limbs that fall into the stream as a result of bank undercutting, mass slope movement, normal tree mortality, or windthrow. Since alder trees characterize a shorter lifespan of 40-60 years and inhabit disturbed riparian and within-channel areas, large quantities of LWD could be deposited within the disturbed site and account for the discrepancy in results (Washington Department of Fish and Wildlife, 2009). This suggested reasoning is also supported by the high frequency of 0-50 cm DBH snags (~140) present along the riparian zone. The high frequency of dead standing trees allows for increased LWD deposits and, thus, a possible explanation for the greater amounts of LWD present in the disturbed site (Braudrick et al., 1997). Even though more large wood is present in the disturbed site, the fast decomposition and small diameter of alder does not provide as high quality habitat in comparison to the introduction of key woody debris, such as large conifers (Wipfli and Deal, 2004).

The main role of key wood in a stream includes stabilizing the stream channel and strongly influencing the deposition and transport of other pieces of large woody debris, thereby creating a debris jam (Opperman et al., 2006). The disturbed site exhibits a slightly lower amount of key wood present in the stream with a mean of 0.143 pieces per 20 m transect compared to the undisturbed with a mean of 0.5 pieces. The results signify a lower ability of the disturbed stream to trap woody debris, a process necessary for stream health and the creation of fish habitat. A possible explanation could include the lack of old growth trees present at the disturbed site due to timber harvesting and, thus, fewer sources of KWD that could fall into the stream.

Based on these results, recommendations for restoration efforts to Shelikof Creek include inputs of large and key woody debris from trees other than the short-lived and quickly decaying alder found in the disturbed stream riparian zones (Wipfli and Deal, 2004). Growing large dimension conifer trees along riparian zones, an active management effort, is one way to restore deficient levels of logs in streams. To augment inputs of woody debris, a predictable supply of logs from planting and thinning may be proposed. The restoration of native levels of conifers on hardwood and brush dominated alluvial surfaces is one of the primary objectives for this management technique. In this regard, slowly decaying, large, and long-lasting woody debris inputs from trees other than alder can aid in the creation of debris jams and pool formation to a previously disturbed stretch of stream and, in response, improve stream health and habitat quality (Berg, 1995).

Substrate

Substrate size is an important factor that directly impacts salmon and other aquatic biota in terms of cover, refuge from high velocity water, fish spawning and rearing surfaces, and rearing surfaces for invertebrate prey. Through pebble count procedures, substrate size data can be fairly easily collected and analyzed, providing valuable insight into the quality of stream conditions for fish and other biota. The Wolman pebble count was utilized in our analysis and is currently the most common method for characterizing substrate particle sizes. It is regarded as a quick, practical, and effective method for determining the mean substrate size of a stream or river (Daniels & McCusker, 2010). The Wolman pebble count also provides a reproducible method of producing grain size distributions and can be used in fish studies as an alternative to visual estimates (Kondolf, 2000). It has also been used to evaluate fine sediment deposition and other cumulative effects of a variety of land management activities and disturbance events (Olsen et al., 2005).

There are multiple potential biases of the Wolman pebble count, that have been discussed in the scientific literature, which could possibly limit the precision of our data. Potential sources of variability in results include substrate heterogeneity at a site, different substrate types among sample locations within a stream reach, substrate variability between streams, differences in when each sample was collected, variations in how different technicians picked up samples, and the consistency with which the intermediate axis of each particle was measured (Olsen et al., 2005). Additionally, the method was originally designed for determining the distribution of substrate present in large gravel-bed rivers with well-sorted materials (Daniels & McCusker, 2010). Thus, utilizing the method for other types of streams has the potential to result in improper conclusions. It has also been shown that the Wolman pebble count tends to under sample fine particles (<15 mm) and over sample larger particles. Studies have also indicated that significant variability occurs between replicate samples and when different operators sample the same location without a standard sampling template, such as a gravelometer. This variability was highest in estimates larger than D50 and in low order streams (Daniels & McCusker, 2010). These potential sources of variability and error could lead to incorrect results and management decisions if the pebble count data is not used with caution.

Taking into consideration these potential errors, we have employed techniques to minimize their impact on the results. To prevent error associated with different operators and measurement of the intermediate axis, we utilized a gravelometer. The gravelometer provided a hand-held template with square holes of different size classes to classify particles, acting like a sieve to sort particles (Stream Systems Technology Center, 1994). Rather than measure the intermediate axis of every particle with a ruler, the sampler instead found the smallest hole in the gravelometer that the particle fit through, minimizing operator error. It has been shown that gravel templates have mostly eliminated errors related to the identification of the intermediate axis and other measurement issues (Daniels & McCusker, 2010). We also attempted to minimize the other major source of error, variability in the selection process, by randomly selecting the first particle that was touched by the index finger of the sampler. It still must be acknowledged that potential biases in the selection process could have occurred (Daniels & McCusker, 2010). Additional actions that could be used in future work to reduce bias and variability include observer training, increasing the number of pebbles counted, assessing several riffles within each reach, evaluating the same site for multiple years, and conducting the counts for all of the sites in as short of a time window as possible (Olsen et al., 2005). In the end, we believe that our field methods were adequate to minimize biases and errors in our substrate samples, providing confidence in the relative accuracy of our substrate results.

Measures of substrate size, such as mean and median values, can be of great value in describing the habitat available to salmonids and invertebrates. A compilation of gravel sizes for spawning salmonids found that the median and mean gravel sizes used for spawning were 25 mm and 16 mm, respectively, and that substrate size was correlated to the size of the fish in the area (Keeley & Slaney, 1996). Both of the Shelikof sites had considerably lower median and mean values, which indicates lower than average spawning quality. With that being said, data sets have also shown that salmonids can utilize a wide range of mean and median substrate sizes, yet cannot adapt to high proportions of fine particles (Keeley & Slaney, 1996). This indicates that even though size metrics like mean and median can be valuable, the percentage of fine sediment is potentially the most valuable and impactful variable in terms of quality of habitat for salmonids.

Many studies have addressed the impacts of fine sediment on fish, particularly salmonids. Studies have found that most species of fish tended to be associated primarily with areas that did not have fine particles. This correlation could have been due to multiple reasons, including prey and egg health. Areas with low proportions of fine particles are believed to provide excellent rearing habitat for aquatic insects, which are then the primary food source for salmonids. Salmonids also require interstitial spaces between substrate particles in order to allow adequate water flow and oxygenation to eggs which are buried in gravel nests (Keeley & Slaney, 1996). Adequate space is also needed to carry off metabolic wastes from the eggs during incubation (Kondolf, 2000). Unfortunately, upstream land uses, such as timber harvest and road construction, have been known to increase the proportions of fine sediment and clog spawning gravels (Kondolf, 2000). These land uses contribute fine sediment by disrupting soils, removing vegetation, increasing soil hazard, and causing erosion and landslides (USDA Forest Service, 2006). A synthesis of published works on the effects of fine sediment on salmonids showed that embryo survival decreased significantly with larger percentages of fines (<6 mm) (Chapman, 1988). Increased mortality of embryos and decreased size at emergence with increased fines also occurred due to a reduction in permeability of water to developing embryos and lower oxygen levels (Keeley & Slaney, 1996). In the end, studies have shown that increased fine sediment generally has negative consequences for the fish community in the area.

Neither Shelikof site met any of the target values set for percent fine sediment or substrate in the preferred range. This suggests that at the time of sampling, there was not adequate oxygen availability for salmon incubation or emergence and not enough substrate in the suitable size range for successful spawning (Klein et al., 2007). Thus, these metrics indicate that both sites provide poor habitat for salmon spawning and egg survival. Both sites were composed of many small particles, as shown by the small mean, median, and dominant size classes as well as the large percentage of particles that were classified as fines. When considering that studies have verified the importance of fine sediment for salmonid spawning (Chapman, 1988; Keeley & Slaney, 1996; Kondolf, 2000; USDA Forest Service, 2006), these metrics imply that the quality of the substrate habitat for salmon and macroinvertebrates in Shelikof Creek is poor.

The above conclusions were unexpected based on the abundant populations of fish and macroinvertebrates that have been observed in Shelikof Creek and surrounding areas. One possible reason for the high levels of fine sediment could be the contribution of fine sediment to Shelikof Creek via landslides, which have been shown to occur on Kruzof Island in areas directly adjacent to streams. A 2004 inventory of landslides for the Sitka Ranger District identified 275 total slides in the Assessment Area of the Kruzof Island Landscape Assessment, with 21% of the slides reaching stream channels. The occurrence of landslides are impacted by slope, soil type, elevation, and aspect, and can also be caused by multiple management activities that have occurred around Shelikof Creek, including timber harvest and road construction (USDA Forest Service, 2006).

Another possible reason for the high levels of fine sediment and relatively small substrate size in Shelikof Creek, especially in the undisturbed site, includes the tendency of large woody debris to create a depositional environment which retains more bedload and particulates compared to areas without large wood (Washington Department of Fish and Wildlife, 2009). Thus, the large wood in the stream could be acting to trap smaller particles that would normally flow downstream, increasing fine sediment, but also positively increasing habitat heterogeneity and cover for fish and macroinvertebrates. The large wood sampling results do not support this hypothesis based on the fact that the Shelikof sites only had slightly more large wood and significantly less key wood than the Starrigavan sites, which had much less fine sediment. Additionally, the Shelikof disturbed sites had more large wood than the undisturbed sites. This would suggest that if large wood was significantly impacting the deposition of fine sediment, then the disturbed site would have had more fine sediment, which was not what the results indicated. Still, the large wood sampling did not take into account the location of the large wood in the water column, which could have affected whether fine sediment accumulation occurred. For example, multiple pieces of large wood resting on the bottom of the stream would tend to block sediment transport and retain fine sediment much more efficiently than multiple pieces scattered throughout the water column.

When comparing sites via the targets (Klein et al., 2007) and all other metrics, the disturbed site tended to have higher quality and substrate size compared to the undisturbed, which was also not expected. This could have been due to variables or activities that impact substrate size other than timber harvest, including the type of soil, soil stability, other past land uses, riparian vegetation, past occurrences of landslides, and slope of the surrounding land. Shelikof Creek has an interesting history of land use and soil type, which could have played a major role in the quality of the substrate habitat. Soils on Kruzof Island have developed from a number of loose and weathered mineral and organic parent materials. Types of mineral soil that exist in the area include volcanic ash, glacial till, alluvial, colluvial, and residual soils (USDA Forest Service, 2006). Also, even though the disturbed site appeared to have larger substrate sizes compared to the undisturbed site, significance tests and cumulative particle size distributions mostly suggested that the two sites were not significantly different from each other in terms of substrate size; only the proportion of particles less than 4 mm was significantly different between the sites. Thus, the appeared superiority of the substrate in the disturbed site compared to the undisturbed site may not be statistically true, with the sites in reality being fairly similar.

Further monitoring, including fish sampling, should be conducted to confirm our results and determine whether the poor substrate quality is significantly impacting fish and macroinvertebrate abundance. If these results are confirmed, then future restoration work will need to focus on increasing the mean substrate size and decreasing the amount of fine sediment in Shelikof Creek. Otherwise, there is the possibility that future work may fail due to the inability of salmonids to successfully spawn because of excessive amounts of fine sediment or lack of substrate large enough for spawning (Klein et al., 2007). Substrate quality can be improved by fixing eroding banks and preventing future erosion. This can be accomplished by armoring banks with natural materials such as rocks, vegetation, and/or woody debris. Additional engineered structures that can be utilized include log vanes, rock vanes, rootwads, coconut fiber rolls, and vegetated geogrids (Iowa DNR, 2006). Plantings and wood structures should be focused at bank areas that are bare and prone to erosion (erosional zones) due to the path of the streamflow. Increasing understory and overstory vegetation will also help prevent erosion by reducing excessive overland runoff into the stream. High flow events will eventually flush away finer sediment that is currently in place, but the key is to prevent those flows from introducing even more fine sediment via erosion. If erosion is stopped, then over time smaller particles will wash downstream, leading to increased substrate size, less fine sediment, and improved spawning habitat. Another potential option for improving substrate quality for spawning salmonids is the direct removal of fine sediment, which has previously been used to restore salmonid spawning grounds in the U.K. and Germany. This option, which could include using a powerful water blaster to wash away all fine sediment in a stream reach, has been shown to have positive short term impacts but is not a long term solution because it does not address the root cause of the high levels of fine sediment, is largely unstudied, and runs the risk of harming stream habitat and biota (Ramezani et al., 2014).

The fact that even the undisturbed site had a high proportion of fine particles implies that past timber harvest was not the reason for the poor substrate quality. Also, the potential biases in the Wolman pebble count procedure (Daniels & McCusker, 2010; Olsen et al., 2005), as discussed earlier, and the fact that we only conducted one sampling event per site, must be acknowledged when making conclusions from the data. If poor substrate quality is shown to have a negative impact on the biota of the stream in future monitoring, determination of the true cause of substrate issues in Shelikof Creek would be a high priority issue that could impact the type of management and restoration that should be conducted to enhance salmon habitat in Shelikof Creek. Monitoring after completion of the upcoming restoration work in Shelikof Creek should also be performed and combined with the data collected for this report in order to monitor possible changes in substrate quality. This could be helpful in advising future restoration work on Kruzof Island and other areas in Southeast Alaska.

Macroinvertebrates

Benthic macroinvertebrates are a well-known, widely used, and fairly quick and easy metric for assessing stream health and were utilized in this analysis to compare the quality of different streams and track changes through time. Macroinvertebrates were used because they display the cumulative impacts of contaminants, habitat alterations, and management actions over a longer time frame than other measures of water quality (ENRI, 2004). Macroinvertebrates are also helpful in comparing the quality of different sites because they are indicative of localized/site-specific conditions due to their limited migration patterns (Barbour et al., 1998). Finally, macroinvertebrates are used as indicators because they are plentiful in most streams, easily and inexpensively collected and analyzed, have a wide range of tolerances, tend to be relatively sedentary, and reflect the health of both primary producers and fish due to the linkage in the food chain (ENRI, 2004).

The macroinvertebrate metrics that were analyzed for Shelikof Creek suggest that the disturbed site was of higher water quality than the undisturbed site. This was not expected because macroinvertebrate quality normally tends to be higher in areas with less disturbance (Barbour et al., 1998). Through our analysis, the disturbed site was designated as high quality by the multimetric index, whereas the undisturbed was determined to be average quality. It is uncertain whether the differences between the sites were significant, yet it does appear that the disturbed site had substantially more pollution sensitive species. Overall, the water quality parameters and previous timber harvest in Shelikof Creek do not appear to be limiting macroinvertebrates due to the fact that both sites were determined to be of high or average quality.

There are multiple variables that could have impacted the macroinvertebrate community and led to our results, which have indicated that areas disturbed by timber harvest contained higher quality macroinvertebrates. One such variable is substrate size. Larger substrate size and less fine sediment in the disturbed site, detailed in the Shelikof Substrate section of this report, provides better habitat for macroinvertebrates and potentially fish. A second potentially important variable is the composition of riparian tree species in the disturbed site, which may provide more suitable allochthonous inputs for macroinvertebrates than in the undisturbed site. As described in the Shelikof Riparian results section of this report, the disturbed site included alders, an early successional deciduous tree, whereas the undisturbed site did not contain any alders and was instead dominated by only coniferous trees. Alders were primarily found immediately at the stream bank. An experiment by Piccolo and Wipfli on the impact of riparian red alder on stream macroinvertebrates and detritus exports from headwater streams was conducted on Prince of Wales Island in the Tongass National Forest of southeastern Alaska. The study concluded that young-growth alder sites contained significantly greater numbers and biomass densities of macroinvertebrates compared to young-growth conifer sites. The differences between sites were so great that they expected alder dominated sites to support almost four times more fish biomass downstream than the conifer dominated sites (Piccolo & Wipfli, 2002). Thus, the extensive amount of alder in the disturbed site and the quality of food and habitat it provides for macroinvertebrates could be the main reason for the higher macroinvertebrate scores in the disturbed site. Our results, supported by the results from the Piccolo and Wipfli study (2002), suggest that alder can provide valuable food resources for macroinvertebrates and fish in the stream that conifers in the area cannot, and thus should be considered and maintained in the management of stream riparian zones during the successional phase after timber harvest or other disturbances.

The fact that the disturbed site appears to have high water quality implies that the restoration will have the ability to succeed. In other words, increasing the amount of available fish and macroinvertebrate habitat with the addition of large and key wood will not be counteracted by poor water quality. On the other hand, the results may suggest that since the benthic macroinvertebrate community in our sample was already high quality in the disturbed site, it is uncertain whether the future restoration will improve their numbers or just provide more possible habitat for them and fish. There is also the potential for the restoration to disrupt the stream and cause a temporary, or possibly long-term, decline in macroinvertebrate quality (Palmer et al., 2005). Post restoration data will be needed to determine whether the quality of the restored streams improves, the restoration disrupts the biota of the stream, or no change is observed. Additional data will also make our results and conclusions more robust, potentially shedding more light on why the disturbed site appeared to have better water quality than the undisturbed site. Whether the disturbed site improves in the future will help determine if the restoration actions are improving habitat quality for macroinvertebrates and overall water quality or are just acting as potential habitat for fish.

Riparian Discussion by Indicators

Forest Composition

The first distinction between the overstory species composition of the undisturbed and disturbed forest stands is that alder only exists in the disturbed areas. As an early successional species that quickly colonizes areas that have been disturbed, it is expected to find alder in stands that were once clear cut harvested (Runkle, 1992). Alder saplings are rapid growers, but have a relatively short life span of about 40-60 years (Hanley, Deal, Orlikow et al., 2006). As nitrogen fixers, they are critical in improving soil health after a large scale disturbance, such as harvest (Batzli & McCray, 1998). The absence of alders in the undisturbed stands indicates that no large scale harvesting occurred in our reference stands, which was expected. A study conducted in southeast Alaska concluded that the presence of red alder in conifer stands is correlated with an increase in the abundance of understory species. An increase in the biomass of understory can increase the carrying capacity for deer, if the vegetation is edible during the winter months (Hanley et al., 2006).

A second distinction between the two stands is that the average density of spruce saplings is less than the larger size class in the undisturbed stands but smaller in the disturbed stands. A varied forest structure depends on a healthy and abundant sapling size class since mortality is high in the young vegetation. Larger spruce sapling densities in the undisturbed stands show a healthy ecosystem that has sufficient light for regeneration. Smaller spruce sapling densities in the disturbed areas indicates an uneven aged stand, which will be further discussed in the following forest structure section (Lieffers et al., 1999).

Hemlock sapling densities are higher than the larger size in both the undisturbed and disturbed stands, which indicate healthy hemlock populations (Lieffers et al., 1999). Spruce and hemlock differ in their regeneration adaptations. Hemlock tends to have higher recruitment densities but a higher mortality rate when compared to spruce. Spruce has less dense seedling and sapling populations but a higher survival rate and a faster growth rate when compared to hemlock (Kamal et al., 2007).

Although less dense populations of spruce are expected when compared to hemlock and, although there is no significant difference between spruce populations in the two sites, the spruce sapling population within the disturbed stands shows signs of poor regenerative ability. Management practices should focus on ensuring spruce sapling survival is increased by improving the forest structure to an uneven aged stand, discussed further in the next section.

Forest Structure

Results indicate that the disturbed forest structure contains fewer large trees, likely a lasting result of timber harvests in 1968 (USDA Forest Service, 2013). The age class of both the disturbed and undisturbed site appears to be of an uneven aged structure. The disturbed sapling size class is not as large as seen in the undisturbed site, which indicates that the stand isn't receiving enough light to successfully regenerate as much as in the undisturbed site. This is likely because the forest was once in a stem exclusion phase but began to self-thin, which allowed the understory saplings to regenerate (Aikman & Watkinson, 1980). A secondary factor is that alder's ability to increase sapling densities is allowing the understory to regenerate (Hanley et al., 2006).

Although the disturbed forest is not in a stem exclusion phase, the amount of saplings that can regenerate into the overstory is significantly less than in the undisturbed site (Lieffers et al., 1999). A stem exclusion phase can occur after a substantial disturbance, like a flood or clear-cut harvest, where most of the vegetation is removed. A forest must then begin recolonization and the majority of new species will begin growing at the same rate. Over time, species growing at the same rate will eventually dominate the forest canopy and stunt one another's growth. Additionally, an even aged forest will prevent regeneration of sapling species in the understory. Without successful recruitment and regeneration of understory species, a forest becomes less resilient to disturbances (Hardiman, Bohrer, Gouch et al., 2014).

In comparing the overall distribution of DBH values between the undisturbed and disturbed sites, a t-test reveals that there is a significant difference between the disturbed and undisturbed sites. The effects of timber harvesting in 1968 are having lasting implications on the overall size of trees in the riparian zone of Shelikof creek. The lack of a significant difference between basal areas of the undisturbed and disturbed sites shows that although there are fewer large trees in the disturbed forest, there are more small trees so the total volume is similar between the two sites.

To reduce the dense canopy that is shading out regenerative saplings, trees in the 20-30cm DBH size class should be thinned to mimic the heterogeneous forest structure of the undisturbed site. Studies show that partial thinning to create a heterogeneous and uneven aged forest structure will increase the understory densities of regenerative species. This has an additive effect of supplying vegetation that deer can forage in the winter months (Deal, 2001). A study in Montreal, Canada found that light gaps 1.5 times the average height of the surrounding trees had the highest success in understory regeneration (Gendreau-Berthiaume & Kneeshaw, 2009).

Understory Composition and Abundance

Results show that the undisturbed forest has a higher density of understory species than the disturbed forest, likely because the overstory is more varied and allows for more light gaps in the undisturbed forest (Lieffers et al., 1999). Data was further categorized to show the higher density of regenerative species, vegetative species and shrub species in the undisturbed sites. There are significantly more understory species that can regenerate in the undisturbed sites, indicating the lasting impacts from clear-cut harvesting practices on forest regeneration within the disturbed sites.

In the disturbed site, the large size class of trees in the 20-30cm DBH range diminishes the available light necessary for understory species. It is important for long term forest health that saplings of species like hemlock and spruce be in abundant densities so they can fill any gaps left in the canopy (Lieffers et al., 1999). With fewer regenerative species in the understory, the overall health of a forest is diminished. The overall health is diminished because, in the event of a large windthrow event and many fallen trees, without a dense regenerative understory invasive species could dominate in the new light gap (Hierros et al, 2011). This was observed with dense amounts of devil's club seen in disturbed sites A dense understory that consists of vegetative species, ones that provide a food source to deer during the winter months, plays an important role for overall ecosystem health (Hardiman, Bohrer, Gouch et al., 2014).

Studies show that deer prefer foraging in old growth forests during the winter because there is less snow, due to a full canopy and an abundant understory. Even-aged stands may act similarly to intercept snow due to their dense canopy, but if there isn't abundant edible understory vegetation, then deer populations in even-aged stands will have a lower carrying capacity (Alaskans & Barton, 2004).

To increase understory populations that include species that are edible or regenerative, light gaps could be created in the canopy. By creating an uneven aged stand in the disturbed forest, the understory will likely grow more abundantly (Deal, 2001). To ensure that successional species that populate light gaps are edible to deer and/or will regenerate the overstory, Vaccinium, hemlock and spruce could be planted.

Deadwood and Snags

Because deadwood is considered an important variable in characterizing old-growth forests and determining the gap phase dynamics of a forest (Wirth et al. 2009), it was expected that, for Shelikof, the percentage of deadwood found in the undisturbed site could be used as reference for the restoration. In terms of the count or frequency of standing deadwood, the undisturbed forest was expected to have a higher frequency of deadwood, both standing and fallen. Nevertheless, there was no significant difference between the disturbed and undisturbed stands. The higher frequency of deadwood in old-growth forests could normally be attributed to the forest structure, where the canopies are multilayered and deadwood is an indirect evidence of canopy mortality (Siitonen et al. 2000; Wirth et al. 2009).

For Shelikof, the lack of significant differences between the stands, in terms of frequency, could be endorsed to a number of variables. On one hand, specific environmental conditions in relation to physiological attributes of the trees found in the area could be resulting in a forest characterized by low deadwood values. This was seen in conifer-dominated boreal forests in Canada when compared to other surrounding forest types (Pedlar et al. 2002).

On the other hand, according to a study by Laussace et al. (2011) that compared deadwood and forest structure of different forest types in Italy, the quantity of deadwood in unmanaged forests represented about 30% of the forest's volume (using the live tree to standing deadwood ratio). Fridman and Walheim (2000) corroborated this value, where deadwood in managed forests represented 2% of the forest's volume. These numbers had a similarity to the snag to tree ratio found for Shelikof Creek. The disturbed site showed 7% of the volume of the forest, while the undisturbed showed a 23%.

Although there were no significant differences in the total amount of deadwood there were differences in the frequency of deadwood in each size class. In the disturbed site the small sizes were the most frequently found. Because the occurrence of deadwood can be indirectly related to canopy mortality and forest structure, this could be a reflection of the current age and species composition of the forest.

The large size gap also seen for the snags in the disturbed site for Shelikof may be describing the past history of clear-cutting since some bigger trees might have been left during this time and have died over time. The occurrence of snags from large size classes in the disturbed site may be an indicator that the there is no self-thinning mechanism happening here, where there is no pressure from the forest to create space in the canopy.

Comparing with the snags frequency distribution in the undisturbed site in Shelikof it shows that the undisturbed has a better representation of most size classes. It provides information of the “naturalness” of the stand, confirming that there was no history of management in this area (Lombardi et al. 2012). This also shows that the forest has a self-thinning phase and continuously creates gaps in the canopy, which is why there are fewer large snags found in the undisturbed.

When comparing living trees with standing deadwood for the undisturbed site, there seems to be a linear relationship, where the more amount of living trees the more amount of deadwood. This would confirm the state of self-thinning found in the forest. On the other hand, for the disturbed site, there seems to be no relationship between living and standing dead trees.

B. Study Site: Starrigavan Creek Discussion

Aquatic Discussion by Indicators

Width to Depth Ratio

Based on the width to depth ratio box plot for Starrigavan Creek, it appears that the restored site displayed the lowest width to depth ratio, with the ratios of the undisturbed and disturbed site being fairly similar (the undisturbed was slightly higher). No significant difference was found at the 0.05 alpha level in means for the width to depth ratio between the disturbed, undisturbed, and restored sites. These results suggest that there is an analogous/comparable stream structure between the undisturbed, restored, and disturbed sites and that the channel shapes are similar. In addition, this verifies the conclusion that the restored stream supports increased fish habitat quality compared to the disturbed site. This is due to the lower width to depth ratio, characterized by a narrower and deeper stream channel. With that being said, it is still important to remember that the mean ratios per site did not statistically significantly differ, indicating that the sites were all fairly similar in structure and quality.

Shade from riparian vegetation, cover from undercut banks, and water temperatures in pools are all affected by the width to depth ratio. A high width to depth ratio increases the water's exposure to solar radiation, resulting in potentially higher temperatures. Undercut banks are often reduced in high ratio stream channels as well, affecting critical cover preferred by many salmonids (Foster et al., 2001). In terms of habitat type and quality, the lowest ratio, found within the restored site, indicates lower salmonid exposure to solar radiation and, thus, lower water temperatures aiding in species survival. In addition, lower width to depth ratios are associated with decreased rates of sedimentation, allowing pools to form and be utilized by spawning salmonids in the restored site (Foster et al., 2001). The higher ratio in the undisturbed site in comparison to the disturbed site, however, proves counterintuitive. The assumed healthier overall quality of the undisturbed site would be expected to display a lower mean ratio, since it is believed that a lower ratio indicates a higher quality habitat for salmonids. A possible explanation for the disturbed site having a lower ratio could be a difference in channel structure within the disturbed stretch of stream. This portion of stream exhibited minimal water flow at 0.095 feet per second. Also, a greater presence of woody debris due to downed alder trees typically found within the riparian zone of disturbed sites could have contributed to changes in the stream channel structure by altering sediment transport and deposition (Foster et al., 2001).

Based on the results, recommendations for future management activities should aim to restore disturbed reaches to healthier environmental conditions than the undisturbed, especially since the disturbed and undisturbed ratios were so similar. One variable for restoration should include bank stabilization measures. Riparian areas that provide cover and food sources for juvenile salmon are destroyed by streambank erosion, which subsequently increases the transport and deposition of sediment. Spawning gravels subsequently become clogged with deposits of fine sediment and lead to reductions of salmon numbers due to habitat loss. Suggested restoration activities include the implementation of man-made bio-degradable logs made of coconut husks and woven into a round cylinder (bio-logs), freshly cut spruce trees cabled together in a bunch, or an engineered combination of bio-logs and cabled spruce trees installed together with willow plantings (Dorava, 1999). Another variable for restoration includes inputs of large and key woody debris for creation of salmonid spawning habitat from species other than quickly decomposing alder, such as conifer. Significant ecological downsides of alder include the lesser volume of large woody debris it provides to the channel system in addition to its short lifespan and faster rate of decay in comparison to conifers (Wipfli and Deal, 2004). On the other hand, alder inputs provide better food sources for stream biota and have been shown to increase macroinvertebrate and food sources compared to conifers. Though the disturbed site contains a slightly lower width to depth ratio in comparison to the undisturbed, other water quality parameters, such as macroinvertebrate composition, show the disturbed site as having the lowest quality with fewer total taxa, less pollution intolerant organisms, and more pollution tolerant midges than the other sites. In terms of flow, the disturbed site also had minimal water flow (0.095 feet per second) and discharge (0.47 cubic feet per second), contributing to the lack of macroinvertebrates and poor water quality. The recommendations must integrate a holistic approach to the improvement of stream health in order to create both healthy and productive streams in the long-term.

Large and Key Woody Debris

In Starrigavan Creek, the least amount of large woody debris was found in the disturbed site, with a mean of 10 pieces of large wood per 20m transect. The undisturbed site contained a mean of 13.25 and the restored site a mean of 11.75 pieces. No significant difference in mean pieces of LWD was found at the 0.05 alpha level between the disturbed, undisturbed, and restored sites of Starrigavan Creek. No significant difference in mean amounts of large wood between sample sites may either be due to the small size of the stream, preventing the accumulation and movement of large wood, or the similarity of the riparian zones in terms of tree composition and the number of trees falling into the stream. This data provides insight into the effectiveness of previous LWD input restoration efforts in Starrigavan Creek.

A greater number of snags (6) present in the riparian zone of the undisturbed site in comparison to the disturbed (1) could account for the greater number of LWD pieces in the undisturbed site and, thus, a greater habitat quality for spawning salmonids in terms of overall stream health and pool formation (Hicks et al. 1991). The similarity in numbers of LWD pieces between the disturbed (10) and restored (11.75) site, however, brings to question the success of the LWD input restoration techniques. Over time, the restored site should exhibit similar stream quality conditions to those of the undisturbed site. Possible explanations for the similarities in LWD presence between the disturbed and restored site could include, first of all, the minimal water flow (0.095 feet per second) in the disturbed site. A slow flow prevents the transport of large woody debris and aids in the accumulation of the woody debris from the upstream restored site. It is impossible to arrive at concrete conclusions without pre-restoration monitoring data, yet it appears from the initial macroinvertebrate and large wood data that the Starrigavan Creek restoration has been helpful in improving the quality of the restored site towards the goal of the undisturbed site. In terms of future recommendations for restoration, monitoring is necessary in order to assess the prevalence of pool formation from LWD deposits for salmonid spawning habitat. The shallowness of the stream reach, especially of the disturbed site, must be taken into account during the introduction process of LWD to the restored site. The slow flow and discharge could be impacting the streams response to the additions of LWD upstream and, thus, confounding the stream quality results.

In terms of key woody debris present within Starrigavan Creek, the least amount was found in the restored site (2.25 pieces per 20m transect), whereas the undisturbed site contained a mean of 3.5 and the disturbed a mean of 2.75 pieces. No significant difference, however, was found at the 0.05 alpha level in mean number of key wood between the disturbed, undisturbed, and restored sites of Starrigavan Creek. The main role of key wood in a stream includes stabilizing the stream channel and strongly influencing the deposition and transport of other pieces of large woody debris, thereby creating a debris jam (Opperman et al., 2006). The debris jam subsequently aids in pool formation and provides the woody debris necessary for salmonid spawning habitat. The results, however, prove counterintuitive. Though the disturbed site contains an expected smaller amount of KWD in comparison to the undisturbed site, due to the increased presence of LWD inputs from alder as opposed to KWD inputs from old growth conifers, the restored site displays a much lower KWD amount than expected (Washington Department of Fish and Wildlife, 2009). Restoration efforts to increase the presence of KWD by a few pieces to the restored site, as opposed to the introduction of many LWD pieces, would aid in debris jams and the creation of pools. The lack of key wood illustrates just one of the many negative impacts of previous timber harvesting. The confounding variable of low stream flow, however, still exists and requires future studies in flow monitoring and potential flow seasonality.

Substrate

In general, the Starrigavan Creek substrate data demonstrates that the undisturbed site had by far the highest substrate quality for salmon, which was expected. The fact that the undisturbed site had significantly higher quality implies that timber harvest may be the cause of more fine sediment and smaller overall substrate size in the other sites, and that the impacts of past timber harvest are still being observed. The disturbed and restored sites were fairly similar to each other, yet the data suggests that the restored site was the lower quality and had more small particles, which are expected to be harmful to fish (Chapman, 1988; Keeley & Slaney, 1996; Kondolf, 2000; USDA Forest Service, 2006). The undisturbed site had much larger substrate than the other sites, with all sites being significantly different from each other in terms of mean substrate size. The proportion of substrate less than 2, 4, and 8 mm were not significantly different for the disturbed site compared to the undisturbed. This indicates that the disturbed and undisturbed sites were not considerably different from each other in terms of the amount of small substrate. On the other hand, most of the size metrics were significantly different for the restored vs disturbed or undisturbed sites, indicating that the restored site had significantly more fine sediment than the other two sites and that the restoration activities have not successfully improved the quality of the substrate compared to a disturbed site. This was reflected in the percent fine and particle size distributions as well, which indicated that the disturbed site was mostly medium sized particles, the undisturbed was mostly large ones, and the restored had a lot of small particles.

If the goal for the proportion of fine sediment at each site was set as the value at the undisturbed site, the disturbed site would have adequate amounts of fine sediment whereas the restored site would have too much fine sediment. On the surface, this implies that the restoration is not having the desired impacts of increasing substrate size and decreasing the amount of fine sediment. Still, this cannot be said with certainty due to the lack of pre-restoration data. Even though the disturbed site was sampled in order to mirror the quality of the restored site prior to restoration, this comparison cannot be made with certainty due to additional factors that may impact each site differently. The restored site may have had even higher levels of fine sediment prior to the restoration or could be impacted by variables not addressed in the restoration. Another potential reason for why the restored site had the most fine sediment and smallest overall size could be that the restoration work disrupted the benthos of the stream and caused a temporary disturbance, which may still need time to naturally adjust back to normal conditions. Without pre-restoration monitoring we can only wait and see how the quality of the site changes in future years and whether any lasting harm to the stream occurred during the construction process (Palmer et al., 2005). Regarding the comparison between sites, it is still valuable to compare each site to the designated targets set for salmon habitat (Klein et al., 2007). All of the Starrigavan Creek sites had adequate oxygen availability for salmon incubation and emergence and more than enough substrate in the suitable spawning range. The only possible exception is that the restored site had more fine sediment <6 mm than desired for oxygen availability for emergence, yet it was reasonably close to the goal. Thus, even though the restored site had the highest amount of fine sediment, substrate does not appear to be negatively impacting or limiting fish hatching and survival in any of the Starrigavan sites that were sampled. This suggests that even though substrate size plays a major role in the quality of habitat for fish spawning and rearing (Chapman, 1988; Keeley & Slaney, 1996; Kondolf, 2000; USDA Forest Service, 2006), the success of future restoration work in Starrigavan Creek will not be inhibited by poor substrate size. Also, future restoration work does not need to focus on increasing overall substrate size or decreasing the amount of fine sediment. More productive work might be to prevent future disturbances from occurring in the area which would negatively impact the substrate of the stream, such as erosion, landslides, or timber harvest (USDA Forest Service, 2006).

Macroinvertebrates

The analyzed macroinvertebrate metrics indicated that the Starrigavan undisturbed site had average water quality, whereas the restored and disturbed sites were poor. The fact that the undisturbed site had significantly higher quality suggests that previous timber harvest may be the cause of the poorer water quality in the other sites and that the impacts of past timber harvest are still being observed. It appears that the disturbed was by far the lowest quality, with the restored site being in the poor category, yet not far from being average. The disturbed site had fewer total taxa, less pollution intolerant organisms, and more pollution tolerant midges than the other sites. The disturbed site also had minimal water flow (0.095 feet per second) and discharge (0.47 cubic feet per second), which could be a major reason for the lack of macroinvertebrates and poor water quality. Future monitoring is needed to determine whether the lack of water in the channel was an anomaly or a regular occurrence for the disturbed site. Adequate hydrology is necessary to support higher level functioning, such as natural geomorphology and biology (Harman et al., 2012). Thus, if the water level and flow is always low, any future work at that site needs to address the hydrology of the stream prior to attempting to add in-stream habitat features.

It is also important to focus on the quality of the restored site in order to assess the possible impact of previous restoration work. The results also indicated that even though the restored site was not as high of quality as the undisturbed, the restored site was more similar to the undisturbed than the disturbed. Large wood additions are expected to improve macroinvertebrate communities, but other studies have shown mixed results. There are examples of large wood additions that increased habitat and improved macroinvertebrate communities, resulted in no net change in populations, or led to a negative impact on stream macroinvertebrates (Washington Department of Fish and Wildlife, 2009). It is impossible to arrive at concrete conclusions without pre-restoration monitoring data, yet it appears from the initial data that the Starrigavan Creek restoration has been helpful in improving the quality of the restored site towards the goal of the undisturbed site. Future data will be instrumental in either confirming or denying this trend.

Overall, the data indicates that the presence and availability of macroinvertebrate prey and acceptable water quality should not be a problem for salmon and other fish in the restored and undisturbed sites, yet could be a problem in the disturbed site. Thus, focusing restoration work on increasing the amount and quality of habitat (large wood) available for fish and macroinvertebrates, rather than improving water quality, appears to be an effective approach that should be continued in areas with adequate hydrology. One potential reason that the restored site was not as high of quality as the undisturbed site, in terms of macroinvertebrates, could be that the restoration actions have disrupted the stream and caused a temporary decline in macroinvertebrates, which were still attempting to recover. With that being said, early results revealed that even though there was work in the stream, there were a significant number of high quality macroinvertebrates that were either unharmed or able to recolonize and take advantage of the large wood that was added. Even though the restoration appears to be successful in the short term, future monitoring is needed to determine whether the quality of the restored site will match the undisturbed site over time. These results will determine whether more work needs to be done or different techniques should be employed.

Future monitoring efforts should also include some sort of fish sampling in order to better understand the direct impacts of timber harvest and ecological restoration on the salmon fishery and habitat quality. This will add to the rigor of our results and allow the direct relation of restoration work to the abundance of fish, specifically salmonids. The impact of timber harvest or restoration work on salmonid populations is also much more relatable and easier to understand for most people in the area, especially those that rely on them for subsistence and/or income. Setting the sites we sampled in Shelikof and Starrigavan Creeks as fish sampling priority sites and coordinating with annual counts and snorkel surveys of Alaska Fish & Game and other groups would increase the odds that fish sampling will be conducted at these sites in order to better quantify the progress of the restoration work.

Riparian Indicators

Forest Composition

In comparing the forest composition found in the undisturbed, restored and disturbed sites, the most distinct difference is the presence of alder. Alder, a colonizing species found after disturbance, is found in restored and disturbed sites but absent from the undisturbed site (Malcom, 2001). This confirms that the undisturbed site wasn't clear-cut harvested and hasn't experienced large scale disturbances, whereas the other two sites have experienced disturbances. The second distinction within each site is the higher abundance of hemlock than spruce. This was expected because hemlock is a more shade tolerant species compared to spruce (Deal, 2001).

Forest Structure

Results show that the undisturbed forest structure is of an uneven age, but contains fewer large trees, possibly explained by the site's location. Since the Starrigavan campsite is easily accessible from Sitka, the diminished abundance of adult trees could be due to subsistence timber harvesting, see appendix 2A.

The disturbed forest structure signifies that an even aged stand exists with many species in the 20-30cm DBH size class. Low densities found in the sapling age class show there is little light for these young species, signifying that the forest is likely experiencing a stem exclusion phase (Lieffers et al., 1999). The lack of trees larger than 60 cm DBH highlights the lasting implications of timber harvests in the late 1960s (USDA Forest Service, 2013).

In comparing the restored forest structure with the undisturbed and disturbed, one can note that the sapling class is much larger than the disturbed site and appears to be in recovery. The presence of a few larger trees indicate that perhaps this stand wasn't as affected by timber harvests as the disturbed stand. Although the overall size distribution differs significantly from the undisturbed stand, the restored stand is also of an uneven age. No significant difference was found between the restored and disturbed stands which indicates that the restored site is more similar to the undisturbed site in terms of forest structure. Restoration efforts aiming to thin and open the canopy has allowed the understory to grow more abundantly, and created a homogeneous forest structure (Lieffers et al., 1999).

Similar restoration measures could be pursued in the disturbed stands. The slight increase in the amount of trees in the 20-40cm DBH show that those trees could be reduced. Since significant difference was found in overall size distributions between the undisturbed stand and the other two stands, the restored and disturbed forest are still experiencing the effects of timber harvests. Thinning the canopy where over-abundances are noted in size class, such as in the 20-40cm DBH size class, is recommended to both open up the canopy, allow for regeneration, and provide deer with sufficient vegetation (Deal, 2001).

Understory Abundance and Composition

The significant difference between the undisturbed stand and the other two stands signify that the understory hasn't recovered from the effects of timber harvesting. Although there were more species that will provide a food source to deer in the restored stand than the disturbed, there are very few species that will regenerate the overstory or provide edible vegetation for deer in the restored stand. The low densities of understory species is likely due to the even age of the overstory, preventing the creation of light gaps in the restored and disturbed forest (Kamal et al., 2007).

The high densities of devil's club, salmonberry, elderberry and blueberry could pose a threat to species that would regenerate the overstory, such as hemlock and spruce. Without an understory that can regenerate the overstory, when a light gap opens in the canopy, the understory will fill with more shrub species and the overall forest health will be diminished (Dodson et al., 2014). Additionally, edible understory vegetation like blueberry, hemlock and spruce that would provide a food source for deer during the winter months are less dense in the restored and disturbed sites. The similarity of the understory composition in the restored site to the disturbed site signify that restoration efforts haven't made a significant effort in improving the habitat quality or long term regenerating health of the forest.

Salmonberry and elderberry are used for berry picking by nearby residents. From the community engagement portion of our study, we found that deer hunting was ranked as more important than berry picking. Since deer depend on blueberry, we recommend favoring blueberry over salmonberry and elderberry.

Since the restored site has significantly less dense amounts of edible vegetation and regenerative species as compared to the undisturbed site, it can be concluded that the effects of restoration haven't improved the understory composition. Restoration efforts should focus on improving the overall densities of understory regenerative species. With high levels of competition from vegetative species like devil's club, blueberry and salmonberry, it is important to not only open the canopy to allow sapling development, but also to plant hemlock and spruce after removing shrub species.

Snags and Deadwood

For Starrigavan the volume of deadwood in each of the sites studied differed from what was found in Shelikof. In Starrigavan, the undisturbed site had a deadwood volume of 11% which, according to the 30% of deadwood volume found by Fridman and Walheim (2000) for unmanaged forests, was significantly lower. The disturbed site showed a deadwood volume of 1.3% and the restored had no snags.

Laussace et al. (2011) determined that areas that were closer to populations had a decrease in the volume of total deadwood found, where the local populations could remove wood residue and coarse woody debris for firewood. The residents of Sitka have historically used the resources on Starrigavan for their subsistence needs. The degree of removal of firewood is uncertain for this area but results found in the social survey suggests that firewood is being collected for personal use. Therefore, if timber harvesting continued to be an ongoing occurrence, firewood may have been removed from the undisturbed area.

The deadwood patterns for Starrigavan were similar to those observed for Shelikof Creek. The frequency distribution for the undisturbed site in Starrigavan showed a wide range of size classes with a descending distribution towards the larger classes. In this case, there was also a wider range of size classes than in Shelikof, with snags over 80 cm DBH (the disturbed showed a range of snags going over 60 cm DBH). The size age pattern seems to be an indication of the type of management that has been occurring in this area, since according to Lassauce et al. (2011) removal of deadwood is evident in unmanaged forests for decades.

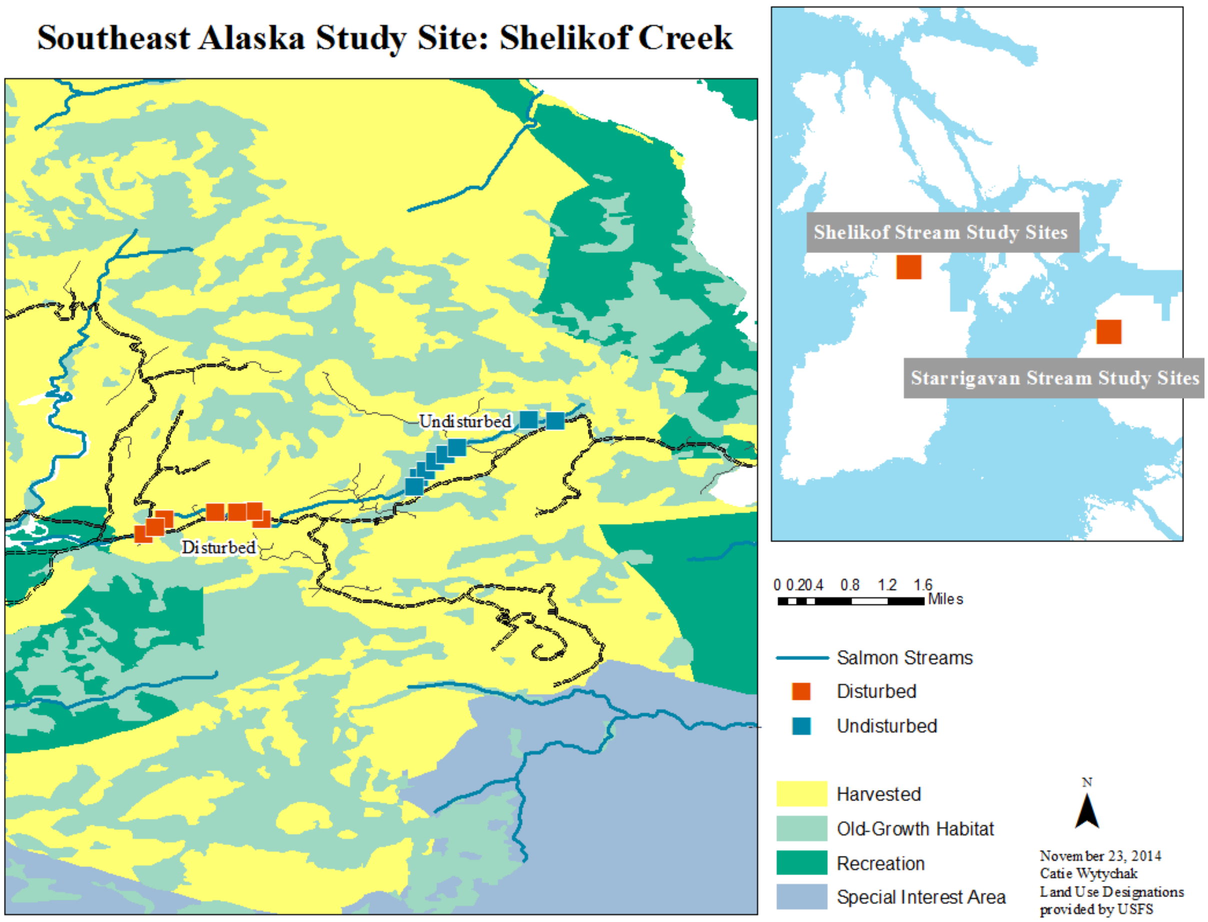
V. Conclusion

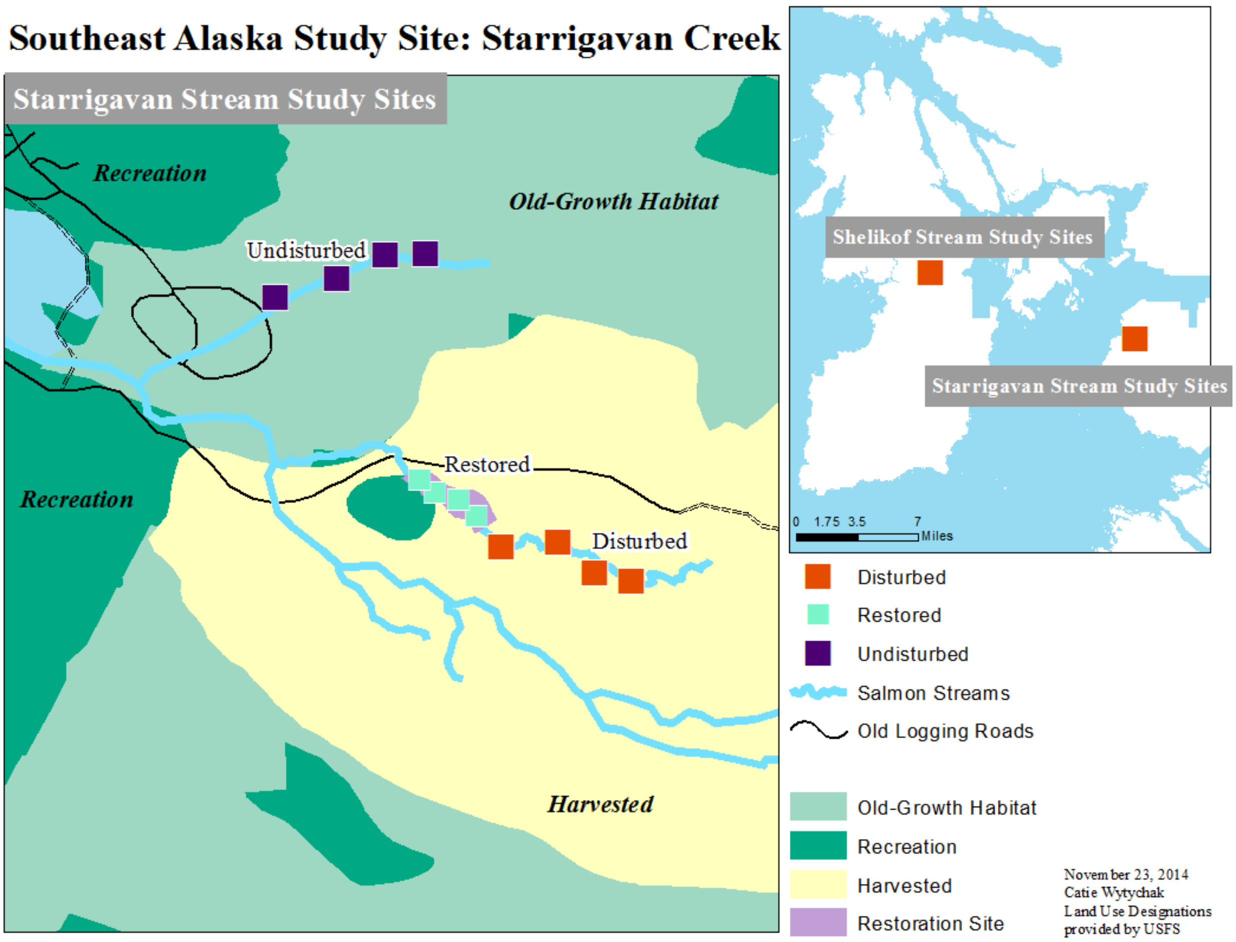
The community engagement portion of our study found that there is widespread support for restoration practices that aim to improve the overall ecosystem health for subsistence and recreation purposes. In assessing the riparian and aquatic habitat quality, we found that the impacts of the clear-cut harvest in 1968 continue to be evident. Restoration efforts appear to have improved the forest structure and macroinvertebrate communities, where significant differences were found between the undisturbed and restored sites. Other indicators show improvement though are not statistically different from the disturbed sites, potentially due to time constraints or variables not measured. Although the disturbed sites served as our baseline, we did not have data from pre-restoration, so our conclusions are not comprehensive. Our overall recommendations for improved land management can be found in the executive summary.

Future restoration work should incorporate monitoring data and adaptive management. Monitoring plans which can be used by volunteers or students groups can be found in the education chapter of our report.

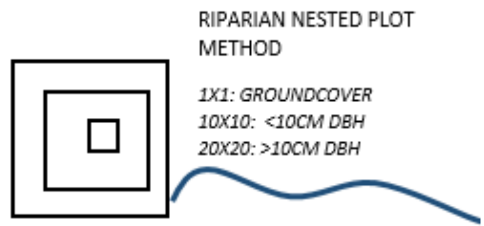
Restoration Assessment Appendices

2A. Land Use Designation and Harvested Stands in Study Sites




Southeast Alaska Study Site: Starrigavan Creek
Starrigavan Stream Study Sites
Recreation
Old-Growth Habitat
Undisturbed
Restored
Recreation
Disturbed
Harvested
Shelikof Stream Study Sites
Starrigavan Stream Study Sites
0 1.75 3.5 7
Miles
Disturbed
Restored
Undisturbed
Salmon Streams
Old Logging Roads
Old-Growth Habitat
Recreation
Harvested
Restoration Site
November 23, 2014
Catie Wytychak
Land Use Designations
provided by USFS

2B. Stream & Riparian Data Sheet



GENERAL INFORMATION			
Transect No		Weather Conditions	
Date		Air Temperature	
Initials		Water Temperature	
Elevation		Photograph Taken	

AQUATIC DATA		
Condition	**Circle All that Apply**	**Notes**
Bank Condition	Exposed or Natural	
Woody Debris	Fallen, Log Complex, Brush, Overhanging Vegetation	Measure diameter or area:
Substrate	Bedrock, Boulder, Cobble, Sand, Silt, Mud, Not Visible	[Pebble test notes in field journal]
Barriers to Flow	Presence or Absence	Type:
Fish	Presence or Absence of actual fish, carcasses or redds	
Wildlife	Presence or Absence	Type:
Stream Depth & Flow	Depth [m] Flow 1. 2. 3. 4. 5.	

RIPARIAN DATA							
Site [Reference, Disturbed, Restored]	**Grid Point**	**Quadrat Size [1, 10, 20]**	**Species**	**DBH**	**Coordinates**	**Tree ID #**	**Grid Point**

Alaska Stream Team Educational Level Water Quality Monitoring Field Guide:
http://aquatic.uaa.alaska.edu/pdfs/EducationLevelBioMonitoringMethods.pdf

2C. Stream Methods Data Sheet Description of Variables

- Bank condition- Whether the bank was exposed/eroded or natural/vegetated/undercut.
- Woody debris- All of the different types of woody debris in the bankfull width of the designated reach of the stream. The possible types include fallen log, log complex, brush, and/or overhanging vegetation. The quantity of each of these types did not matter, just whether they were present.
- Number of large wood- The approximate number of large wood pieces within the bankfull width of the 20 meter reach. The piece must be at least 0.1 m in diameter (using DBH tape at widest part) and 1 m long in order to be considered large wood (Nichols et al., 2013).
- Number of key wood- The approximate number of key wood pieces within the bankfull width of the 20 meter reach. The size of a piece, in order to be considered key wood, depended on the width of the stream. The following chart was used to determine what was considered key wood (Nichols et al., 2013).

Channel width (m)	Wood diameter (m)	Wood length (m)
0-4.9	0.3	> 3
5-9.9	0.3	> 7.6
10-19.9	0.6	> 7.6
> 19.9	0.6	> 15

- Substrate- The dominant substrate types within the stream reach. More than one type could be selected. The substrate types are bedrock, boulder, cobble, sand, silt, mud, and not visible.
- Fish? - A pool or snag, within the reach, was observed for one minute while standing still. It was then marked whether or not the presence of a fish was observed and whether it is an actual fish, carcass, or redd.
- Wildlife- While performing the stream and riparian observations, we kept an eye out for any signs of wildlife. If there was a sign of wildlife, then we recorded what type and whether it be an actual animal, feces, tracks, or carcass. Birds were not considered wildlife for this part. The wildlife could be observed in the stream or in the riparian plot area.
- Location of width and depth measurements- The width and depth measurements needed to be taken at a riffle in order to be used for determining the wetted width-to-depth ratio. The ideal location was at the waypoint or within the designated reach, but if there were not any riffles within that area, then it was acceptable to find the nearest riffle. We made sure to note the location, relative to the waypoint, of the area that was measured. We did not measure a cross-section that has a pool, which would skew the results, and only measured the wetted channel.
- Stream width- The width of the wetted channel at the determined riffle cross-section was measured. The width was recorded in feet and inches and then converted to inches later.
- Stream depth- The depth of water along the determined riffle cross-section was measured at many points along transect. The depth was measured about every foot in a small stream and every three feet in a large stream. The depths were then averaged to get an average depth in feet and inches. The depths were recorded in inches to make the conversion easiest.
- Wetted width to depth ratio- Once all the data had been recorded and the depths were averaged, the dimensionless width-to-depth ratio was calculated by dividing the average width by the average depth.
- Notes/description- It was important to write down any additional observations in an attempt to describe the channel or anything that might've been important. Some possibilities included describing the slope, habitat types, relative substrate size, flow speed, water clarity, types of large wood, amount of pools, or anything else that helped us better understand the reach. This was also a good place to try to qualitatively describe the stream in an effort to help those reading the data in the future understand what we were observing.

2D. Shelikof Creek & Starrigavan Creek Aquatic & Riparian Summary Results

Shelikof Aquatic	Sample Size	Undisturbed	Disturbed
Sediment Mean	100	10.446 mm	12.718 mm
% Fine (<2 mm)	100	27%	17%
% Fine (<6 mm)	100	63%	47%
% Preferred range (13-128 mm)	100	19%	32%
Dominant Size Class	100	<2 mm	<2 mm
Median Sediment	100	4.12 mm	6.49 mm
D84	100	12.99 mm	21.51 mm
Large Wood/20 m	8	12	16
Key Wood/20 m	8	0.625	0.5
Macroinvertebrate Multimetric Index	282 m^2;414 m^2	60.513876	84.879727
Taxa Richness	283 m^2;414 m^2	12	12
EPT Richness	284 m^2;414 m^2	6	11
Non-EPT Richness	285 m^2;414 m^2	6	1
% EPT	286 m^2;414 m^2	0.77	0.9912
Width to Depth Ratio	8	37.18	58.04
% Sites with Fish	8	0.625	0.25
Average Water Temperature	8	7.78 C	7.99 C
Average Air Temperature	8	12.36 C	12.43 C
DO Saturation %	1	0.85	0.96
Flow Rate	3	1.21 ft/sec	0.95 ft/sec
Bank Condition	8	75% natural	75% natural

Shelikof Riparian	Undisturbed	Disturbed
Diameter of Adult	50.11 cm	32.69 cm
Age Structure	uneven	uneven
Most common understory species	Vaccinium, Hemlock & Spruce	Vaccinium, Salmonberry & Spruce
Snag Abundance	26	8
Dead Wood Abundance	16.26	11
Percent Plant Groundcover	11.5	18.44
Basal Area/1km2	7,770.16	3,338.61
Average Understory Abundance	118.17	91.1

Starrigavan Aquatic	Sample Size	Undisturbed	Disturbed	Restored
Sediment Mean	100	65.744 mm	28.566 mm	20.354 mm
% Fine (<2 mm)	100	4%	1%	9%
% Fine (<6 mm)	100	7%	9%	22%
% Preferred range (13-128 mm)	100	63%	80%	57%
Dominant Size Class	100	128-181 mm	16-22.6 mm	16-22.6 mm
Median Sediment	100	32 mm	18.7 mm	13.46 mm
D84	100	130.59 mm	38.07 mm	32.87 mm
Large Wood/20 m	4	13.25	10	11.75
Key Wood/20 m	4	3.5	2.75	2.25
Macroinvertebrate Multimetric Index	~50 m^2	67.132564	18.45459	50.38647
Taxa Richness	~50 m^2	13	5	9
EPT Richness	~50 m^2	9	1	5
Non-EPT Richness	~50 m^2	4	4	4
% EPT	~50 m^2	0.8743	0.2	0.641
Width to Depth Ratio	4	34.92	32.33	22.4
% Sites with Fish	4	0.25	0.5	0.75
Average Water Temperature	4	9.58	10.14	9.03
Average Air Temperature	4	16.25	17.23	16.81
DO Saturation %	1	0.88	0.71	0.72
Flow Rate	3	1.71	0.095	0.43
Bank Condition	4	100% natural	25% natural	75% natural

Starrigavan Riparian	Undisturbed	Disturbed	Restored
Diameter of Adult	41.9	32.6	29.6
Age Structure	uneven	even	uneven
Most common understory species	Salmonberry	Salmonberry	Salmonberry
Snag Abundance	6	1	0
Dead Wood Abundance	9.25	14.25	16
Percent Plant Groundcover	20.4	8.9	10.08
Basal Area/1km2	1619.3	930.2	895.9
Average Understory Abundance	14.9	5.87	9.43

Chapter 3 | Place-based Environmental Education

Sitka, Alaska

Education Team Members: Esther D'Mello and Amanda Harvanek

I. Background

Students in the United States often lack a strong relationship with nature, tending to spend the majority of their time indoors, both at school and at home. This is often called "nature deficit disorder" (Louv, 2005). Exposure to environmental education in the typical American classroom occurs intermittently over a child's education through an occasional field trip to an aquarium or in a single environmentally-focused course (Elder, 2003). However, a review of multiple studies shows that integrating environmental education into school curricula results in improved scores on standardized measures of academic achievement, reduced classroom management issues, and improved student GPA (Duffin et al., 2005).

Sitka, Alaska's setting as a subsistence community in the Tongass National Forest provides an excellent opportunity for place-based environmental education. The Sitka Conservation Society engages students and community members of all ages in numerous environmental education activities throughout the year. These activities take place both within schools and throughout the community.

One existing environmental education effort conducted by the Sitka Conservation Society is a program called Stream Team. The classroom component of this program teaches students about stream ecology and salmon habitat. This is paired with a field trip which brings 7th grade students from Sitka to Starrigavan Valley to conduct and monitor stream restoration efforts. The Sitka Conservation Society sponsors Stream Team with support from several other partners, including the Sitka Ranger District, the Sitka School District, the Alaska Department of Fish and Game, and the National Park Service.

Students are also able to work closely with local scientists through the Sitka Conservation Society's Science Mentor Program. Students engage in a variety of research activities with local scientists and research questions are selected by the student and mentor in order to address a relevant local environmental issue. The Sitka Conservation Society organizes the Science Mentor Program with support from several other partners, including the Sitka School District, the University of Alaska Southeast, the U.S. Forest Service, and the Alaska Department of Fish and Game.
Our goal, however, was not to audit their existing environmental education programs. Rather, we sought to add additional support in areas of need identified by the organization and the community. Additionally, we utilized new data collected by our team in order to develop educational materials that support restoration monitoring efforts. The educational component of this project focuses on creating awareness of marine invasive species and the importance of monitoring ecological health and restoration efforts. Overall, this project serves to help younger generations understand and explore ecological issues that are affecting the region.

II. Methodology

The first step in creating educational material in the form of lesson plans, field guides, and monitoring labs for the Sitka School District was conducting expert interviews with teachers and scientists. In conducting these interviews, we were able to narrow our educational focus to topics which aligned well with Alaska science curriculum standards as well as information that was relevant to the local Sitka area.

Our overall goal was to create environmental education material that applies to the Sitka area and that can also be adopted in other areas of Alaska.

A. Expert Interviews

In Sitka, we met with teachers, scientists, and environmental professionals who conduct science educational outreach programs with students in local schools. To find topics that were needed in the Sitka area, we talked to veteran teacher Patti Dick who teaches science for 6th grade students in Sitka schools. She emphasized a more hands on method for teaching students about the environment and ecology. Our goal was to create material that connected students with their environment, helped them understand how they impact their surroundings, and how they can improve it. Patti suggested creating material that focused specifically on 6th grade because the curriculum for this grade level focuses on life sciences (P. Dick, personal communication, August 12, 2014).

The next step was to address a topic that would be relevant to the Sitka community. We contacted Marnie Chapman, a professor of Biology at the University of Alaska, Southeast. She conducts student research projects with an invasive tunicate species called D. vex (*Didemnum vexillum*). This tunicate is of interest to scientists and community members in Sitka because it has already emerged in areas around local harbors. The Alaska Department of Fish and Game states that the mats that D. vex produces can cover a large area of the ocean floor (Davis 2011). These mats encase rocks, seaweed, and living organisms like hydroids, sea anemones, and other animals (Davis 2011). One main concern with these invasive tunicates is that native marine species important to commercial, subsistence, and recreational fisherman will not have access to prey that live on the seafloor because it is beneath the mats of the invasive tunicate (Davis 2011). Marnie collaborates with Steve Lewis, the science education coordinator for the Scientists in the Schools Program in Sitka. In the past, Marnie and Steve worked together to create a Plate Watch Project to teach 6th graders about marine invasive species (M. Chapman, personal communication, August 14, 2014). With the support of Patti, Marnie, and Steve, we were able to obtain our target audience and topics for the project. We also met with our client organization, the Sitka Conservation Society and gathered information regarding the organization's environmental education efforts from Scott Harris. Scott reiterated the need to create material on marine invasive species for students in Sitka Schools (S. Harris, personal communication, August 10, 2014). Scott also encouraged us to create material on the monitoring protocols the University of Michigan Master's Project Restoration Team conducted in June.

B. Creating Marine Invasive Species Documents

When creating the lesson plans for the marine invasive species curriculum, we first identified a need for materials specific to 6th grade that complemented Alaska State Standards. Veteran teacher Patti Dick helped us focus our audience to 6th grade students because this is the grade level where students learn life science. In 7th and 8th grade students take physical science courses that do not cover biology and ecology. Additionally, we updated information from an existing field guide created by Steve Lewis and Marnie Chapman currently being utilized in sixth grade classrooms by researching current invasive and native species information. This mini-unit on marine invasive species has five different sections or lessons.

C. Creating Monitoring and Restoration Documents

The European Green Crab (*Carcinus maenas*) monitoring document was created using the Smithsonian Institute Green Crab Protocol. This is an initiative led by the Smithsonian Environmental Research Center which began their monitoring efforts in 2000. The Green Crab Monitoring Protocol was developed to teach students how to sample for European Green Crabs.

The riparian and stream monitoring and analysis lesson plans were created to help students in the Sitka School District continue collecting ecological data in order to build on the baseline data that our group collected in the field in June 2014. The monitoring labs were adapted from the Restoration team methodology. Scott Harris, the Conservation Science Director of the Sitka Conservation Society, helped format the information that is included in these lessons.

The purpose of the Riparian Lesson Plan is to target high school students grades 9-12 on field methods for monitoring managed areas around Sitka and Kruzof Island. The lessons were created because there was a need to monitor the forest management efforts made in previous years.

III. Results

The educational component of this project resulted in the creation of lesson plans and field labs to be used by students and teachers in the region. Lesson plans and a field guide introduce sixth grade students to issues involving marine invasive species in the region. Field labs help guide students in middle and high school through monitoring of aquatic and riparian zones.

A. Marine Invasive Species Lesson Plans

Lesson plans were created in order to support existing activities addressing marine invasive species that are conducted in sixth grade classrooms in Sitka, Alaska. These existing activities include a plate monitoring laboratory activity for invasive tunicate species such as D. vex, and a marine invasive species Bingo game. All lesson plans are designed to meet specific Alaska State Standards for science education.
The first is **Lesson 1**: Identifying Sitka Marine Invasive Species. This lesson includes a PowerPoint Presentation on the background of what invasive species are and why they are a concern. The PowerPoint also goes over five marine invasive species that are a concern in the Sitka area. There is a worksheet that students must complete on these invasive species called “The Fearful Five”. As part of this activity, students must also complete a Research Worksheet that teaches students how to research these five invasive species. Students are required to complete these worksheets at home. This lesson also includes a project component; students are required to create identification cards on “The Fearful Five”. The teachers are given a rubric which outlines the requirements for the completion and grading of the cards.

Lesson 2 of the marine invasive species curriculum is a field guide exercise with Steve Lewis. This lesson will be a class period consisting of a PowerPoint presentation on 37 native and invasive marine species. The PowerPoint goes through information on each species including taxonomic information, description, habitat, range, and size. This lesson was part of a class that Steve Lewis formerly taught. Steve expressed a need for the Field Guide to be more engaging for students and to include credible sources to cite the information and pictures used (S. Lewis, personal communication, October 30, 2014). The overall goal of the Marine Invasive Species Field Guide is to teach students the range of invasive and native marine species in the ecosystem. It helps students have a visual guide for identifying marine species in the Sitka region.

Lesson 3 and **Lesson 4** were already created by Steve and Marnie as citizen science projects in the Sitka School District. For lesson 3, Steve created a bingo activity which is an interactive way for students to learn and identify species from the Marine Invasive Species Field Guide. For lesson 4, Marnie developed a D. vex collection lab where she collects marine settlement plates from local harbors and inspects them with students. Marnie sets up the lab in 6th grade classrooms to teach students how to use a scientific method for finding marine organisms. Through these two activities students learn about marine invasive species, identify native and invasive species, and analyze plates used to help the community monitor the presence of invasive species.

Lesson 5 called 'Addressing Marine Invasive Species' was created to assess students' knowledge of invasive species and ability to synthesize information from the mini-unit to think about ways in which to address the potential problems caused by marine invasive species. In this lesson students review information gathered from the previous four marine invasive species lessons. This lesson includes activity directions and a rubric for assessment of students' abilities to communicate information regarding marine invasive species and management strategies to the public. Students and teachers are encouraged to display posters or similar project deliverables in the community or in a public space in the school setting.

Lesson plans can be viewed in Appendix 3A.

B. Marine Species Field Guide

This field guide is designed to help students learn how to distinguish between native marine species in the local area and marine invasive species. The field guide was updated to include new information and pictures of relevant species. A total of 37 marine species, five invasive and 32 native species, are included in the guide. Each species is identified through a picture, its common name, and its scientific name. Taxonomic information, habitat requirements, a physical description and regional information are also included for each species. This guide is introduced to students during the second day of lessons about marine invasive species, as discussed above, and then utilized in the existing Bingo activity, the plate laboratory activity, and the science communication activity.

Information from this field guide can be viewed in Appendix 3B.

C. European Green Crab Monitoring Guidelines

This document provides guidelines for students on how to sample for the presence of invasive green crabs based on pre-existing protocol established by the Smithsonian Environmental Research Center. As presented, this monitoring is aimed toward small groups of 8th grade students in a mentoring environment. The monitoring lab will be led by Scott Harris from the Sitka Conservation Society. Scott has experience with this monitoring protocol and uses his boat to set crab traps along the bay area. The traps are collected the next day and are inspected for the presence of the European Green Crab. All other organisms found in the trap are keyed out, recorded, and set free. This activity gives students hands-on experience identifying marine organisms and differentiating between invasive and native species. It also helps students conduct field work with a scientist in the area. By following a methodology to assess the organisms that are living the marine environment, students are able to engage in conducting useful ecological research. Overall, this experience engages students to participate in scientific research that impacts their community.

This document can be viewed in Appendix 3C.

D. Riparian Field Lab

This document is designed to be utilized by teachers and students in conjunction with the Sitka Conservation Society in order to monitor the success of restoration practices conducted after clear-cut harvesting by identifying and comparing three sites. These sites include undisturbed, restored and disturbed areas along streams and forests. Through the riparian lesson plan students are able to go through methodology, assessment and analysis questions that help them compare the sites. The difference between the sites can help land managers assess efforts to improve the environmental conditions in these areas. The lesson plan complies with Alaska State Standards for science curriculum in order to help students analyze the success of past land management efforts in the area. The goal is to continue obtaining data, including information on width to depth ratio, amount of woody debris, and substrate size, to monitor the success of past restoration efforts and to make suggestions for future management practices.

This field lab can be viewed in Appendix 3D.

E. Alaska Stream Team Water Quality Analysis Worksheet

These lessons are in addition to the current Stream Team Manual used for 7th grade students in Sitka. The current Stream Team Manual includes a data collection and field element, but it lacks an analysis component. The Alaska Stream Team Water Quality Analysis Worksheet is part of a new lesson that teaches students how to use Excel in order to analyze data they collected using the original Stream Team field methods. In these lessons the students will complete a worksheet in which they compare their data to data from previous years in order to analyze and discuss the implications of timber harvest/disturbances and ecological restoration based on their results.
This worksheet can be viewed in Appendix 3E.

F. Educational Level Stream Monitoring Field Guide

The Stream Team manual currently monitors water quality using qualitative and quantitative metrics such as temperature, dissolved oxygen, water discharge, and benthic macroinvertebrates. We created the Educational Level Stream Monitoring Field Guide to add on to the existing Stream Team Manual used by 7th grade students. In order to monitor aspects of stream health and ecological restoration success, this field guide was designed to assist science educators in using additional rapid bioassessment methods with their students that are not directly measured in Alaska Stream Team monitoring. The new material includes the following methods to assess stream quality and past restoration success: width to depth ratio, amount of woody debris, and a pebble count.

This new field guide includes background information for using this manual and the measured variables, step-by-step field methods, data analysis steps, and discussion questions for analyzing stream quality. Overall, this guide provides students and teachers with additional methods and indicators for assessing stream health and habitat quality and can be used during annual monitoring field trips in order to better assess the success of land management and restoration practices.

These materials can be viewed in Appendix 3F.

IV. Discussion

The goals of this project were met by creating materials that increased students' awareness of marine invasive species as well as ecological processes through lab and field based scientific investigations. The recommendations for the future of this education program are geared towards expanding the current science curricula in Sitka to include lessons focused on community-level environmental awareness. The goals of the lesson plans are to help school teachers teach their students about environmental issues and ecology. The lessons are set up in a way that is easy to follow and comprehend for teachers who might not have a strong background on the subject. The clear list of Alaska State Standards at the beginning of each lesson helps teachers assess the topics covered. The supporting materials like PowerPoint presentations, worksheets, activities, and rubrics at the end of each lesson give teachers all the tools needed to teach specific topics.

The riparian and stream team monitoring protocols are lessons used to engage students in continuing with the collection of data that the restoration group did in June. Aquatic monitoring lessons can be used to supplement the existing Stream Team protocols currently used by 7th grade students. Riparian monitoring lessons at the high school level can be implemented by volunteers or students interested in learning more about conducting fieldwork. Through continued data collection, aided by these ecological restoration labs and activities, monitoring efforts can become scientifically based and quantifiable. The monitoring lessons can also teach students about the impacts of human disturbances (particularly timber harvest) by allowing them to compare sites with different levels of disturbance. A study on the effects of ecological fieldwork on students' perception of environmental protection by Manzanal et al. (1999) found that fieldwork helps clarify ecological concepts for students. Fieldwork can also aid in the development of positive attitudes toward the protection of the local ecosystem (Manzanal et al. 1999). Monitoring also teaches students about local ecological issues and helps them become better stewards of the land as they learn the hands-on techniques that scientists in the field use to monitor areas. These experiences are valuable for students' understanding of their surroundings and what it takes to maintain a balance between humans and the environment. Overall, the goal of creating these lessons is to support student development while also determining success of past restoration efforts and advise future land management strategies.

Education Appendices

3A: Marine Invasive Species Lesson Plans

Marine Invasive Species Curriculum
Grade 6
Lessons created for Sitka Conservation Society
By:
Esther D'Mello and Amanda Harvanek

Contents Page

Lesson 1 (6th grade)
Identifying Invasive Marine Species

Alaska State Standards:
[6] SE1.1 The student demonstrates an understanding of how to integrate scientific knowledge and technology to address problems by recognizing that technology cannot always provide successful solutions for problems or fulfill every human need
[6] SA1.2 The student demonstrates an understanding of the processes of science by [6] SA1.1 asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating* collaborating to design and conduct simple repeatable investigations (L)
[6] SA3.1 The student demonstrates an understanding that interactions with the environment provide an opportunity for understanding scientific concepts by gathering data to build a knowledge base that contributes to the development of questions about the local environment (e.g., moose browsing, trail usage, river erosion) (L)

Grade Level: 6th

Assessment Strategies: Asses students' knowledge of invasive species by using rubric for card activity.

Learning Objectives: Students are taught basics on marine invasive species in Southeast Alaska. During the course of the lesson the students will be able to identify the "Fearful Five" marine invasive species based on in class and take home activities.

Time required: 1 class period (45 minutes long)

Materials/ Technology Needed:
Powerpoint presentation
5in x 8in (or 4in x 6in) Notecards that students can use to create identify cards for the nuisance species

First Lesson Activity:

1. The activity is introduced by the Power Point Presentation on an overview of invasive species and the "Fearful Five"
2. Students complete "Sitka's Most Unwanted Marine Species Worksheet" in class
3. Homework Assignment Students complete "Research Worksheet: Lesson 1".
4. Students complete 5 Marine Species Cards using the format of the "Sitka's Most Unwanted Marine Species Worksheet" on the front of the card and cite websites in MLA format on the back of card.

Background Information:

a. **What are marine invasive species?**
    a. According to the IUCN (2009), marine invasive species are plants or animals that have been intentionally or accidentally introduced into a marine environment through human activity. This new marine environment is an area where the plants or animals are not naturally found.

b. **How do they spread in marine environments?**
    a. The main way these species spread is through human transporting materials from one area of the world to another. These species are being transported far beyond their natural range. Most species are introduced by ballast water transfer and hull-fouling which is when new species attach on the underside of vessels. (IUCN)

c. **What changes do they make to the environment?**
    a. Sometimes these invasive species compete with native species and therefore threaten their diversity and abundance. They can change whole ecosystem processes by upsetting the natural balance. IUCN (2009)

d. **How they affect marine ecosystems?**
    a. They can change whole ecosystem processes by upsetting the natural balance. This lowers the ecosystem's ability to cope with different pressures and impacts. All of this can result in lower biodiversity and an unhealthy ecosystem. It is also believed that invasive species have caused extinctions in land environments but there is not enough evidence yet to prove that marine invasive species have caused extinctions in the marine environment. IUCN (2009)

e. **Why we care about marine invasive species in Alaska? Sitka**
    a. Some marine invasive species lower the number of native species in the ecosystem which can decrease the aesthetic quality of the environment. This could impact the tourism industry. They can also affect native fisheries by reducing the number of fish being caught. Lastly they are very expensive to get rid of once they are established. IUCN (2009)

Sources:
https://www.iucn.org/about/work/programmes/marine/marine_our_work/marine_invasives/seychelles/about_marine_invasive_species/

a. **Who are the marine species?**

. Examples of species: **"The Fearful Five"**

1. European Green Crab, *Carcinus maenus*
2. D. Vex, *Didemnum vexillium*
3. Wakame, *Undaria pinnatifida*
4. Club Tunicate, *Styela clava*
5. Orange sheath tunicate, *Botrylloides violaceus*

Sitka's Most Unwanted Marine Species Worksheet

Directions: Pick one of the 5 species mentioned in the Power Point and fill out this worksheet. This will help you with your species identification cards.

Name________________________________ **Period**_______ **Date**__________________

Common Name_______________________________________

Scientific Name_______________________________________

Classification

Kingdom_______________________________

Phylum_________________________________

Class__________________________________

Order__________________________________

Family_________________________________

Habitat:_______________________________
____

Range: _______________________________

How does it travel?
____

How can it be prevented?
____

Why is it dangerous?
____

Draw a picture of the species with a brief description

____
____
____
____
____

Research Worksheet: Lesson 1

Name:__________________________ Period:______ Date:____________________

When completing the worksheet make sure to note the website and author to validate your answers.

Sources: Websites and authors	
	1. Name and describe 3 Marine Invasive Species in Sitka. i.____________________ ii.____________________ iii.____________________ **2. Give 3 reasons why preventing the spread of the above species is important.** i. ____________________ ii.____________________ iii. ____________________ **3. Name and describe 3 ways in which the spread of marine invasive species occurs and can be prevented:** 1. ____________________ 2.____________________ 3.____________________

Make sure you included the websites you got the information from at the side table.

Card Rubric: Lesson 1

Teacher Name:
Student Name:

CATEGORY	**5 points**	**3-4 points**	**1-2 points**	**0 points**
Content	The cards include all needed information.	The cards include some information.	Includes information however some is incorrect or invalid.	The cards are not completed.
Attractiveness & Organization	The cards are exceptionally neat attractive and the information is well organized.	The cards are attractive and the information is well organized.	The cards are organized well.	The cards are confusing to understand.
Picture/Drawing	Drawing show important features of organism.	Drawing is not very detailed.	Drawing is sloppy and does not represent the organism.	No drawing.
Spelling & Proofreading	No spelling or grammar errors.	One spelling errors but the information is accurate.	No more than three spelling and grammar errors.	Several spelling and grammar errors.
Sources	Careful and accurate records of documents that are used. Students cite information using MLA style on the back of the card.	Students cite MLA style but not accurately.	Students use websites and authors	Sources are not documented at all.

Total: ______/ 25 points

PowerPoint Presentation: Lesson 1

Marine Invasive Species

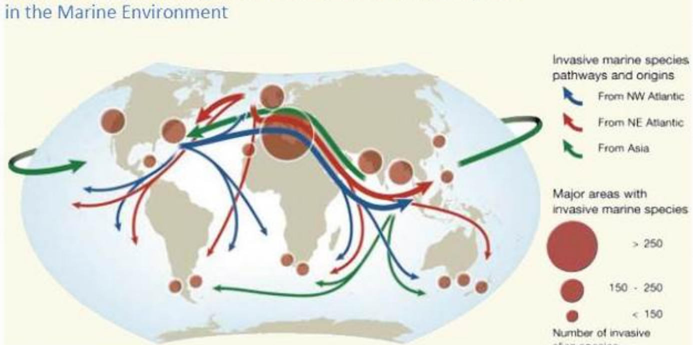
Lesson 1

1

What are marine invasive species?

- According to the IUCN (2009), marine invasive species are plants or animals that have been intentionally or accidentally introduced into a marine environment through human activity. This new marine environment is an area where the plants or animals are not naturally found.

Major Pathways and Origins of Infestations of Invasive Species in the Marine Environment



Source: PNUMA/GRID-Arendal. 2009.

2

How do they spread in marine environments?

- The main way these species spread is through humans transporting materials from one area of the world to another.
- These species are being transported far beyond their natural range.
- Most species are introduced by ballast water transfer and hull-fouling which is when new species attach on the underside of vessels. (IUCN)

Hull Fouling
coatzyme.dk

Ballast Water www.nio.org

3

What changes do they make to the environment?

- Sometimes these invasive species compete with native species and therefore threaten their diversity and abundance.
- They can change whole ecosystem processes by changing the natural balance.

http://juneauempire.com

4

How do they affect marine ecosystems?

- As mentioned, they can change whole ecosystem processes by upsetting the natural balance.
- This lowers the ecosystem's ability to cope with different pressures and impacts.
- All of this can result in lower biodiversity and an unhealthy ecosystem.

http://smithsonianscience.org

http://smithsonianscience.org

5

Why do we care about marine invasive species in Sitka?

- Some marine invasive species lower the number of native species in the ecosystem which can decrease the aesthetic quality of the environment.
- This could impact the tourism industry.
- They can also affect native fisheries by reducing the number of fish being caught.
- Lastly, they are very expensive to get rid of once they are established.

http://www.adfg.alaska.gov/

www.akcruises.com

6

Who are the marine species?

"The Fearful Five"

- European Green Crab, *Carcinus maenus*
- D. Vex, *Didemnum vexillium*
- Wakame, *Undaria pinnatifida*
- Club Tunicate, *Styela clava*
- Orange sheath tunicate, *Botrylloides violaceus*

www.rimeis.org

wdfw.wa.gov

http://wdfw.wa.gov

http://www.adfg.alaska.gov

www.dpi.nsw.gov.au

7

What can you do?

- Keep an eye out for these species
- Get involved with monitoring programs at your school and through local organizations like the Sitka Conservation society
- Always remember to:
  - CLEAN
  - DRY
  - DRAIN
    - BEFORE YOU TRANSPORT YOUR BOAT OR EQUIPMENT

SITKA CONSERVATION SOCIETY

8

Identification Card Activity

- Create 5 identification cards of "The Fearful Five" using this template:

Sitka's Marine Invasive Species

Species Common Name
Scientific Name

Classification
Kingdom: ________
Phylum: ________
Class: ________
Order: ________
Family: ________

Habitat:
Range:

Drawing of organism

Description
____
____
____
____

9

Resources

- https://www.iucn.org/about/work/programmes/marine/marine_our_work/marine_invasives/seychelles/about_marine_invasive_species/

10

Lesson 5 (6th grade)
Addressing Marine Invasive Species

Alaska State Standards:
[6] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating*
[6] SA3.1 The student demonstrates an understanding that interactions with the environment provide an opportunity for understanding scientific concepts by gathering data to build a knowledge base that contributes to the development of questions about the local environment (e.g., moose browsing, trail usage, river erosion) (L)
[6] SE1.1 The student demonstrates an understanding of how to integrate scientific knowledge and technology to address problems by recognizing that technology cannot always provide successful solutions for problems or fulfill every human need
[6] SE2.1 The student demonstrates an understanding that solving problems involves different ways of thinking by identifying and designing a solution to a problem

Grade Level: 6th

Assessment Strategies: Assess students' knowledge of invasive species and ability to synthesize information from the mini-unit using the project rubric.

Learning Objectives: Students review information learned about marine invasive species from the mini-unit of lessons. During the course of the lesson the students will be able to identify the ecological concerns associated with marine invasive species and communicate ways to prevent the spread of these species.

Time required: 1-2 class periods (45 minutes long each); Project may be completed within the classroom or as a homework assignment

Materials/ Technology Needed:
Large Paper or Posters
Art Supplies (crayons, markers, paint, etc.)

Fifth Lesson Activity:

Do Now: Have students individually complete the following question as they enter. This may be done on a sheet of paper to collect, or in a student notebook.

Q: What benefits do we receive from the ocean as a community? What are some of the negative impacts of invasive species on the ocean?

Discussion: Ask students to share their responses with the class. Consider having students discuss in small groups to identify similarities and differences in their responses. Write responses on the board in a “brainstorming” session for topics that can be addressed with their projects.

Activity: Students will complete a RAFT (Role/ Audience/ Format/ Topic) activity in order to communicate the importance of preventing the spread of marine invasive species.

Present students with the following assignment:

Work in small groups to design a poster to educate the public about the importance of preventing marine invasive species. Complete the assignment using the following RAFT format:

ROLE: Concerned Conservationists
AUDIENCE: Sitka Community Members (or similar local setting)
FORMAT: Informational Poster
TOPIC: Educate the community about the importance of a healthy marine ecosystem and the negative impacts of the invasive species.

Include the following information in your poster:

1. Information about the importance of one or more native species to the community (Consider economic, recreational, or personal value.)
2. Information about how your selected invasive species is (or could) threaten the ecosystem and/or the economy of the community
3. Ways to prevent or solve the problems associated with this invasive species

Utilize the attached rubric for grading. This project could also be assigned for homework if class time is limited.

Activity Alternatives and Extensions:

- Allow students to present information in an alternative format: PowerPoint presentation, multimedia display, pamphlet, news broadcast, commercial, skit, etc.

- Allow students to select alternative RAFT examples:
    - ROLE: A Native Species
      AUDIENCE: Sitka Community Members (or similar local setting)
      FORMAT: Persuasive Letter
      TOPIC: Convince community members to prevent or remove a marine invasive species based on its negative impact to you (the native species) and the community

    - ROLE: An Invasive Species
      AUDIENCE: Sitka Community Members
      FORMAT: Greeting Card

TOPIC: Introduce yourself to the community, announcing your arrival and convincing the audience that you will be a good neighbor in this ecosystem

- ROLE: An Invasive Species
  AUDIENCE: Other Invasive Species
  FORMAT: Travel Diary
  TOPIC: Describe your journey to Sitka and explain to them why they should or should not join you in this new ecosystem

- Identify public spaces in which students can display their creations. This may be in a school hallway, the school cafeteria, the community library, or other high-traffic center.

- Find additional invasive species science articles and activities through the USDA Forest Service's middle school science journal *Natural Inquirer.* The Invasive Species Edition of this journal can be retrieved on: http://www.naturalinquirer.org/Invasive-Species-Edition-i-10.html

Project Rubric: Lesson 5

Student Name: ____

CATEGORY	4 points	3 points	2 points	0 points
Overall Content	The project includes all required information.	The project includes most required information.	Includes some information however some is incorrect or invalid.	The project lacks most information or is off-topic.
Attractiveness & Organization	The project is exceptionally neat, attractive & the information is well organized.	The project is attractive and the information is well organized.	The project is organized, but lacks some creative effort.	The project is sloppy and/or confusing to understand.
Ecosystem Value	Project presents strong & persuasive information on the value of native species & threats from an invasive species.	Project presents persuasive information on the value of native species & threats from invasive species, but isn't as strong as it could be.	Project leaves out some information about native or invasive species, or is not persuasive.	The project lacks information about native and invasive species.
Prevention & Solutions	The project suggests strong, interesting and creative solutions.	The project suggests decent and creative solutions.	The project suggests solutions, but they lack creativity or strength.	The project lacks information about solutions to the problem of invasive species.
Accuracy	The project includes factual and informative information from class lessons and lab activities.	The project includes mostly factual information, but might contain a couple errors.	The project contains a few errors.	The project contains several factual errors and it is clear the student did not use class resources.

Total Score: _______/ 20 points

3B. Marine Species Field Guide

Table of Contents

2

Introduction

Purpose of this Field Guide

- This is a field guide that goes over native and invasive marine species found in Southeast Alaska.

Goals of this Field Guide

1. Provide information on what invasive species are and how they spread
2. Give details on marine species found in the Southeast Alaska region
3. Create awareness of issues with marine invasive by proving a useful guide on how to identify specific organisms

3

Field Guide Organization

- This guide contains 34 species of native and potential invaders in marine ecosystems around Southeast Alaska.
- This guide is organized by phylogenetic casts (see page 7).
- Within each species, the common name, scientific name, description, range, habitat, and size are provided.
- Citations and image credits are listed in the back by species' common names.

4

How to use this guide

(Red= invasive species, Green= native species)

Common Name

Scientific Name

Phylum:

Class:

Order:

Family:

Picture of species

Description: physical description

Range: where the species can be found around the world

Habitat: where the species lives

Size: how big the species can get

5

Invasive Species

- **Definition:** According to the IUCN (2009), marine invasive species are plants or animals that have been intentionally or accidentally introduced into a marine environment through human activity. This new marine environment is an area where the plants or animals are not naturally found.

- **Means of Travel:** The main way these species spread is through human transporting materials from one area of the world to another. These species are being transported far beyond their natural range. Most species are introduced by ballast water transfer and hull-fouling which is when new species attach on the underside of vessels. (IUCN)

- **Prevention:** Keep an eye out for these species Get involved with monitoring programs at your school and through local organizations like the Sitka Conservation society

Always remember to:
  - CLEAN
  - DRY
  - DRAIN
    - BEFORE YOU TRANSPORT YOUR BOAT OR EQUIPMENT

6

The Phylogenetic Cast

Phylum	Class	Order	Common name
Ochrophyta	**Phaeophyceae**	**Laminariales**	**Brown Kelps**
Porifera			**Sponges**
Cnidaria	**Hydroida**		**Hydroids**
Mollusca	**Gastropoda**	**Bivalvia**	**Mussels**
Bryozoa			**Bryozoans**
Annelida	**Polychaeta**	**Sabellidae**	**Tubeworms**
Arthropoda	**Cirripedia**	**Thoracica**	**Barnacles**
Arthropoda	**Malacostra**	**Decapoda**	**Crabs**
Arthropoda	**Malascotra**	**Amphidoa**	**Skeleton Shrimp**
Urochodata	**Ascidiacea**		**Sea squirts or tunicates**

7

Species List

By Common Name

Brown Kelps
- Sugar Kelp - *Saccharina latissima*
- Ribbon Kelp - *Alaria marginata*
- Wakame -*Undaria pinnatifida*

Sponges
- The Bread-crumb sponge - *Halichondria panicea*
- Purple Encrusting Sponge - *Haliclona permollis*
- Red Volcano Sponge - *Acarnus erithacus*

Hydroids
- Purple Carpet or Purple Encrusting Hydrocoral - *Stylantheca porphyra*
- Orange Sea-Tree - *Garveia annulata*
- Bushy Wine-glass hydroid - *Obelia dichotoma*

Sea Slugs
- Barnacle-eating Onchidoris- *Onchidoris bilamellata*
- Ringed Doris - *Diaulula sandiegensis*
- Spiny Doris -*Acanthodoris nanaimoensis*
- The Opalescent nudibranch - *Hermissenda crassicornis*

Mussels
- Pacific Blue Mussel - *Mytilus trossulus*

Bryozoans
- The Sea Muff - *Flustrellidra corniculata*
- The Northern Staghorn Bryozoan - *Heteropora pacifica*
- Mummy Bryozoan - *Celleporella hyalina*
- Kelp Lace - *Membranipora membranacea*

8

Species List

By Common Name

Tubeworms
- The Calcareous Tubeworm - *Serpula vermicularis*
- The Western Serpulid - *Pseudochitinopoma occidentalis*
- The Glassy Dwarf Tubeworm - *Paradexiospira vitrea*

Barnacles
- The Goose Neck Barnacle – *Pollicipes polymerus*
- The Common Acorn Barnacle - *Balanus glandula*
- The Northern Rock Barnacle - *Semibalanus balanoides*
- The Thatched or Rock Barnacle - *Semibalanus cariosus*

Skeleton Shrimp
- The Alaskan Skeleton Shrimp - *Caprella alaskana*

Crabs
- The Dungeness Crab - *Metacarcinus magister*
- The Green or Yellow Shore Crab - *Hemigrapsus oregonensis*
- The European Green Crab - *Carcinus maenas*

Tunicates or Sea Squirts
- Finmark's Tunicate - *Cnemidocarpa finmarkiensis*
- Wrinkled Sea Pump or Wrinkled Sea Squirt - *Pyura haustor*
- Club Tunicate - *Styela clava*
- Sea Pork - *Aplidium californicum*
- Western distaplia - *Distaplia occidentalis*
- Dvex - *Didemnum vexillum*
- Orange Sheath Tunicate - *Botrylloides violaceus*
- Transparent Tunicate - *Corella inflata*

9

Sugar Kelp

Saccharina latissima

Phylum: Ochrophyta
Class: Phaeophyceae
Order: Laminariales
Family: Laminariaceae

Description: Kelp and brown seaweeds

Habitat: Found attached to rocks in the low intertidal to subtidal

Range: Arctic Ocean, Bering Sea and Aleutian Is., Alaska, to Santa Catalina I., California, Korea, Japan, Russia

Size: 50 cm (20in) long, blade can be up to 3.5m (10 ft) long

10

Ribbon Kelp

Alaria marginata

Phylum: Ochrophyta
Class: Phaeophyceae
Order: Laminariales
Family: Alariaceae

Description: Kelp and brown seaweeds

Habitat: This kelp is an annual found on rock in the mid to low intertidal from semi-protected to exposed habitats.

Range: Aleutian Island, Alaska, to Point Conception, California

Size: Slope may be 30 cm (12in) and the blades up to 3m (10ft) long with solid midrib. Sporophylls branch off the stipe in spring growing to 25 cm (10in) long.

11

Wakame

Undaria pinnatifida

Phylum: Ochrophyta
Class: Phaeophyceae
Order: Laminariales
Family: Alariaceae

Description: : Large brown kelp with a branched holdfast giving rise to a stipe. It can spread by hitchhiking on boats, anchors, floats and aquaculture gear.

Habitat: Found growing on man-made structures such as marina pontoons. In its native habitat, it occurs in dense stands, forming a thick canopy on a wide range of shores from low tide level down to 15 m in clear waters.

Range: From Southeast Alaska to Baja California

Size: Usually 1.5-2 m long

We don't think this is in Sitka yet, but keep an eye out!

12

The Bread-crumb sponge

Halichondria panicea

Phylum: Porifera
Class: Demospongiae
Order: Halichondrida
Family: Halichondriidae

Description: Green or yellow color, smooth surface, Consistency firm, texture crumb-of-bread. It emits a characteristic disagreeable smell.

Habitat: This species occurs in the intertidal and sublittoral regions down to more than 500 m. In the intertidal region it occurs on upper, lateral and undersides of boulders and holdfasts of brown algae.

Range: Northern Atlantic, both along the European and American coasts

Size: Typical volcano-shaped chimneys, up to 4 or 5 cm high. Oscules are relatively large, conspicuous, 2-4 mm in diameter. Sponge body may be up to 25 cm thick and 60 cm across.

Smells like gunpowder and garlic!

13

Purple Encrusting Sponge

Haliclona permollis

Phylum: Porifera
Class: Demospongiae
Order: Haplosclerida
Family: Chalinidae

Description: Sponge varies form pink to purple color, crust is composed of tightly packed mounds with volcano shaped pores.

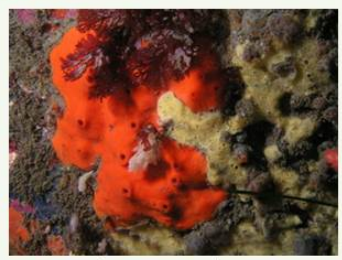
Habitat: Found in rocky intertidal areas, found in tidepools and rock crevices

Range: Southern Alaska to Southern California

Size: Two square inches, areas covering 18 to 24 inches in diameter

Red Volcano Sponge

Acarnus erithacus



Phylum: Porifera
Class: Demospongiae
Order: Poecilosclerida
Family: Acarnidae

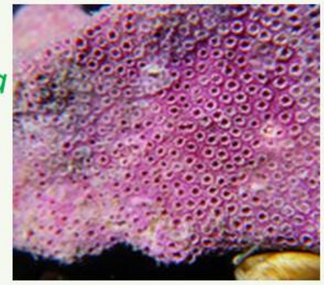
Description: The red volcano sponge is an encrusting scarlet to bronze-colored sponge. The consistency is crusty and hard to firm but slightly compressible.

Habitat: Low intertidal zone to depths of 2300 feet. This species is most often found encrusting on both living and dead barnacles along with sea urchins in deeper water.

Range: From southern Alaska to the Gulf of California

Size: The sponge can reach 1.5 inches in height and 12 inches in diameter, with "smokestacks" on the surface.

Purple Carpet or Purple Encrusting Hydrocoral



Stylantheca porphyra

Phylum: Cnidaria
Class: Hydrozoa
Order: Anthoathecatae
Family: Stylasteridae

Description: Forms a calcareous, purple encrustation on rocks. The surface is pitted with numerous scalloped pits, each of which contains up to 12 polyps.

Habitat: Found in the low rocky intertidal and subtidal, on sides of rocks or in crevices, usually in areas with significant wave action

Range: Central California to Sitka Sound, Southeast Alaska

Size: Colonies range from less than 1 cm in diameter to over 50 cm

16

Orange Sea-Tree

Garveia annulata

Phylum: Cnidaria
Class: Hydrozoa
Order: Anthoathecatae
Family: Bougainvilliidae

Description: Orange hydroid, colonial

Habitat: Pelagic; depth range 0 - 120 m

Range: Eastern Pacific: Alaska, USA and Canada

Size: Can get up to 15 cm

17

Bushy Wine-glass hydroid

Obelia dichotoma

Phylum: Cnidaria
Class: Hydrozoa
Order: Anthoathecae
Family: Bougainvilliidae

Description: *Obelia dichotoma* is generally a colonial hydroid. The colonial form varies from being large, erect and loosely fan-shaped or elongate up to 35 cm in height, to being short and either bushy or unbranched up to 5 cm in height.

Habitat: *Obelia dichotoma* is usually found on floats, pilings, rocks, shells and other solid objects.

Range: Found throughout the British Isles and Ireland

Size: Fan-shaped colony up to 35 cm in height or bush-like colony or solitary up to 5 cm in height

18

Barnacle-eating Onchidoris

Onchidoris bilamellata

Phylum: Mollusca
Class: Gastropoda
Order: Nudibranchia
Family: Onchidorididae

Description: It bears many (usually white) club shaped projections (tubercles) on its mantle and has two ringed sensory tentacles on its head.

Habitat: Found in the intertidal and shallow sublittoral, to a depth of 20 m

Range: North Atlantic - Britain and France north along Norwegiian coast to White Sea, Spitzbergen, west to Iceland, Greenland and down North American coast to Connecticut. Also, North Pacific with records from Bering Sea, Alaska, Puget Sound south to California.

Size: Grows up to 4 cm in length

Halibut Point in Sitka is currently the northern limit of known distribution for these sea slugs.

19

Ringed Doris
Diaulula sandiegensis

Phylum: Mollusca
Class: Gastropoda
Order: Nudibranchia
Family: Discodorididae

Description: The overall body color is whitish-yellow to a very pale brown, with brown to black rings or occasionally blotches of various sizes.

Habitat: Found from the intertidal to 35 m depth

Range: Sea of Japan, and northern Alaska to northern Mexico

Size: The size ranges from 30 mm to 150 mm.

20

Spiny Doris
Acanthodoris nanaimoensis

Phylum: Mollusca
Class: Gastropoda
Order: Nudibranchia
Family: Onchidorididae

Description: The mantle is covered in prominent conical papillae which are tipped with milky yellow. There is a milky yellow border to the mantle.

Habitat: Low intertidal to 10 m

Range: Baranof Island, Alaska to Santa Barbara, CA

Size: Grows to about 35 mm in length

21

The Opalescent nudibranch

Hermissenda crassicornis

Phylum: Mollusca
Class: Gastropoda
Order: Nudibranchia
Family: Facelinidae

Description: Have bright orange areas on their backs and blue lines along each side. Cerrata (fingerlike projections) on their backs are brownish yellow, with white and gold tips.

Habitat: Lives in lower intertidal to depths of 35 m

Range: Found along the Pacific coast of North America from Alaska south to Baja California, Mexico. Also found in Japan.

Size: Can grow up to 3 inches (80 mm) long

22

Pacific Blue Mussel

Mytilus trossulus

Phylum: Mollusca
Class: Bivalvia
Order: Mytiloidea
Family: Mytilidae

Description: The outside of the shell is smooth and ranges from bluish black to brown. The shell is pointed at the anterior end and round on the posterior end. Unlike many other mussel species, *M. trossulus* has three small teeth adjacent to the hinge. The animal is a continuous filter feeder when immersed in water.

Habitat: Found in the mid intertidal to subtidal zone

Range: Populations are currently found from the Arctic Ocean to northern California, eastern Canada, Baltic Sea, and eastern Russia.

Size: Can reach up to 10 cm in length

23

The Sea Muff

Flustrellidra corniculata

Phylum: Bryozoa
Class: Gymnolaemata
Order: Ctenostomata
Family: Flustrellidridae

Description: Colonies form a fleshy, leathery, erect structure of soft, flattened lobes and covered with many forked, antler-like spines. The color is pale tan to dark brown.

Habitat: Attached in the lower rocky intertidal, or as sheaths on seaweeds.

Range: Alaska to Point Buchen, central CA

Size: It reaches a height of 4 inches (10 cm)

24

The Northern Staghorn Bryozoan

Heteropora pacifica

Phylum: Bryozoa
Class: Stenolaemata
Order: Cyclostomata
Family: Heteroporidae

Description: Often yellowish-green to gray in color, occasionally with lighter or pinkish tips.

Habitat: Very low intertidal to 27 m. Mostly subtidal, attached to rocks in areas of fast water action

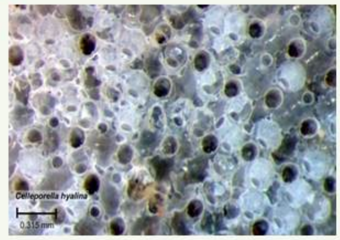
Range: Alaska to Central CA

Size: An erect bryozoan colony of inflexible rounded branches up to 5 mm in diameter, and 10 cm high

25

Mummy Bryozoan

Celleporella hyalina



Phylum: Bryozoa
Class: Gymnolaemata
Order: Cheilostomata
Family: Hippothoidae

Description: Often colonies are aggregated in flat clumps. Young colonies appear glassy at first, later turning opaque and ivory-white.

Habitat: Found encrusting rock, shell, algae, and hermit crabs from the intertidal to more than 130 m depth.

Range: North Atlantic; known as a species complex in the eastern Pacific and is found in Alaska, from San Francisco to the Channel Island in California, and the Galapagos Islands.

Size: Up to 20 cm in diameter

26

Kelp Lace

Membranipora membranacea

Phylum: Bryozoa
Class: Gymnolaemata
Order: Cheilostomida
Family: Membraniporidae

Description: The calcified colony is flexible and is able to bend as the current moves kelp or other substrates.

Habitat: Colonies usually grow on blades of kelp and other seaweeds, but can also be found on floats and rocks from intertidal to shallow subtidal.

Range: Native to the Northern Pacific, also found as an invasive species in the Northern Atlantic from Canada to Great Britain

! Eaten by nudibranchs and urchins. Colonies may grow spines in response to predation.

27

Calcareous Tubeworm

Serpula vermicularis

Phylum: Annelida
Class: Polychaeta
Order: Sabellida
Family: Serpulidae

Description: This tube worm has a yellow body and red, pink, or orange tentacles or cirri. It lives in a curvy calcareous tube.

Habitat: Found on floats, pilings, rocks and shells from the intertidal to 100 m

Range: Occurs in the Pacific, Atlantic, and Indian Oceans; Can be found from Alaska to Mexico along the western coast of North America

Size: Tube can be up to 20 cm long and the body can be up to 10 cm long

28

Goose Neck Barnacle

Pollicipes polymerus

Phylum: Arthropoda
Class: Maxillopoda
Order: Pedunculata
Family: Scalpellidae

Description: This barnacle has a dark-brown fleshy peduncle and hard, whitish plates that cover the cirri it uses to filter their prey.

Habitat: Found on open coastlines, often near mussels; can live on other barnacles found on humpback whales

Range: Found in the Pacific Ocean from Southeast Alaska to Mexico

Size: Up to 8 cm (3 in) long

31

Common Acorn Barnacle

Balanus glandula

Phylum: Arthropoda
Class: Maxillopoda
Order: Sessilia
Family: Balanidae

Description: This species is grayish-white to white and has thick wall plates.

Habitat: Typically found on rocks in the upper half of the intertidal; also on pilings and floats

Range: From Aleutian Islands in Alaska to Baja California, Mexico

Size: Typically about 1.5 cm across, but can be up to 2.2 cm (less than 1 inch)

32

Northern Rock Barnacle

Semibalanus balanoides

Phylum: Arthropoda
Class: Maxillopoda
Order: Sessilia
Family: Archaeobalanidae

Description: This species has white to gray plates and a darker interior.

Habitat: Typically attach to rocks, pilings, and other hard surfaces in the intertidal and subtidal

Range: Found along Pacific coasts from Alaska to British Columbia; in the Atlantic it is found south to North Carolina & in Great Britain and Spain

Size: Up to 4 cm (1.5 in)

33

Thatched or Rock Barnacle

Semibalanus cariosus

Phylum: Arthopoda
Class: Maxillipoda
Order: Sessilia
Family: Archaeobalanidae

Description: White, gray, or brownish wall plates made of vertical, raised ribs

Habitat: Attaches to rocks, floats, and pilings; not common near fresh water; often grow below the line of acorn barnacles

Range: Found near Japan and from the Bering Sea to California; Common in Southeast Alaska

Size: Can be up to 6 cm in diameter

This species is often called the “thatched” barnacle because its wall plates look like a pile of straw.

34

Dungeness Crab

Metacarcinus magister

Phylum: Arthropoda
Class: Malacostraca
Order: Decapoda
Family: Cancridae

Description: This crab has a red-brown to purple carapace that has a spine-tipped edge on its front half. Its carapace is wider than it is long.

Habitat: Typically found in sandy bottoms of sub-tidal regions and prefers eelgrass beds, lives to a depth of 230 m

Range: Found from Alaska to California

Size: Male carapace up to 25 cm, females up to 18 cm

This species is a very important and popular seafood.

36

Green or Yellow Shore Crab

Hemigrapsus oregonensis

Phylum: Arthropoda
Class: Malacostraca
Order: Decapoda
Family: Grapsidae

Description: These crabs have a rectangular carapace and are typically gray-green, but their color can greatly vary.

Habitat: Mainly found in the intertidal, on open mud flats, eelgrass beds, in estuaries, and other regions with fine sediment

Range: Found from Alaska to Baja California, Mexico

Size: Less than 3.5 cm (or 1.5 in)

37

European Green Crab

Carcinus maenas

Phylum: Arthropoda
Class: Malacostraca
Order: Decapoda
Family: Portunidae

Description: This crab often is a greenish color but can also be dark brown, mottled, and has small, yellow spots. It has 5 spines on each side of its eyes.

Habitat: Can live on rocky shores, sandflats, tidal marshes, and other types of habitat

Range: Native to the Atlantic coast of Europe and Africa; Invasive to both the North American Atlantic and Pacific Coasts. This crab has been seen from California to British Columbia– Keep an eye out for it in Alaska!

Size: Carapace can be up to 10 cm (4 in) wide

? Some studies suggest that these crabs can out compete Dungeness Crabs. Why is this a big concern in Alaska?

38

Finmark's Tunicate

Cnemidocarpa finmarkiensis

Phylum: Chordata
Class: Ascidiacea
Order: Stolidobranchia
Family: Styelidae

Description: This is a solitary tunicate that is white when very young, but changes to a pink-red color as it grows.

Habitat: Found on hard surfaces in well-circulated waters, floats, can live in holes

Range: Alaska to California, also live in the Arctic

Size: Typically less than 3 cm, but up to 5cm across; up to 2.5 cm high

39

Wrinkled Sea Pump or Wrinkled Sea Squirt

Pyura haustor

Phylum: Chordata
Class: Ascidiacea
Order: Stolidobranchia
Family: Pyuridae

Description: This tunicate is reddish brown or tan in color and is solitary. It is tough and wrinkly in appearance.

Habitat: Lives on rocks, floats, pilings, and kelp

Range: Found from Alaska to California

Size: Up to 5 cm across, up to 3.5 cm high

40

Club Tunicate

Styela clava

Phylum: Chordata
Class: Ascidiacea
Order: Stolidobranchia
Family: Styelidae

Description: This solitary tunicate is typically leathery and brown with two clear siphons.

Habitat: Found on rocks, pilings, docks, mooring lines, and other hard surfaces

Range: Native to Pacific coasts in Asia, considered invasive on the coast of North America

Size: Can grow up to 15 cm (6 in) long

41

Sea Pork

Aplidium californicum

Phylum: Chordata
Class: Ascidiacea
Order: Enterogona
Family: Polyclinidae

Description: This tunicate lives in irregularly shaped colonies that can range in color from tan to gray to orange-brown.

Habitat: May live on docks, shells, tubeworn tubes, and other hard surfaces that are protected from strong surf

Range: Alaska to Baja California, Mexico, also found in the Galapagos Islands

Size: May grow up to 3 cm thick and 30 cm across

42

Western distaplia

Distaplia occidentalis

Phylum: Chordata
Class: Ascidiacea
Order: Enterogona
Family: Clavelinidae

Description: This compound tunicate can be a variety of colors including: yellow, orange, purple, or brown. It can grow flat or in a globular mass.

Habitat: May live on floats, pilings, rocks, or open coast

Range: Vancouver Island, Canada to California

Size: Most colonies are smaller than 2 cm across, but can be up to 10 cm

43

Dvex

Didemnum vexillum

Phylum: Chordata
Class: Ascidiacea
Order: Aplousobranchia
Family: Didemnidae

Description: This invasive species is a colonial tunicate that may appear orange, pink, tan, or cream. It feels smooth and leathery.

Habitat: Often found growing on nets, lines, ships, and other hard substrates

Range: Believed native to Japan, invasive along North American Pacific coasts, northern Europe, and New Zealand

Size: Colonies can grow quite large, often covering entire nets or surfaces.

Dvex was found in Whiting Harbor, Sitka in 2010. It is often called "carpet tunicate" because of its ability to grow like large mats.

44

Orange Sheath Tunicate

Botrylloides violaceus

Phylum: Chordata
Class: Ascidiacea
Order: Pleurogona
Family: Botryllidae

Description: This colonial tunicate can be tan, yellow-orange, brown, or light purple in color.

Habitat: Lives in protected waters, can grow on ship hulls, docks, aquaculture, and any other hard substrate.

Range: Native to Japan, China, and Siberia; Invasive on the Pacific coast of North America

Size: Typically forms thin patches up to 30 cm in diameter

This tunicate has been to our south since the early 1990's and found in Prince William Sound in 1999. Let's hope you don't find it on the plates!

Transparent Tunicate

Corella inflata

Phylum: Chordata
Class: Ascidiacea
Order: Phleobranchia
Family: Corellidae

Description: This tunicate is solitary and has a smooth transparent or translucent body.

Habitat: Often found on floats

Range: British Columbia, Canada to San Juan Islands, Washington

Size: Twice as tall as it is wide

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Tunicates or Sea Squirts

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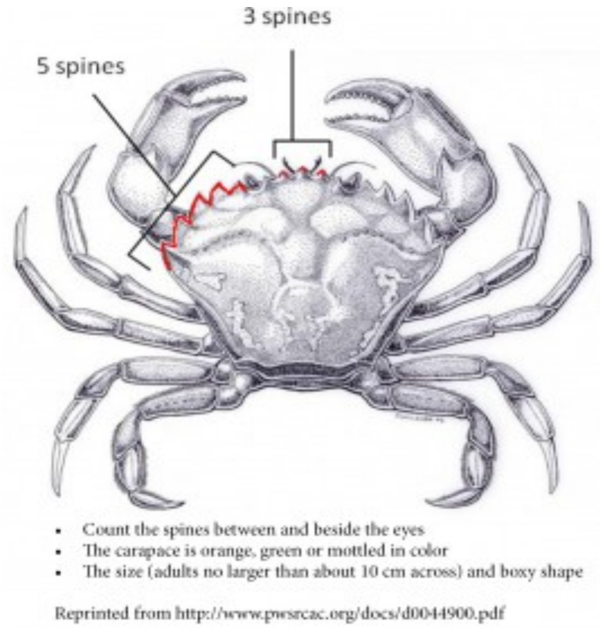
3C. Green Crab Monitoring Guidelines

GREEN CRAB MONITORING PROTOCOL



SAFETY: Wear lifejackets when on the boat.

Before leaving to check traps, make sure your kit includes all of the following:

Deployment equipment:

- Folding Fukui style 20x45x60cm Traps (6)
- Hammer
- Wooden or metal stakes Bucket (if not already attached to trap)
- Zip Ties Bait
- Bait containers
- Parachute Cord
- Knife or clippers

Monitoring equipment:

- Watch or Phone (time)
- Tide book
- Knife or Clippers Clipboards
- Data sheets
- Pencils Bucket for holding crabs ID cards for fish
- crab and inverts Vernier calipers, or rulers Camera (check card and batteries)
- Laminated photo numbers
- Thermometer
- GPS (optional)
- Refractometer or YSI for salinity
- Flagging tape for marking stakes

DEPLOYING AND RETRIEVING TRAPS BY BOAT:

1. You will need to have a buoy with a line attached to the trap in order to retrieve it.
2. Make sure the line is long enough to float at high tide.
3. Traps can be staked or weighted to keep them in place.
4. If you have chosen a calm site, the buoy and line should be enough to find the trap again and you shouldn't need a weight.
5. If your site is subject to currents or wave action, you may need to use a set of anchors and a long line.
6. Snap the traps to the line with a buoy on each so it looks like this.
7. If necessary, traps may be placed closer together than in a land based deployment, though about 30 ft apart is still the goal.

MONITORING:

Traps should be checked only after being submerged for 24 hours or a full tide cycle. Having at least two people working a trap is best. One person should be assigned as data recorder while the other removes crabs from the trap and measures and determines the sex of each. Any other monitors can be charged with releasing crabs back into the water, and taking pictures.

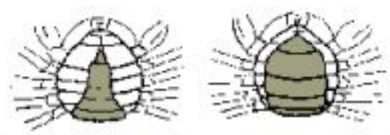
1. **Fill out monitoring information:**
   a. Site and Monitors: It is easier to fill out site information before pulling traps. Each site should have a documented site name and site description. List monitoring location, trap deployment date and time on the **datasheet**. Write the trap check date and start time on the datasheet. Collect temperature and salinity data and enter on data sheet.
2. **Fill out catch information:**
   a. Catch Removal: Open the trap and put all captured organisms into the bucket. Wear gloves so you don't get pinched or bitten. Be gentle with all the organisms you catch. When measuring crabs, hold them gently by their main body cavity from the back, not by their claws or legs. **If you turn a crab upside down they will hold still for you.**
   b. If crabs are missing appendages or have parasites, be sure to note this on data sheet. If the trap is empty, write "Empty" adjacent to trap number. For each individual crab record the following:
      i. Trap Number: Assign each organism to a trap number.
      ii. Record and list information for all catch individually— each on a separate line.
      iii. Identification: Identify the organisms using the identification information provided on the Green Crab Watch website.
      iv. For non crabs, identify them (or take a photograph), using the species list at the end of this protocol for reference. Any crab that is not easily identified or is suspected of being an invasive crab should be photographed.

Figure 1: Measuring the carapace width

      v. Size: Measure the total length (fish or other organisms) or carapace length (crab) using calipers or a small ruler. The size of a crab is determined by measuring its maximum carapace width (mm). The carapace width is the distance across the crab's back at the widest point. (See Figure 1)

vi. Sex: The sex of a crab is determined by the width of its abdomen (shaded area) which curls around the crab's underside. The male crab has a narrow, triangular abdomen, while the female has a much broader abdomen. (See Figure 2)

MALE



FEMALE

Figure 2: Illustration showing the narrow male abdomen and the wide female abdomen.

vii. Reporting Green Crabs: In the event that you catch a European green crab - or any other unidentifiable crab – after you have recorded the data and photographed the crab, place the animal in a bag or container to be put into your freezer.

viii. Please fill out a label with the container that includes the date the trap was set, trap location (be specific), the name and phone number of the monitor, as well as the name of the organization (if applicable).

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Monitoring Coordinators Southeast Alaska: Linda Shaw linda.shaw@NOAA.gov

Please return data sheet to Monitoring Coordinator: fill in your info here

Invasive Green Crab Monitoring Data Sheet

Page ___of ___

Monitoring Site:________________________ Lat.______________Long_____________

Salinity : ________________

Water Temperature : __________________

Monitoring Team:

1) ______________________________

2) ________________________________

3) ______________________________

4) _______________________________

Trap Set

Date/Time: ___________________ AM/PM

Tide at setting:________________

Bait Used:____________________

 # Traps Set: Folding ____Minnow ____Pit____

Trap Check

Date/Time: _____________________AM/PM

Tide at check:____________________

Capture Information:

Trap #	Trap Type (folding, minnow, pit)	Species	Sex (F, M, U)	Crab Carapace or body Length (in mm)	Photo #	Notes (parasites, broken appendages, etc)

Please continue recording data on back of data sheet

Capture Information:

Trap #	Trap Type (folding, minnow, pit)	Species	Sex (F, M, U)	Crab Carapace or body Length (in mm)	Photo #	Notes

Habitat:

Check all boxes that apply:

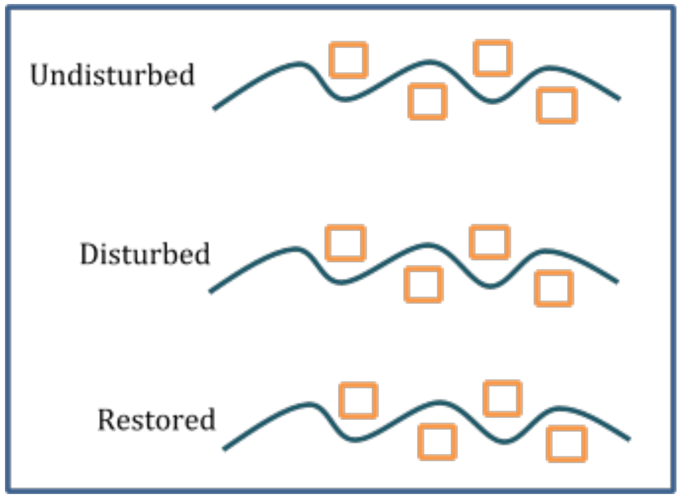
- ☐ **Sandy Beach**
- ☐ **Cord or eel Grass**
- ☐ **River/Stream Mouth**
- ☐ **Rocky/Cobble Beach**
- ☐ **Algae**
- ☐ **other:** ____________

Draw a sketch of trap layout with any key characteristics or markings:

Number the traps on the sketch from left to right, facing the water. Distance between traps ___

3D. Riparian Field Lab

RIPARIAN LESSON PLAN



Alaska State Standards
Grade Levels 9-11 Overall Science and Technology Standards:
SC Students develop an understanding of the concepts, models, theories, facts, evidence, systems, and processes of life science.

SC1 Students develop an understanding of how science explains changes in life forms over time, including genetics, heredity, the process of natural selection, and biological evolution.

SC2 Students develop an understanding of the structure, function, behavior, development, life cycles, and diversity of living organisms.

Grade Level Standards:
[9] SE2.1 questioning, researching, modeling, simulating, and testing a solution to a problem

[10] SE2.1 questioning, researching, modeling, simulating, and testing multiple solutions to a problem

[11] SE3.1 researching a current problem, identifying possible solutions, and evaluating the impact of each solution

Background Information
Restoration work is an important component of forest management in which improvements are made to forests and streams to support wildlife habitat. In the past, restoration projects have not been monitored so their success is largely unknown. To monitor the success of past restoration, it is important to first identify three sites for data collection: an undisturbed site, a restored site and a disturbed site. In this case, we will be comparing areas that have been clear-cut harvested to those that were left untouched. Some sites have undergone restoration work where trees from the forest have been thinned to open the canopy and then placed into the stream.

Sites that were studied in the summer of 2014 by students of the University of Michigan are shown in the Study Sites map in Appendix 3A. Restoration efforts in these sites focused on opening the canopy to allow light into the understory of the riparian zone. This allows the understory plants to grow, providing food for deer and other animals. Restoration efforts also moved large fallen trees into streams to slow the water down, create pools and improve fish habitat.

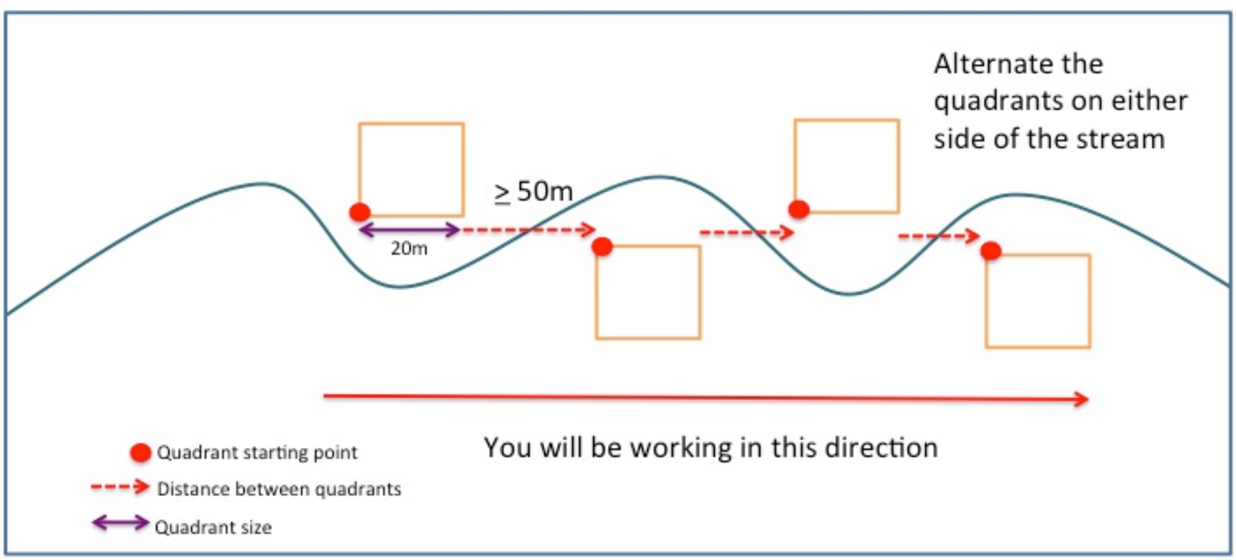
Planning Steps
Step 1: Use the following materials (materials for each quadrant, if two quadrants are measured at once, then double materials):

- 20 flags
- At least 1 tape measure that is 100 meters long
- Compass
- Field notebook (waterproof is best!) and pencil
- GPS to find site locations
- Plant field guide (trees are likely identifiable but shrubs may not be)
- DBH tape
- Data sheets
- Wear appropriate clothes and boots
- Clinometer to measure slope

Step 2: Plan sites and transportation needed. Break into groups of 4-6 people per quadrant. Sites shown on map designate where harvesting occurred in 1968, where the forest was left untouched and where restoration occurred. Quadrants should alternate sides of the stream and should be placed as close to the stream as possible.
Tip: Place the beginning edge of the quadrant as close to the stream as possible but straight and make sure your line can be 20 meters long.

All quadrants for each site (disturbed, restored and undisturbed) should be evenly spaced within the eastern and western coordinates noted on the map. There should be at least 50 meters between each site. The tape measure or a GPS can be used to measure the distance between sites.

Step 3: Assign quadrants to groups, if necessary. Make a safety plan! Head out to the field and decide which direction you will be moving as you complete your quadrants. For example, if you start on the easternmost side of the restored site, then you will move to the west with each quadrant.



Field Work

Step 1 Choosing your Starting Point: Set the beginning point of your quadrant, here you can place your first flag! Take a GPS point to mark the location. Fill into your data sheet your name and date at the top of the page. Enter your site and transect number information into the first two columns.

Step 2 Setting up the Quadrant: Measure the edge of your quadrant that borders the stream in the direction decided during the planning phase. Remember that your line should be straight and border the stream as close as possible.

Tip: To make 90 degree angles with your compass for the quadrant the person holding the measuring tape places the compass over the measuring tape and sets an initial degree on the compass. Now, add 90 degrees to your initial number and turn the dial, this is the direction for the next side.

a. At the beginning point, person A holds the tape measure and the compass. This person will be directing the straight line that person B will walk, reeling out the tape measure. As person B reels out the tape measure, they will place a flag at 1m, 15 m and 20 m.

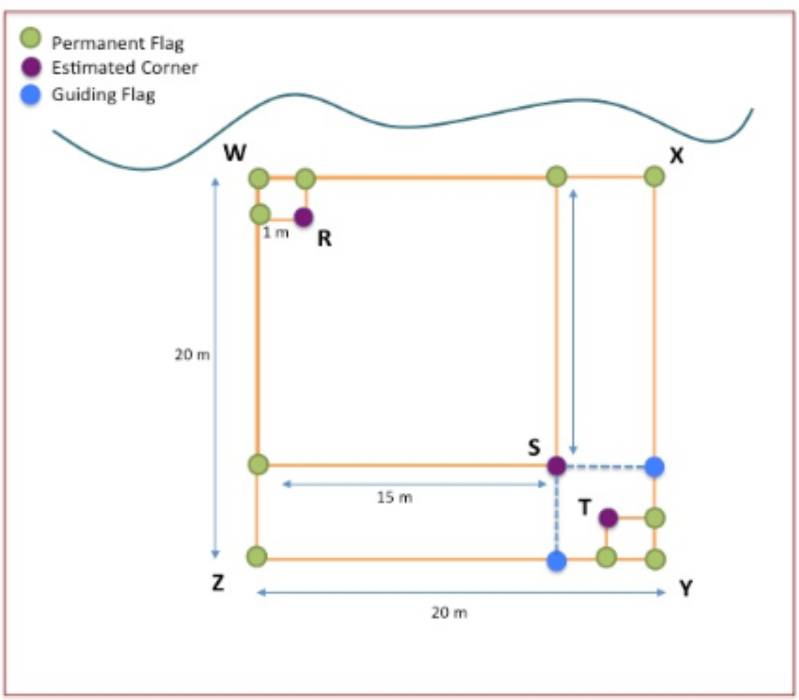
b. Once the 20 m flag has been placed, reel in your tape measure from the side along the stream. Person A and B will meet at the 20 m flag. Using the compass, person A will turn 90 degrees and direct person B to walk in a straight line out another 20 m.

c. Person B will place a flag at 15 m (guiding flag/blue dot), 19 m, and 20 m.

d. Repeat b, then place the flags at 1 m, 5 m (guiding flag/blue dot) and 20 m.

e. Repeat b, then place the flags at 5 m, 19m and 20 m.

Look at the diagram and visualize the boxes that you are making. Find your 1x1 box that is farthest from stream (corner Y on the diagram) and have a person stand at each flag that is 5 m away from corner Y (stand on the blue dots in the diagram below). A third person will stand equal distance between those two people and diagonal from corner Y to place a flag at the 15x15 m box's corner (this will make corner S). Remove the flags at 5 m (flags represented by the blue dots). Remember that you are making squares so visualize the corners. Repeat this process to create the inner corners for the 1x1 boxes (corners R and T).



Step 3 Measure and Record:

a. Within the 1x1 m boxes, count and record the total number of plants in your data collection sheet.
b. Within the 15x15 m box, you will be looking for woody plants that are above ½ meter, about knee height, and have a diameter at breast height (DBH) that is less than 20 cm. Record each species found and the total count of each in your data collection sheet.
c. Within the 20x20 m box, you will be looking for woody plants that are greater than 20 cm in DBH. Identify the species, take a GPS point and create a code for the tree. For example, if you are in the restored site, transect number 1 and it is the first tree then your code may be R11. Record the DBH measurement, species and GPS code in your data collection sheet. Snags (standing dead trees) should also be recorded and measured for DBH but not GPS'd and not identified for species.

Step 4 Woody Debris in Stream:
Along the edge of your quadrat that borders the stream, count the number of pieces of wood (fallen trees, rootwads, large branches, etc.) that are anywhere within the stream banks of the 20 meter long reach. Classify each piece as "large wood" and/or "key wood". A piece must be at least 0.1 meter in diameter (use the DBH tape at the widest part of the tree) and 1 meter long in order to be considered "large wood". The minimum size of a piece of fallen wood that is required to be classified as "key wood" depends on the width of the stream channel. The following chart should be used to determine what should be considered key wood (Nichols et al., 2013).

Channel width (m)	Wood diameter (m)	Wood length (m)
0-4.9	0.3	>3
5-9.9	0.3	>7.6
10-19.9	0.6	>7.6
>19.9	0.6	>15

Record the number of large and key wood pieces on your data sheet. If a piece is counted as key wood, then it should also be counted as large wood. Take a picture of the stream and the woods at the beginning point and record the picture number on the data sheet.

Step 5: Calculate the slope from the beginning point with your back to the stream, using a clinometer, and record on your data sheet. Double check that your data sheet is accurate and includes all important information. Return to the classroom!

Data Analysis

From your observations in the field, is the restored site more similar to the undisturbed or more similar to the disturbed site? Could you explain why this might occur?

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____
____
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Within a blank excel workbook, create column headings that are identical to your field data sheet. Enter your data into the class excel workbook so all data is joined. A google doc may be the best way to do this at one time.

Site	Transect No.	Box	Species	Abundance	DBH	Code
Undisturbed	1	1		25		
Undisturbed	1	1		282		
Undisturbed	1	15	devils club	19		
Undisturbed	1	15	salmonberry	134		
Undisturbed	1	15	hemlock	3		
Undisturbed	1	15	vaccinium	22		
Undisturbed	1	15	m.ferruginea	3		
Undisturbed	1	2	hemlock	1	4.894	TSU11
Undisturbed	1	2	spruce	1	34.36	TSU12
Undisturbed	1	2	spruce	1	52.7	TSU13
Undisturbed	1	2	spruce	1	38.862	TSU14
Undisturbed	1	2	spruce	1	54.12	TSU15
Undisturbed	1	2	Sg	1	25.654	
Undisturbed	1	2	spruce	1	6.452	TSU16

Step 1 Data Summary: To find the size structure of the forest, we need to know what the differences are in DBH, snag abundance, between the disturbed, restored and undisturbed sites. Next to your data columns, create a section to put summary data.

EXAMPLE of a data summary table.

DATA SUMMARY TO BE GRAPHED								
Forest Structure				**Forest Aging & Mortality**				
	DBH mean	St. Dev			Snag Count	Live Tree Count	Ratio	%
Undisturbed	40	20		Undisturbed				
Restored	38	18		Restored				
Disturbed	20	15		Disturbed				
Edible Understory Vegetation				**Large Tree Composition**				
	Undisturbed	Restored	Disturbed		Undisturbed	Restored	Disturbed	
Hemlock				Alder				
Spruce				Spruce				
Blueberry				Hemlock				
Regenerative Understory Vegetation				**Shrub Understory Vegetation**				
	Undisturbed	Restored	Disturbed		Undisturbed	Restored	Disturbed	
Hemlock				Devils Club				
Spruce				Salmonberry				
				Menziesia				

Forest Structure
Within the forest structure table, use the average command to find mean and then select the DBH data from each site. For example, the cell for the mean of the undisturbed site will look like this:

Forest Structure		
mean	DBH mean	St. Dev
Undisturbed	=AVERAGE(F9:F83)	
Restored		
Disturbed		

The range is included because all DBHs for the undisturbed site are recorded within cells F:9 and F:83, in this case. Your data will have different ranges depending on how many trees you recorded. Then find the mean for the restored and disturbed sites. Next find the standard deviation for each site using the formula =stdev(F9:F83). The standard deviation is a measurement of how much variability or difference in DBHs that were found. If there is a high variability or standard deviation, then there are many different sizes of trees. This means that the forest has a healthy amount of both large, small and medium trees.

If there is a low variability or standard deviation, then there are similar sizes of trees throughout the stand. This likely means that the forest has so many trees of the same size, the canopy is closed and little light can reach the understory. This is called a stem exclusion phase and certain understory species that are more shade tolerant have an advantage over others. These species may not be the ones that are best for deer to eat.

Why do you think there might be a high standard deviation or variability in a forest? Why might there be a low level of variability? "What does a high standard deviation mean in a forest? What does a low standard deviation tell us?"

____
____
____
____
____

What mean and standard deviation did you find in each site? Record as mean +- standard deviation.
*Undisturbed:*____
Restored: ____
*Disturbed:*____

Forest Structure

	DBH mean	St. Dev
Undisturbed	40	20
Restored	38	18
Disturbed	20	15

Graph the forest structure table by first highlighting the mean column and all three site rows. Second, within the insert tab click on the insert column chart icon  and choose the first graphing option. Add the standard deviation bars by clicking on the + icon, then add error bars. Choose the option to add custom error bars and then highlight your column of standard deviations. If all the error bars are the same in your graph but are not the same in your data, then the error bars are not custom made but generic ones. You will have to make them custom to represent your data! Add in a title, change the colors if you would like and make sure both axes have labels.

Understory Composition: ***Edible Vegetation, Regenerative Vegetation & Shrub Species***
It is important to understand the composition of the understory species (recorded in the 15x15 m box) because some are critical for deer and other native animals to eat in the winter. These include hemlock, spruce and blueberry. Other understory species are important to regenerate, or take the place of, overstory species. These include hemlock and spruce. Other, less desirable species are shrubs that will never grow into the overstory and do not serve as a food source for deer during the winter. These are devil's club, salmonberry and menziesia.

Count the total abundance of each understory species that was recorded as part of the 15x15box within each site. You will have to add up the total number of each species found in all quadrants for the undisturbed, restored and then disturbed sites. Then find the mean, divide the total by the amount of quadrants. For example, if within the undisturbed site 15 spruce were found in the first quadrant, then 20, then 8, you will find a mean of 14.3 spruce in the undisturbed. Record that in the summary table.

Repeat the process of finding the mean for each species of each site to fill in all of the summary tables for the understory composition.

Create graphs for each table using the methods detailed in the last paragraph under 'forest structure'. Choose the stacked column chart so each species is shown for all sites. You will not have error bars for these graphs. Make sure you have a title and axis labels, include units.

Is the restored forest more similar to the disturbed or the undisturbed for each graph?
Edible Vegetation:______________________________
Regenerative Vegetation:_________________________
Shrub Vegetation:_______________________________

What might happen in 20 years if the understory regenerative vegetation is not very dense?

____

____

What might happen if the shrub vegetation is too dense?

____

____

Large Tree Composition

The composition of trees can show us if disturbances have happened in the forest. Alder only exists where disturbances like clear-cut harvesting or extreme floods have happened. Since alder is a nitrogen fixing plant (like beans!) they help improve the soil health and allow other plants to grow. If alder is still present, then we know the site is still showing impacts from clear-cut harvesting.

Count the total abundance of each species from all quadrants within each site; undisturbed, restored and disturbed. Note the total numbers of each species for each site. This will be used in the next section. Find the mean by dividing by the number of quadrants and enter the number in the summary table.

Graph the table using the insert column chart, then stacked column chart. The stacked column chart will show each species type for each transect. Add in your title and axis labels, again you will not have any error bars.

In what sites are alder present?

____

____

For each site, write which species is most common:
Undisturbed: _______________________________________
Restored: ____
Disturbed: ____

Forest Aging & Mortality

Standing dead or fallen trees give us information on the mortality rates in the forest. By looking at the snags found in each transect and comparing them to the number of live trees we can determine if the forest's life cycle is occurring in a way expected for this type of forest. Snags are also important for bird habitat. For example, many species of birds build their nests in the snag's hollow trunks.

Scroll through your excel sheet and count the total number of snags found in all of the transects. This number will be compared to the number of live trees found in all of the transects. Use the information noted from the previous section. To get the snags to live tree ratio, divide the total snag number by the total live tree number. To get this number in a percentage, simply multiply the ratio by 100. You have calculated the percentage of the volume of standing deadwood in the forest.

To graph this data, highlight the first column and the percentage column and insert a clustered column chart. Don't forget to add the axis labels and a title. You should see the three sites on the x-axis and the percentage values on the y-axis.

Which site had the highest percentage of deadwood?

____

What information does this give us about the forest?

____

____

How does the undisturbed compare to the disturbed and restored sites?

____

____

____

____

Woody Debris in Stream

Large and key woody debris (trees, logs, rootwads, and large branches that fall into streams) play a critical role in the functioning of healthy stream systems by interacting with the water, substrate, and biota of the channel. Woody debris provides habitat and food for aquatic organisms, alters the shape of the channel, slows down the flow of water, prevents streambank erosion, affects nutrient and sediment transport, creates pool habitat, and increases the complexity of the channel. The largest pieces of woody debris, termed key woody debris (KWD), greatly impact the stream by stabilizing the channel and strongly influencing the deposition and transport of other pieces of large woody debris, thereby creating debris jams. Debris jams subsequently aid in large pool formation and provide the habitat necessary for fish spawning, specifically salmon and trout. Overall, it can generally be said that a healthier stretch of stream should contain a greater amount of woody debris.

Count the total number of woody debris in the streams for each site and record below:

*Undisturbed Large Wood:*________________ *Undisturbed Key Wood:*________________

*Restored Large Wood:*___________________ *Restored Key Wood:*___________________

*Disturbed Large Wood:*__________________ *Disturbed Key Wood:*__________________

Which site has the most woody debris within the stream channel? Why do you think this is?* Is there a difference between the relative amounts of large and key wood? Based on the amount of woody debris in the stream, which site do you think provides higher quality habitat for macroinvertebrates and fish?

*Our data showed that the disturbed sites sometimes had more in-stream woody debris, which we think may be because of the higher amount of alder that was found along the streambank. Alder has a shorter lifespan than spruce or hemlock.

Conclusion

From all of the data collected and your analysis, do you think that the restored site is more similar to the undisturbed or the disturbed site? Why?

Why do you think monitoring a restoration project is important?

In what areas (forest structure, understory composition, etc) is the restoration working?

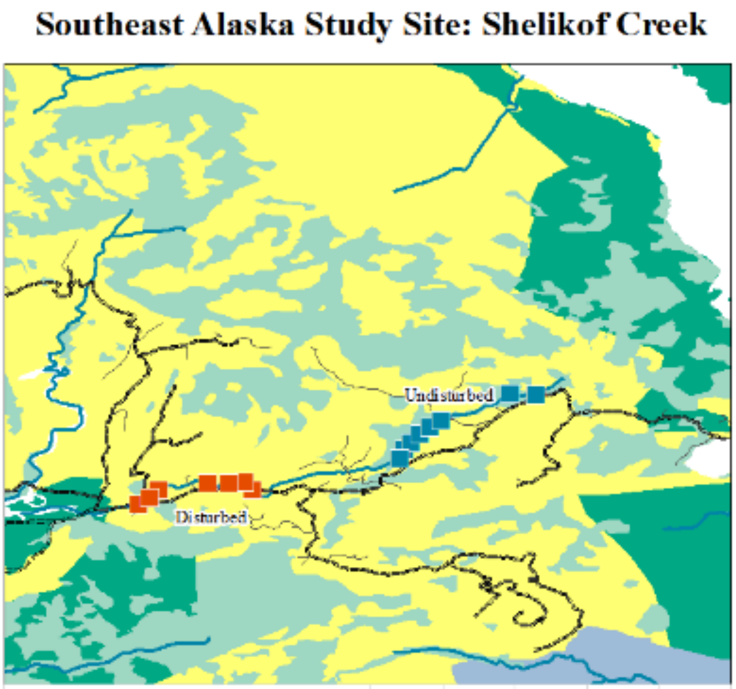
In what areas (forest structure, understory composition, etc) is the restoration NOT working?

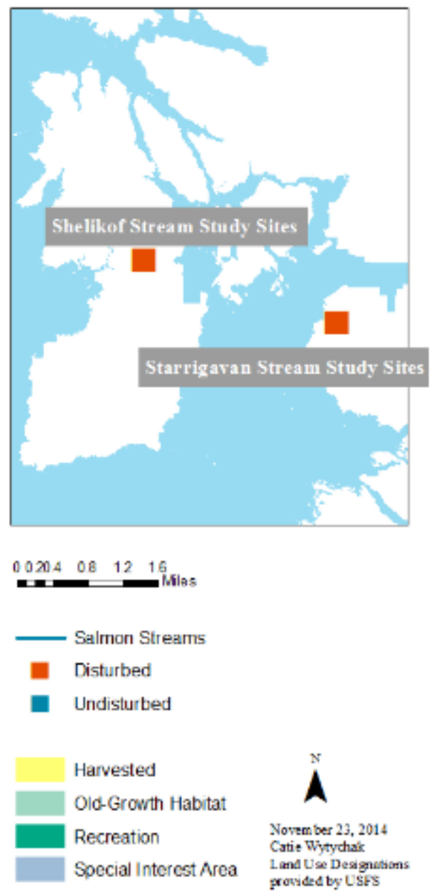
Are the impacts of the clear-cut timber harvest still visible in the forest and stream?

How does the overstory (large trees in the 20x20 m plot) density affect the deer population?

Field Lab Appendix

A: Study Sites

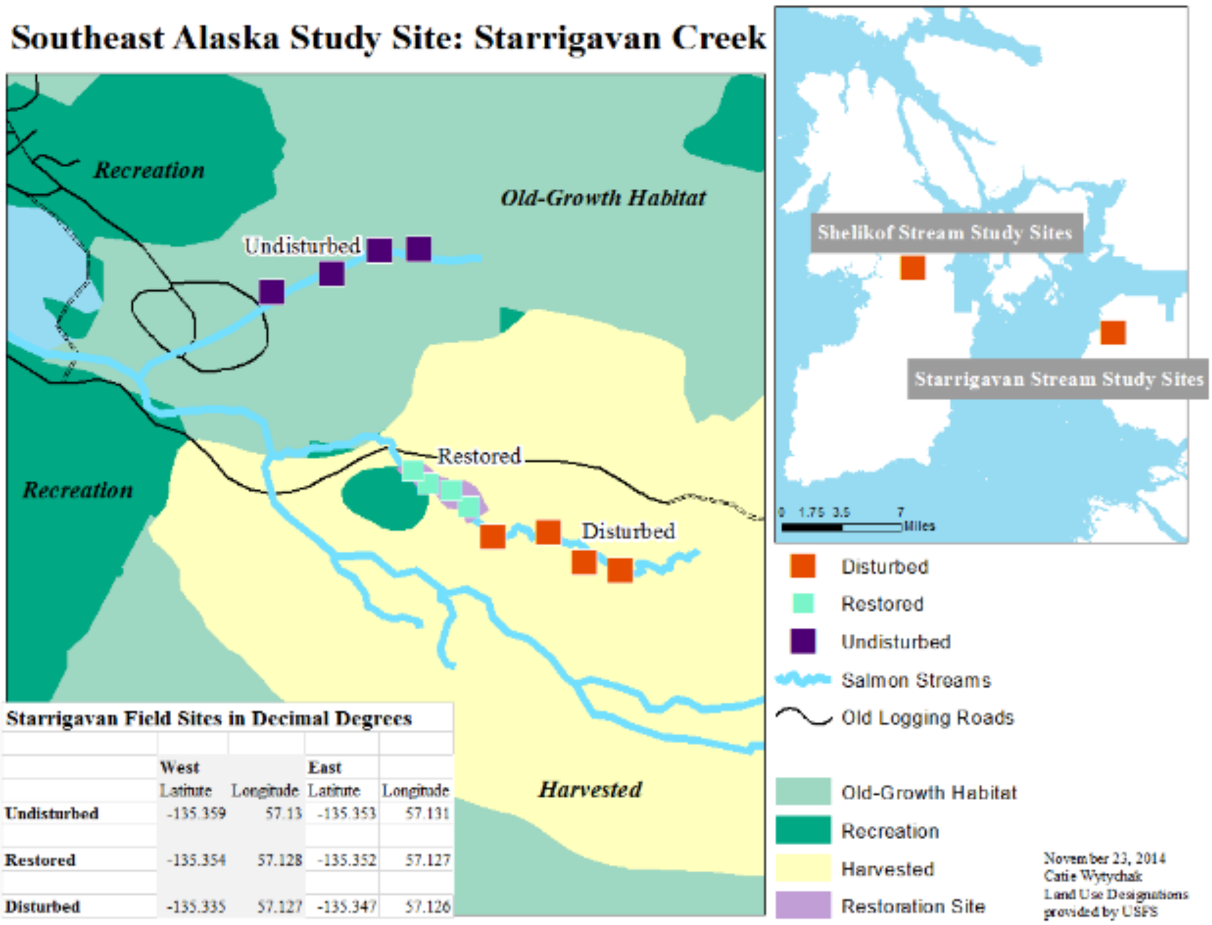




Shelikof Field Sites in Decimal Degrees

Segment 1 is on the western edge of the transect block and segment 2 is on the eastern edge

	1. West		1. East		2. West		2. East	
	Latitute	Longitude	Latitute	Longitude	Latitute	Longitude	Latitute	Longitude
Undisturbed	-135.668	57.177	-135.659	57.185	-135.651	57.187	-135.644	57.189
Disturbed	-135.712	57.171	-135.706	57.173	-135.7	57.174	-135.691	57.172



	West		East	
	Latitute	Longitude	Latitute	Longitude
Undisturbed	-135.359	57.13	-135.353	57.131
Restored	-135.354	57.128	-135.352	57.127
Disturbed	-135.335	57.127	-135.347	57.126

There are tagged trees in each of the transects.

3E. Alaska Stream Team Water Quality Analysis Worksheet

"Alaska Stream Team" Water Quality Analysis Worksheet

This worksheet was created in order to provide students with a follow-up analysis activity for the "Alaska Stream Team Educational Level Water Quality Monitoring Field Guide". This analysis attempts to use stream data, collected via rapid bioassessment methods, to evaluate the quality of Southeast Alaska streams, specifically those impacted by timber harvest and ecological restoration.

Alaska State Standards:

[7] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating

[7] SA1.2 The student demonstrates an understanding of the processes of science by collaborating to design and conduct simple repeatable investigations, in order to record, analyze (i.e., range, mean, median, mode), interpret data, and present findings

[7] SG3.1 The student demonstrates an understanding that scientific knowledge is ongoing and subject to change by revising a personal idea when presented with experimental/observational data inconsistent with that personal idea (e.g., the rates of falling bodies of different masses)

Background

Monitoring is a crucial part of any type of management, especially for habitat and water quality. We need monitoring data in Southeast Alaska to assess the current quality of our streams and forests, determine how to best manage the environment (adaptive management), figure out what areas need special attention, prioritize sites for future intervention (ecological restoration), and establish what methods are successful. Monitoring data can also allow us to directly observe when changes occur in streams, allowing professionals to work to improve quality before negative impacts occur.

You have already learned a lot about how we monitor water quality by conducting a rapid bioassessment using the Alaska Stream Team Field Guide. The next step is to take the data we have collected and determine what is says (analyze the data). In this activity we are going to compare the data you have collected to data collected at three sites on Starrigavan Creek by University of Michigan students in June of 2014. Your data is important in monitoring potential changes in water quality and evaluating the success of restoration work (in-stream wood additions) on Starrigavan Creek.

First, write down your hypothesis about which site type (undisturbed, disturbed, or restored) you think will have the highest overall quality (water and habitat quality) and which site type will have the lowest.

Hypothesis: ____

____

Inputting Alaska Stream Team Collected Data

Begin by filling in the following chart with your Stream Team collected data (In the gray boxes). Each column should be filled in with the Stream Team data from one site. In general, having more data (both for different sites and multiple years) is preferred and allows us to better understand what is happening in the stream and how to manage it in the future. Therefore, make sure to input as much data into the below table (different sites and years) as you have available.

Site	Starrigavan Creek	Starrigavan Creek	Starrigavan Creek			
Type (Undisturbed, Disturbed, or Restored)	Undisturbed	Disturbed	Restored			
Date Sampled	6/27/14 11:00 AM	6/28/14 1:00 PM	6/28/14 3:00 PM			
Water Temperature (□C)	9	9	9			
Dissolved Oxygen (mg/L)	10	8	8			
Discharge (ft^3/sec)	3.64	0.47	1.04			
EPT Richness	9	1	5			
Non-EPT Richness	4	4	4			
Taxa Richness	13	5	9			
Percent Non-EPT	12.6%	80.0%	35.9%			
Percent EPT	87.4%	20.0%	64.1%			

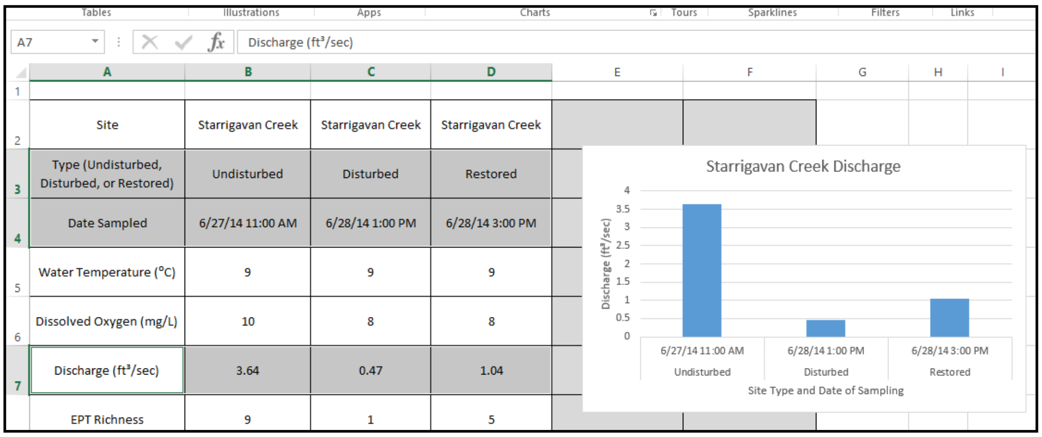
Analysis of Data

The next step in the analysis is to graph all available data so that we can compare the different sites and assess the success of the restoration work. These graphs can be created by hand using graph paper or using a computer program, such as Microsoft Excel. This section will walk you through the process of graphing your data using Excel.

Begin by inputting the table from the previous section into Excel. Make sure to input both your data and the data from previous years and sites.

Next, plot the chemical quantitative data (water temperature, dissolved oxygen, and discharge) by creating three separate graphs. The site should be on the x-axis (horizontal) of all three graphs. The site can be further divided by type (undisturbed, disturbed, or restored) and year. The chemical quantitative variables should be on the y-axis (vertical).

1. Begin by plotting the discharge data for all the sites. Highlight the three rows that will go into the chart (site type, date/year, and discharge).
    - Excel tip: hold down the "ctrl" key while highlighting data in order to select multiple rows of data that may not be directly connected.



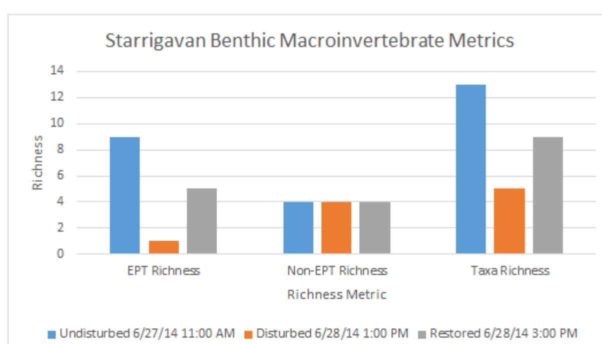
2. Next, create a clustered column chart by selecting "Insert" → Recommended Charts" → "Clustered Column" chart type. Some versions of Excel may differ in exactly how to create graphs.

3. Add a chart title and axis titles. **Don't forget units!** You can add these chart elements and others by clicking the  in the top right corner of the graph. You could also select "Chart Tools" → "Design" → "Add Chart Element". Feel free to change the chart colors and styles.

4. Follow the same directions to plot water temperature and dissolved oxygen on their own plots.

Next, plot the benthic macroinvertebrate data (EPT richness, non-EPT richness, taxa richness, percent non-EPT, and percent EPT) on two different graphs using the clustered column chart type.

The first graph (similar to the image on the right but with your data included as well) should have the three richness metrics (EPT richness, non-EPT richness, and taxa richness) on the x-axis and the richness value on the y-axis. To do this you will need to highlight the stream type, date, EPT richness, non-EPT richness, and taxa richness rows prior to inserting the clustered column chart.



The different sites should be included in the legend and represented by different color bars. This could alternatively be graphed with the site type on the x-axis and the richness metrics in the legend, but grouping the x-axis based on richness metrics allows us to directly compare the values between sites. *Make sure to include a chart title, axis title, and legend with the different site types.*

Follow the same directions to plot the two percentage benthic macroinvertebrate metrics (Percent non-EPT and Percent EPT) on a second chart.

Discussion Questions

Answer the following questions based on your results.

1. Which type of site (undisturbed, disturbed, or restored) appeared to be most favorable for benthic macroinvertebrates and is therefore believed to have the highest water quality?
Remember from the Stream Team Manual that EPT macroinvertebrates are generally less tolerant of pollution than non-EPT, which means that higher numbers of EPT organisms (% EPT and EPT richness) indicate better water quality. On the other hand, higher numbers of non-EPT organisms (% non-EPT and non-EPT richness) imply more pollution and lower water quality. Also, when there is more diversity in the types of organisms present in a stream (Taxa richness), it tends to indicate better water or habitat quality.

____
____
____

2. Which type of site (undisturbed, disturbed, or restored) was least favorable for benthic macroinvertebrates and is therefore believed to have the lowest water quality?

____
____
____

3. Did the above results agree with or disagree with your initial hypothesis from the beginning of this exercise? If possible, try to use the temperature, dissolved oxygen, and/or discharge data to help explain the results.
For example, if a site has an extreme temperature (high or low), very low discharge (water is stagnant/not moving), or low dissolved oxygen, it suggests that the water has poor quality for the life in the stream and would explain why benthic macroinvertebrate variables might indicate low quality.

____
____
____
____

4. Compare your results to the results collected in 2014 from the same type of site (if you measured a restored site, then compare it to past data from restored sites). Has the quality improved, declined, stayed the same, or are the results inconclusive/uncertain? Explain if this was expected and why you think you might have obtained these results.

5. Overall, what do the results say about the relative quality of fish habitat between the three types of sites? Which variable do you think would be most important/relevant for fish health? Support your results with scientific or ecological reasoning.

Consider that all of the above variables play some sort of role in impacting the quality of habitat for fish. Benthic macroinvertebrates are an important food source for fish and indicate overall water quality. Still, fish are also sensitive to extreme temperatures, dissolved oxygen concentrations, and water discharge. Also, consider that the water temperature, dissolved oxygen, and discharge measurements represent a specific point in time (snapshot), whereas the benthic macroinvertebrates show the cumulative impacts of water quality and stream stressors over a potentially longer time period.

6. Finally, answer any two of the following four conceptual questions.

a. Do you have any recommendations for future management of the area after seeing these results?
b. Based on these results, does disturbances (timber harvest) impact stream water quality?
c. Has the restoration work been successful in improving fish habitat quality? What other work could be done to improve water and/or habitat quality for stream life?
d. Is there anything you would do differently if you were to conduct this study again in the future? Would you change anything about how the data collection or analysis was designed?

3F. Educational Level Stream Monitoring Field Guide

Educational Level Stream Monitoring Field Guide

Alaska State Standards:

[7] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating

[7] SA1.2 The student demonstrates an understanding of the processes of science by collaborating to design and conduct simple repeatable investigations, in order to record, analyze (i.e., range, mean, median, mode), interpret data, and present findings

[7] SD2.1 The student demonstrates an understanding of the forces that shape Earth by identifying strategies (e.g., reforestation, dikes, wind breaks, off road activity guidelines) for minimizing erosion

[7] SG3.1 The student demonstrates an understanding that scientific knowledge is ongoing and subject to change by revising a personal idea when presented with experimental/observational data inconsistent with that personal idea (e.g., the rates of falling bodies of different masses)

Using this Manual

To complement data that will be collected via the "Alaska Stream Team Educational Level Water Quality Monitoring Field Guide" (ENRI, 2004), the following additional field methods were selected and designed to assist science educators in using **rapid bioassessment** methods with their students to **monitor** aspects of stream health and **ecological restoration** success not directly measured in Alaska Stream Team monitoring.

It is crucial that ecological restoration efforts are monitored in order to determine success and advise future work. In order to best monitor restoration success, it is preferred if more than just the site that is being restored is monitored. If possible, the following three types of sites should be monitored:

1. **Restored site-** the site that is having or has had some kind of ecological restoration actions done to it.
2. **Disturbed site-** a similar site that is not being restored yet has experienced an environmental disturbance.
3. **Reference site-** a high quality site that displays similar characteristics to the target site and can act as the eventual goal of the restoration work

The following methods can be conducted for each site or specific methods can be selected based on the variables of interest. The importance of each measurement and reasons for its potential uses are described in the appropriate sections.

It should be noted that these methods were selected specifically for restoration procedures that involve additions of **large wood** into the stream in an attempt to mimic natural processes interrupted by past logging activities. With that being said, these methods are still applicable to, and should be utilized in, future monitoring of other types of restoration work and habitat quality in general.

The **bolded** terms in this manual are defined further in the glossary.

Preparation

Site Locations

The following methods should be conducted at the same reaches as the "Stream Team" surveys. The specific stream reach should be 20 meters long and marked with flags or something to allow the boundaries to be easily identifiable. The methods describe where each measurement should be taken.

Wetted Width to Depth Ratio

The **wetted width to depth ratio** is a **dimensionless** ratio that describes the shape of the **stream reach** and the maximum flow that can be transported through the stream (Brierley et al., 1996). The ratio can be used as an indicator of habitat quality for fish due to the fact that the width and depth of a channel greatly influences fish **spawning** and growth (Flosi et al., 1998).

In general, a *lower width to depth ratio suggests that the stream is thinner and/or deeper*, which is normally associated with:

- increased number of pools (needed for fish habitat)
- decreased **sedimentation**
- lower water temperatures, and
- *better overall fish habitat* (Foster et al., 2001).

The width to depth ratio can also be used to determine whether sites are similar in shape, and thus appropriate to be compared for other variables. Finally, the ratio can be used over multiple years to indicate the stability of the stream channel (if the value is changing significantly) and whether **erosion** or **aggradation** are occurring. Channel stability and erosion are known to greatly impact fish and **benthic macroinvertebrate** habitat (Flosi et al., 1998).

Materials

- Wetted width to depth ratio methods
- 100 meter long tape measure
- Waterproof field journal and pencil
- Pair of hip/chest waders

Methods

1. Begin by determining the location within the 20 meter stream reach where the width and depth locations are to be recorded.
    - In order to accurately calculate the wetted width to depth ratio, the measurements need to be taken at a **riffle**, which is where the stream is relatively shallow and turbulent.
    - The ideal location for the measurement is at the beginning point of the reach or within the designated reach, but if there are not any riffles within that area, then it is acceptable to find the nearest riffle.
    - It is also preferable to conduct the measurements at a location that appears to be representative (in width and depth) of the entire reach.

- Make sure to note the general location, relative to the beginning point of your stream reach, in your field journal.

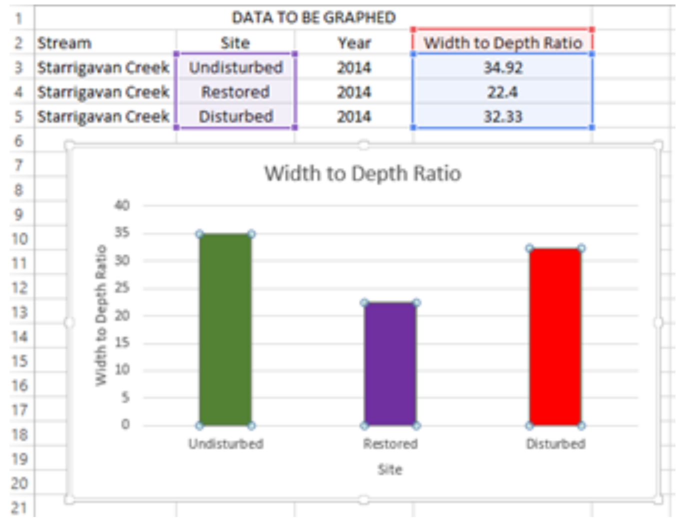
2. Next, using the tape measure and two students, measure the width of the current wetted channel (area that has flowing water in it) at the determined riffle **transect**. This measurement can be recorded in any unit of length, but should be converted to inches at the end.

3. While the tape measure is still being held across the stream, measure the water depth (in inches) at multiple points along the transect/tape measure. See the image on the right for a visual of how this should be done (Miller, 2001).
    - In order to receive an average depth that is representative of the entire stream channel, the depth should be measured and recorded about every foot in a small stream (<30 ft.) and every three feet in a large stream (>30 ft.).
4. Calculate the average depth by summing all of the measurement and then dividing by the total number of measurements.

	A	B
1	Observation Number	Depth (inches)
2	1	8
3	2	16
4	3	16
5	4	10
6	5	6
7	Average Depth:	(8 + 16 + 16 + 10 + 6) / 5

5. Finally, calculate the width to depth ratio by dividing the average width by the average depth of the stream channel. Make sure that both values are in the same units.
6. Write down any additional observations you have. These could include information about why you chose the specific location for measurements, water clarity, water velocity, presence of woody debris, habitat types, or anything that could help you better understand the reach for when you analyze the results or when other people look back on your data.
    - The following is an example of additional observations: “Measurements were recorded about 10 meters downstream of the beginning of the reach in order to measure an area with riffle habitat. There is a sandbar on the left bank. A fallen tree is creating a mini-waterfall a few meters upstream of the measurements. The water is clear and is flowing at a high speed.”

Analysis



In order to analyze the width to depth ratio data, begin by entering the data into a blank excel workbook. Enter the data by:

1. Stream
2. Site type (undisturbed, restored, or disturbed), and
3. Year (if you have data for multiple years).

Compare the width to depth ratios between sites by creating a bar graph with the different sites on the x-axis (horizontal) and the width to depth ratio on the y-axis (vertical). If you have data for multiple years, plot the year on the x-axis (horizontal) and the width to depth ratio on the y-axis (vertical). If you have multiple samples of the same site, calculate and graph the average width to depth ratio.

Answer the following questions based on the results:

1. Do the ratios appear to be similar or different between sites? Which site possesses higher quality habitat characteristics for fish, specifically salmon and trout? Remember that a lower ratio is believed to be better for fish habitat. The Rosgen delineation criteria assigns low width to depth ratio values as less than 12, moderate to high between 12 and 40, and very high greater than 40 (Flosi et al., 1998).

2. From these results, what can you infer about what has happened in the past at the sites or what might happen in the future (timber harvest, disturbances, bank erosion)?

3. If you have data for multiple years, how has the width to depth ratio changed from year to year? What does this tell you? ____

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4. Overall, were these the results you expected based on what you know about the history of the different sites? What was different than expected, if anything? Give one possible reason for this difference.____

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5. Do you feel that the restoration work at the restored site has been successful? Remember that it is expected that an increase in large wood will slow water and form pools, improving fish habitat and causing the width to depth ratio to decrease. Do you have any recommendations for future **management**?____

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6. Is there anything you would do differently if you were to conduct this study again in the future? What would you change about how the data collection or analysis was designed?

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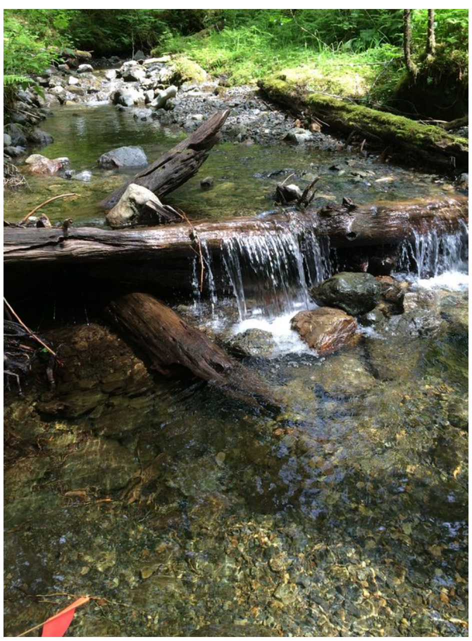
In-stream Woody Debris

In-stream large and key **woody debris**, which are dead trees, logs, rootwads, and large branches that have fallen into streams, play a critical role in the functioning of healthy stream systems by interacting with the water, **substrate**, and **biota** of the channel. They impact the shape of the channel and provide cover and food for aquatic organisms. It has even been said that "no other structural component of the environment is as important to salmon habitat as is large woody debris" (Opperman et al., 2006).



When a large piece of wood enters and remains in a stream, it

1. alters the flow of water in the channel,
2. affects nutrient and sediment transport,
3. **scours** (digs) out pools, which provide shelter for fish,
4. provides habitat for fish and invertebrates,
5. increases channel complexity, and
6. provides food and allochthonous (from outside of the stream) inputs for stream biota.

In this regard, *it can generally be said that a healthier stretch of stream should contain a greater amount of debris*. Juvenile **salmonid** (mainly salmon and trout) abundance in rivers, particularly juvenile coho salmon, has even been experimentally shown to be positively correlated to the abundance of large wood (Hicks et al., 1991).

The largest pieces of woody debris, termed **key woody debris** (KWD), impact the stream by stabilizing the stream channel and strongly influencing the **deposition** and transport of other pieces of large woody debris, thereby creating debris jams. Debris jams then aid in pool formation and provide the habitat necessary for salmonid spawning (Opperman et al., 2006).

Unfortunately, timber harvest and other **riparian** disturbances negatively impact the amount of woody debris that falls into adjacent streams, which is why it is important to monitor the amount of woody debris.

Materials

- Woody debris methods
- Waterproof field journal and pencil
- Pair of hip/chest waders
- Tape measure
- DBH (diameter at breast height) tape measure

Methods

1. Walk along the streambank of your 20 meter sample reach and count the number of pieces of woody debris that are anywhere within the stream banks.
2. Using a tape measure and DBH tape, classify each piece as "large wood" and/or "key wood".
    - A piece must be at least 0.1 meter (10 cm) in diameter (use the DBH tape at the widest part of the woody debris) and 1 meter (100 cm) long in order to be considered "large wood".
    - The minimum size of a piece of woody debris that is required to be classified as "key wood" depends on the width of the stream channel. The following chart should be used to determine what should be considered key wood (Nichols et al., 2013).

Channel width (m)	Wood diameter (m)	Wood length (m)
0-4.9	0.3	>3
5-9.9	0.3	>7.6
10-19.9	0.6	>7.6
>19.9	0.6	>15

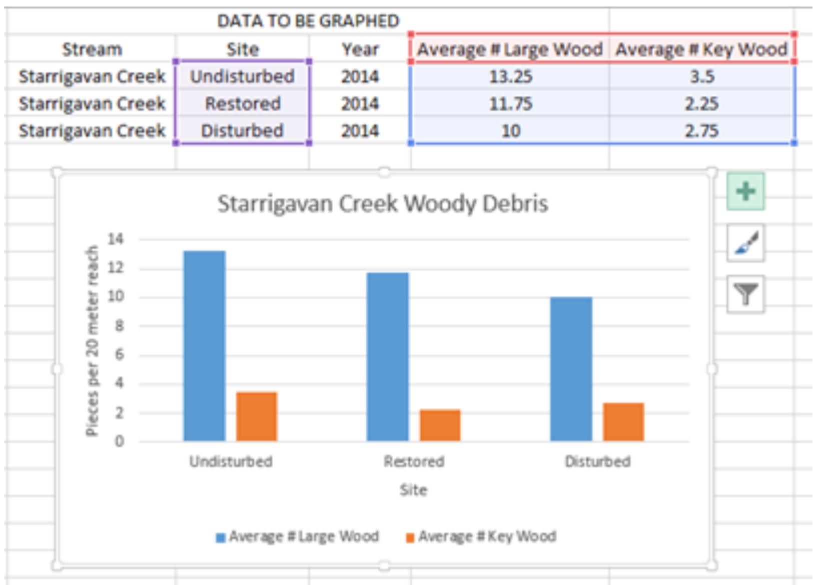
    - It may be necessary to use hip or chest waders to wade in the stream to measure the average width of the channel and the diameter and length of each piece of woody debris.
    - **Safety tip**: It might be impossible or impractical to measure every piece of woody debris due to stream depth or pieces being totally submerged (under water). It is *acceptable* to use your best judgement based on using a tape measure and DBH tape to determine what a piece needs to look like in order to be considered large or key wood.

3. Separately record the total number of large and key wood pieces for each site in your field journal. If a piece is counted as key wood, then it should be counted as large wood as well.

4. It may be helpful for future analysis to take a picture of the stream and the adjacent riparian zone at the beginning point of your reach and record the picture number in your field journal.
5. Also, write down any observations you have regarding the amount, type, or location of woody debris in the stream, as it may be helpful in discussing your results

Analysis

In order to analyze the woody debris data, begin by entering the data into a blank excel workbook. Enter the data in the following columns:



DATA TO BE GRAPHED

Stream	Site	Year	Average # Large Wood	Average # Key Wood
Starrigavan Creek	Undisturbed	2014	13.25	3.5
Starrigavan Creek	Restored	2014	11.75	2.25
Starrigavan Creek	Disturbed	2014	10	2.75

1. Stream
2. Site type (undisturbed, restored, or disturbed)
3. Number of large wood pieces
4. Number of key wood pieces
5. Year (if you have data for multiple years).

If you have multiple samples from within the same site, calculate the average number of large wood pieces and average number of key wood pieces per 20 meter long reach.

Compare the amount of woody debris between sites by creating a bar graph with the different sites on the x-axis (horizontal) and the number of woody debris pieces per 20 meter long stream reach on the y-axis (vertical). If you have data for multiple years, plot the year on the x-axis (horizontal) and the amount of large wood on the y-axis (vertical).

Answer the following questions based on the results:

1. Do the values appear to be similar or significantly different? Which site appears to be of higher quality for fish, specifically salmonids? Did the same site have the highest amount of both large and key wood?____

2. Why do you think you obtained these results? Do these results tell you anything about what has happened in the past at the sites (timber harvest, disturbances, etc.)? ________________________________

3. If you have data for multiple years, how has the amount of woody debris changed from year to year? What does this tell you about the site and the overall quality of the stream habitat for fish?

4. Overall, were these the results you expected based on what you know about the history of the different sites? What was different than expected, if anything? Give one possible reason for this deviation.

5. Do you think the restoration work is being successful? Is it worth it to continue to add large wood to the restored site? Other than adding woody debris, what else can you do to prevent erosion of a streambank (stop soil from moving into the stream)? Do you have any recommendations for future management?

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6. Is there anything you would do differently if you were to conduct this study again in the future? What would you change about how the data collection or analysis was designed?

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Pebble Count

The stream **substrate**, sometimes called sediment, is the material that composes the bottom of the stream channel. The overall size of the substrate is important in that it directly impacts salmon and other aquatic biota in terms of

- cover,
- **refuge** from high velocity water, and
- spawning and rearing surfaces.

From the image on the right (Safanda, 2012), you can see salmon as they are preparing to spawn by depositing/releasing eggs on the stream substrate.

Through pebble count procedures, substrate size data can be fairly easily collected and analyzed, providing valuable insight into the quality of stream conditions for fish and other biota. The Wolman pebble count is currently the most common method for characterizing substrate particle sizes and is regarded as a quick, practical, reproducible, and effective method for determining the mean substrate size of a stream or river (Daniels & McCusker, 2010). It can also be used to evaluate **fine sediment** (very small pieces of sediment, typically less than 6 mm large) deposition and other cumulative effects of a variety of land management activities and disturbance events (Olsen et al., 2005).

Measures of overall substrate size, such as **mean** and **median** values, can be of great value in describing the habitat available to salmonids (we are mainly worried about salmon and trout) and invertebrates. For example, a collection of studies of gravel sizes used by spawning salmonids found that the median and mean gravel sizes used for spawning were 25 mm and 16 mm, respectively, and that *substrate size was correlated to the size of the fish in the area* (which means that fish are bigger in areas with larger substrate size).

Studies have also found that most species of fish tend to be associated primarily with areas that do not have high levels of fine particles. Fine sediment provides poor habitat for fish and macroinvertebrates by clogging spaces between larger pieces of substrate, preventing adequate water flow and oxygenation of eggs (Keeley & Slaney, 1996). Unfortunately, upstream land uses, such as timber harvest and road construction, have been known to increase the proportions of fine sediment and clog spawning gravels (Kondolf, 2000). These land uses contribute fine sediment by

- disrupting soils,
- removing vegetation,
- increasing soil hazard, and
- causing erosion and landslides (USDA Forest Service, 2006).

In the end, *studies have shown that high levels of fine sediment and small mean substrate sizes generally have negative consequences for the fish community in the area*.

Materials List

- Pebble count methods
- Pebble Count Data Entry Sheet
- Waterproof field journal and pencil
- Pair of hip/chest waders
- Gravelometer or ruler
- Waterproof gloves (optional)

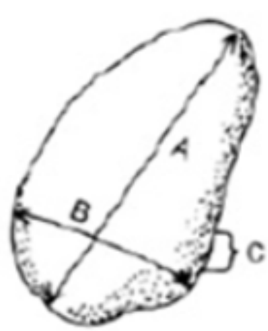
Methods

The following methods are based off of the Wolman pebble count methods, which assess the size distribution of the stream substrate by measuring 100 randomly selected **pebbles/particles** (Wolman, 1954). The below image shows Forest Service employees conducting the same Wolman pebble count methods that you will be using (Casper et al., 2000).

1. Begin by selecting a 20 meter long stream reach that you are interested in determining the substrate particle size distribution.
2. In order to collect your 100 samples from throughout the 20 meter reach, divide the reach into five transects, beginning at one end of the reach, that are evenly spaced out. A total of 20 particle samples will be collected along each transect.

3. Begin measuring by taking one step into the water perpendicular to the flow and picking up the first pebble you touch with your index finger. Do this while averting your eyes and always touch the particle at the tip of your boot in order to reduce the bias for larger rocks.

4. Measure the width (**intermediate axis**) of the pebble and record it in your field journal.
    - It is preferable that you utilize a **gravelometer** to do this, which provides a hand-held template with square holes of different size classes to classify particles (Stream Systems Technology Center, 1994).
    - The gravelometer, which can be seen in the above image (Sitka Conservation Society), acts like a sieve to sort particles in a standard way, minimizing potential errors in measurement (Daniels & McCusker, 2010).
    - The pebble size (mm) is recorded as the smallest hole of the gravelometer that the pebble is able to fit through, which corresponds to the length of the intermediate axis.
5. If a gravelometer is not available, then it is also acceptable, yet not as accurate or efficient, to utilize a ruler to measure the width/intermediate axis (in mm) of each pebble.
    - The intermediate axis is perpendicular to the longest axis and is neither the longest nor shortest side.
    - Refer to the below images to illustrate how to measure the intermediate axis (West Virginia DEP).
    - Anything below 2 mm can be noted as fine.



Axis of a pebble

(A) – Long axis
(B) – Intermediate axis
(C) – Short axis

6. Continue to randomly move along the transect, perpendicular to the bank of the stream, measuring and recording the size of pebbles by the above stated methods. Try to randomly space out your samples so that you can transverse the entire stream width with the 20 samples.
7. Once all 20 samples have been recorded, move to the next transect within the reach (approximately four meters away) and sample 20 more pebbles, using the same methods as above.
8. Repeat this process until five transects have been sampled with a total of 100 pebbles selected, measured, and recorded in your field journal. Alternatively, you can use the attached "Pebble Count Data Entry Sheet" to record your pebble count data. Whenever a pebble is measured, mark a tally in the box corresponding to the appropriate size range. In the end, sum all the tallies in each range and write the number in the corresponding "Total Count" box. All of the "Total Count" boxes should sum to 100 ("Total Number of Pebbles").

Analysis

In order to analyze the pebble count data, begin by entering the data into a blank excel workbook. Create a column for each site/reach and enter the measurement width of all 100 pebbles/particles that were sampled. If you used the "Pebble Count Data Entry Sheet", enter the upper limit of the range (i.e. enter 4 mm for any pebble in the 2.8-4 mm range).

M	N	O	P
	Measured Substrate Sizes		
Sample #	Undisturbed	Restored	Disturbed
1	5.6	4	22.6
2	32.0	5.6	2
3	2.0	2	45
...	...	...	...
99	64.0	32	4
100	8.0	16	5.6
Mean	AVERAGE(N3:N103)	AVERAGE(O3:O103)	AVERAGE(P3:P103)
Median	MEDIAN(N3:N103)	MEDIAN(O3:O103)	MEDIAN(P3:P103)
% Fine (<2 mm)	COUNTIF(N3:N103, "<=2")/100	COUNTIF(O3:O103, "<=2")/100	COUNTIF(P3:P103, "<=2")/100
% Fine (<6 mm)	COUNTIF(N3:N103, "<=6")/100	COUNTIF(O3:O103, "<=6")/100	COUNTIF(P3:P103, "<=6")/100

Below all the samples, create rows for the mean size, median size, percentage of samples less than or equal to 2 mm (% Fine ≤2 mm), and the percentage of samples less than or equal to 6 mm (% Fine ≤6 mm).

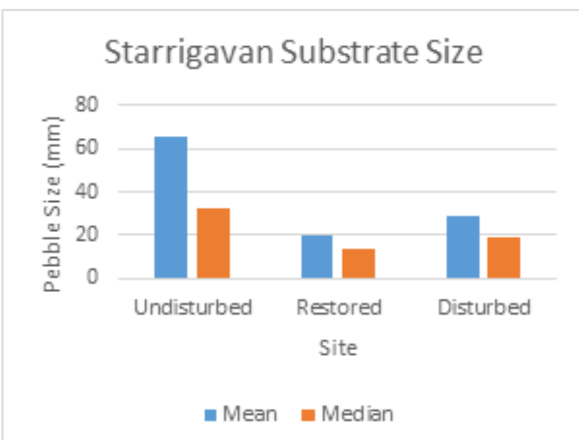
- The mean particle size is a standard calculation that sums up the average sized particle at each site into a single number.

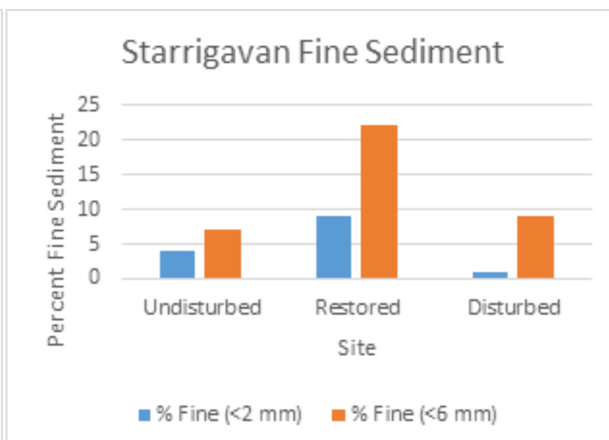
- The median particle diameter, or D50, is the size that 50% of the sample is finer than. It is commonly used in hydrology, geomorphology, and engineering to measure the middle value of a distribution and is not skewed by outliers.
- Percent fine sediment describes the percentage of the particles in the sample that are either less than 2 mm or 6 mm in size. The presence of fine sediment plays a major role in the functioning of a stream and can be indicative of further problems (Kondolf, 2000). It has been determined that fine sediment less than 2 mm clogs open spaces between larger pieces of substrate and decreases oxygen availability for salmonid eggs during **incubation**. On the other hand, larger fine sediment (<6 mm) impacts the availability of oxygen for hatching salmonids during **emergence**.

Compare the different sites by creating two bar graphs (below).

1. On one graph plot the mean and median substrate size on the y-axis (vertical) and the sites on the x-axis (horizontal)
2. On the other graph plot the percent fine sediment less than 2 mm and less than 6 mm on the y-axis (vertical) and the sites on the x-axis (horizontal).

If you have data for multiple years, plot the year on the x-axis (horizontal) and the pebble count variables (mean, median, percent fine) on the y-axis (vertical).





Answer the following questions based on the results:

1. Do the values appear to be similar or significantly different? Did the same site tend to have the largest overall size (mean and median) and lowest amount of fine sediment?

2. Which site appears to be of higher quality for fish, specifically salmonids? Why?

Refer to the background information to determine what constitutes a higher quality site for fish. Also, think about whether the sites met the target values for amount of fine sediment (Less than 14% fine sediment <2 mm indicates adequate oxygen availability during salmonid egg incubation. Less than 20% fine sediment <6 mm indicates adequate oxygen availability during salmonid hatching and emergence).

2. Overall, what do the results suggest the quality of the sites for spawning fish is and why do you think you might have gotten these results? Can you infer anything about what has happened in the past at the sites based on these results (timber harvest, disturbances, landslides, restoration work, etc.)?

3. If you have data for multiple years, how has the substrate changed from year to year? What does this tell you?

4. Overall, were these the results you expected based on what you know about the history of the different sites? What was different than expected, if anything? Give one possible reason for this deviation.

5. Do you have any recommendations for future management of the area after seeing these results?

6. Is there anything you would do differently if you were to conduct this study again in the future? What would you change about how the data collection or analysis was designed?

Pebble Count Data Entry Sheet			
Size Categories	Size Ranges (mm)	Mark a tally for every pebble that is sampled within each size range	Total Count
Sand	< 2		
Very Fine Gravel	2-2.8		
Very Fine Gravel	2.8-4		
Fine Gravel	4-5.6		
Fine Gravel	5.6-8		
Medium Gravel	8-11.3		
Medium Gravel	11.3 - 16		
Coarse Gravel	16 - 22.6		
Coarse Gravel	22.6 - 32		
Very Coarse Gravel	32 - 45.3		
Very Coarse Gravel	45.3 - 64		
Small Cobble	64 - 90.5		
Small Cobble	90.5 - 128		
Large Cobble	128 - 181		
Large Cobble	181 - 256		
Small Boulder	256 - 362		
Small Boulder	362 - 512		
Medium Boulder	512 - 1024		
Large Boulder	1024 - 2048		
Very Large Boulder	2048 - 4096		
Bedrock	> 4096		
		Total Number of Pebbles	

Glossary

Aggradation: When there is more sediment accumulating than is being transported downstream, causing the build-up of the stream bed.

Allochthonous inputs: Something that is from another location. Food sources, such as leaves and bugs, that originate outside of the stream and fall into the stream.

Benthic macroinvertebrates: Small organisms (such as insects and snails) that live among stones, logs, sediment, and aquatic plants on the bottom of bodies of water, are visible with the naked eye, and have no backbone.

Biota: The animal and plant life in an area.

Deposition: Process by which sediment, soil, woody debris, and rocks in water are blocked or slow down enough to fall out of motion and accumulate.

Dimensionless: A number without units.

Disturbance: A temporary disruption of normal environmental conditions that causes a noticeable change, such as a flood or timber harvest.

Disturbed site: A study site that has experienced an environmental disturbance.

Ecological management: Work that is done to conserve natural resources and ecological services while also meeting economic, political, social, and cultural needs of current and future generations.

Ecological restoration: An intentional activity to assist in the recovery of an area that has been degraded, damaged, or destroyed.

Emergence: The process by which a fish hatches and comes out of their egg.

Erosion: The wearing away and breaking apart of rocks and soil by the flow of water.

Fine sediment: very small pieces of sediment, typically less than 2 or 6 mm wide. Fine sediment can be produced in streams by erosion and can negatively impact the quality of fish habitat.

Gravelometer: A hand-held template with square holes of different size classes that acts like a sieve to sort particles in a standard way, minimizing potential errors in measurement

Incubation: The process by which eggs develop and which typically requires a constant temperature.

Intermediate axis: The width of the particle/pebble, which is perpendicular to the longest axis and is neither the longest nor shortest side.

Key woody debris (KWD): The largest pieces of woody debris which greatly impact the stream by stabilizing the stream channel and causing the accumulation of woody debris in logjams.

Large woody debris (LWD): A log, tree, rootwad, or branch that has fallen into the stream channel and is at least 0.1 meter in diameter and 1 meter long.

Mean: The average/central value of a group of numbers/samples.

Median: The midpoint value of a group of numbers/samples. There is an equal probability of obtaining a value above or below it.

Monitoring: To observe and check the progress or quality of an area over a period of time.

Pebbles/particles: Stones/rocks that are located on the bottom of a body of water.

Rapid bioassessment: A fairly quick and easy method of using biological, physical, and chemical information to evaluate water quality.

Reference site: a high quality site that displays similar characteristics/conditions to the target site and can act as the eventual goal of the restoration work.

Refuge: An area in which an organism can take shelter and survive during a period of unfavorable conditions or to hide from a predator.

Restored site: A site that is having or has had ecological restoration actions done to it.

Riffle: A rocky or shallow part of a stream with turbulent/rough water.

Riparian zone: The area along the banks/margins of a stream or a river. It acts as an interface between the land and body of water.

Salmonid: A fish from the salmon family, which includes salmons, trouts, chars, and whitefishes.

Scour: The act of digging out land/substrate by fast moving water.

Sedimentation: The process of depositing sediment in a body of water.

Spawning: When a fish reproduces by releasing many small eggs.

Stream reach: Specific area of a stream identified for a study.

Substrate: The material that makes up the bottom of a stream channel.

Transect: A straight line or cut perpendicular to the stream bank and along which data is recorded.

Wetted width to depth ratio: A way to describe the shape and size of the channel, which is the area that has water at the time of sampling. It is a ratio of the average width of the channel divided by the average depth.

Woody debris: Fallen dead trees, logs, rootwads, and large branches that have fallen into streams and other bodies of water.

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