Research Program Annual Report

FISCAL YEAR 2020–2021

BRITISH COLUMBIA

Ministry of
Forests, Lands, Natural
Resource Operations
and Rural Development

Contents

Executive Summary

In 2021 the Research Program of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (the Ministry; FLNRORD) celebrates 100 years since hiring the Ministry's first researcher in 1921, J.L. Alexander. To mark this important achievement, a special series of articles highlighting the rich history of the program was published in the Association of BC Forest Professionals (ABCFP) magazine, and a video was produced to celebrate the ongoing support to the sustainable management of British Columbia's natural resources.

In 2020–2021 the Research Program funded 145 projects, and an additional 29 collaborative projects were funded externally, for a total of 174 projects. The Research Program investigated a broad range of topics including the impacts of climate change on British Columbia ecosystems, silvicultural treatments in post-wildfire areas (e.g., regeneration), landslides, and wildlife habitat. Ministry researchers collaborate extensively with academia, research institutions, provincial and federal governments, First Nations, and industry. These collaborations enhance the ability of the Research Program to support the Ministry as a global leader in sustainable natural resource management.

In 2020–2021 the Research Program launched the new Research Program Strategic Plan for 2021–2024 and also completed the first cycle (in 12 years) of the Research Scientist Achievement Review Framework (RSARF). A virtual Research Program event was held in the fall of 2020 with presentations from invited experts in science communication. For the second year in a row, a Mitacs fellow was hired to enhance the integration of science into policy by developing an online course on Policy Development Fundamentals for Researchers, which is now available on the government Learning System.

More information on the current research projects is available on the B.C. Public Service YouTube channel (i.e., 17 short and informative videos), as well as in newsletters such as The Understory (previously known as The DIRT). The year was once again highly productive – the Research Program continues to provide innovative solutions to natural resource sector challenges in British Columbia through research, science, data, and extension products. The Program's previous annual reports are available online.

Introduction

Working in partnership with provincial agencies within the natural resource sector, the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (the Ministry; FLNRORD) plays a significant role in stewardship and authorizations of the Province's Crown land and natural and cultural resources. Overseeing a land base of 94.8 million hectares, the Ministry sustainably manages forest, range, mineral, and land-based resources.

In 2011, the Ministry committed to an integrated Research Program to provide timely, relevant, high-quality, credible information and to inform innovative solutions to British Columbia's complex natural resource sector challenges through research, science, data, and extension. The Office of the Chief Forester also manages additional operational research investments in forest carbon and forest genetics. Research scientists are integrated throughout Ministry operations at both provincial and regional levels to provide direct linkages between researchers and staff involved in decision-making, policy development, and resource management practices.

Establishing research priorities is complex, considering the scale of operations and the dynamic nature of the Ministry's mandate. Results and data from short- and longer-term research are essential to inform decision-making. New and existing long-term research installations continue to support development and validation of modelling and decision tools for sustainable forest management. Annual research priorities are established by the Research Oversight Committee, composed of representatives from regional and provincial operations groups within the Ministry and chaired by the Deputy Chief Forester. The Research Program Strategic Plan 2021–2024, which defines the program's vision, values, governance, and strategic goals, was launched in April 2021.

Research Program Achievements in 2020–2021

Goal 1

ACHIEVE EXCELLENCE IN APPLIED RESEARCH

Actions taken to ensure that the Research Program is valued as a trusted provider of science information to support sustainable resource management decisions and policy development:

- Planned and held the Research Program's Biennial Face-to-Face event, virtual edition
- Finalized recruitment of the Research Program Specialist
- Refined and applied the Research Program's business cycle including planning, development, submission, and review of proposals to ensure research alignment with Ministry needs and priorities
- Implemented the Terms of Reference of the Research Oversight Committee (ROC)

Goal 2

MAINTAIN AN EFFECTIVE AND RESPONSIVE RESEARCH CULTURE

Actions taken to ensure that the Research Program is delivered by expert, experienced, and respected research professionals:

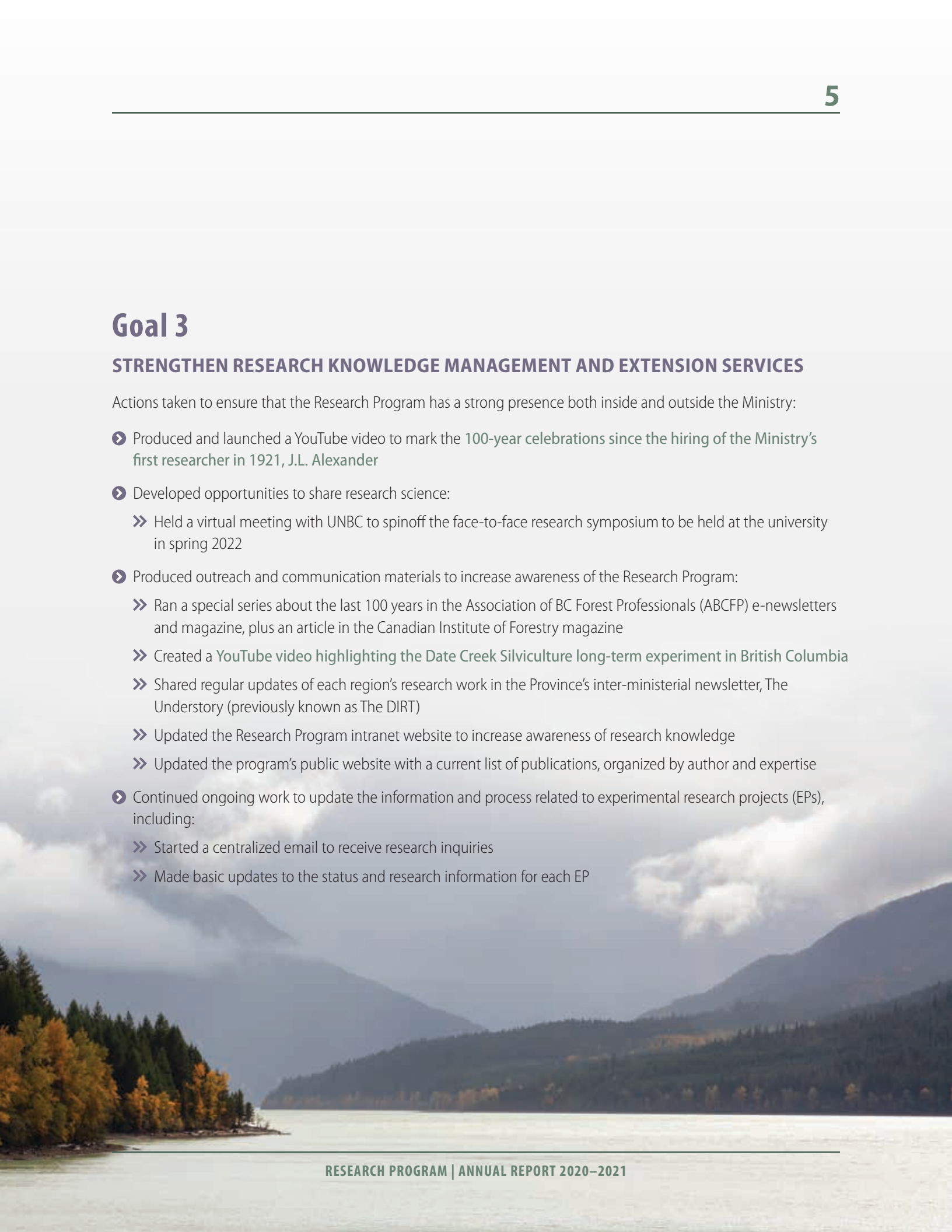
- Completed the first cycle of the Research Scientist Achievement Review Framework (RSARF) that had been dormant for 12 years
- Updated the Research Program Strategic Plan for 2021–2024
- Identified partnership opportunities with other agencies (e.g., universities, the Canadian Forest Service) to continue leveraging expertise and addressing issues of mutual interest and benefit:
  - Held a virtual meeting with the University of Northern British Columbia (UNBC) to discuss opportunities for enhancing research collaboration
- Held the ROC monthly meeting and provided regular updates to the Research Program's executive

Goal 3

STRENGTHEN RESEARCH KNOWLEDGE MANAGEMENT AND EXTENSION SERVICES

Actions taken to ensure that the Research Program has a strong presence both inside and outside the Ministry:

- Produced and launched a YouTube video to mark the 100-year celebrations since the hiring of the Ministry's first researcher in 1921, J.L. Alexander
- Developed opportunities to share research science:
  - Held a virtual meeting with UNBC to spinoff the face-to-face research symposium to be held at the university in spring 2022
- Produced outreach and communication materials to increase awareness of the Research Program:
  - Ran a special series about the last 100 years in the Association of BC Forest Professionals (ABCFP) e-newsletters and magazine, plus an article in the Canadian Institute of Forestry magazine
  - Created a YouTube video highlighting the Date Creek Silviculture long-term experiment in British Columbia
  - Shared regular updates of each region's research work in the Province's inter-ministerial newsletter, The Understory (previously known as The DIRT)
  - Updated the Research Program intranet website to increase awareness of research knowledge
  - Updated the program's public website with a current list of publications, organized by author and expertise
- Continued ongoing work to update the information and process related to experimental research projects (EPs), including:
  - Started a centralized email to receive research inquiries
  - Made basic updates to the status and research information for each EP



Research Program Overview

The Research Program includes more than 75 research scientists and dozens of technicians, co-op students, graduate students, and auxiliary personnel who plan and conduct research throughout British Columbia (Figure 1).

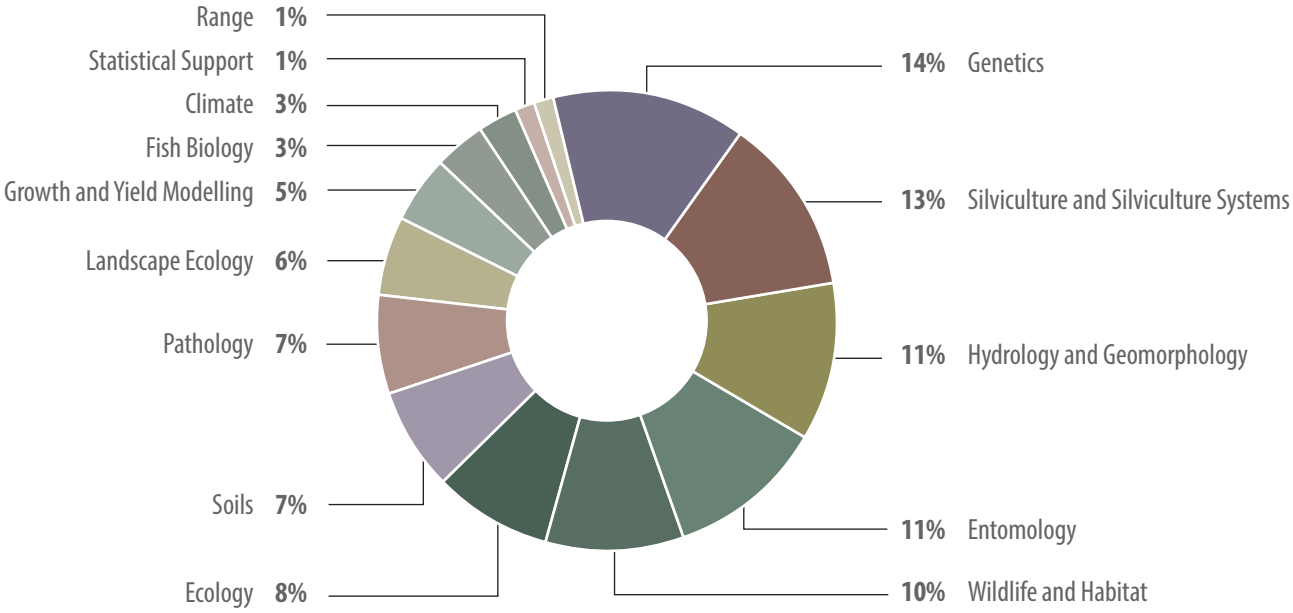
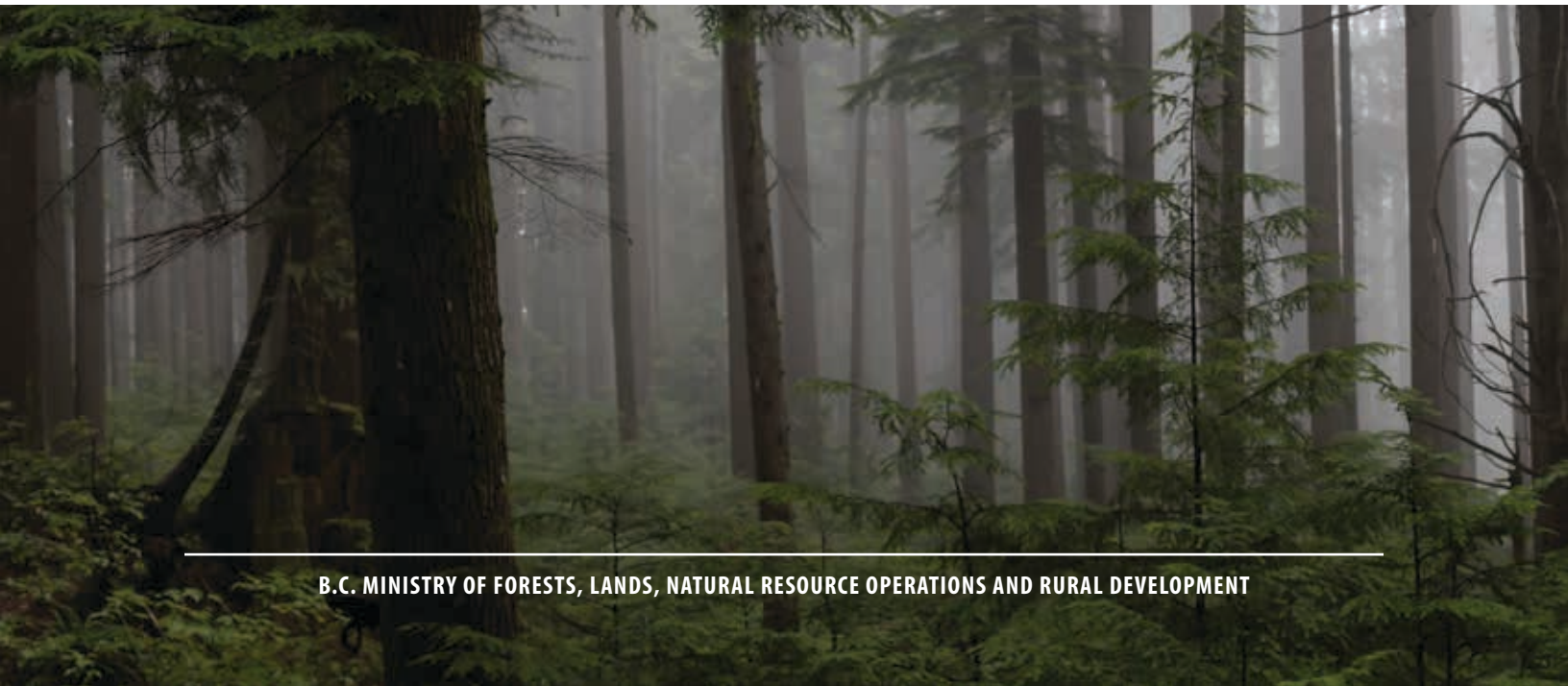


Figure 1. FLNRORD research scientists by area of expertise.



During the 2020–2021 fiscal year, Ministry scientists delivered 145 projects funded through the Research Program, plus 29 projects funded outside the program, for a total of 174 projects. Most of the Research Program projects span multiple forest districts and regions – the geographical location of the principal investigator is indicated in Figure 2. The 29 projects funded externally were mainly in the south (11) and Victoria (8), with the rest in the north (6) and on the coast (4).

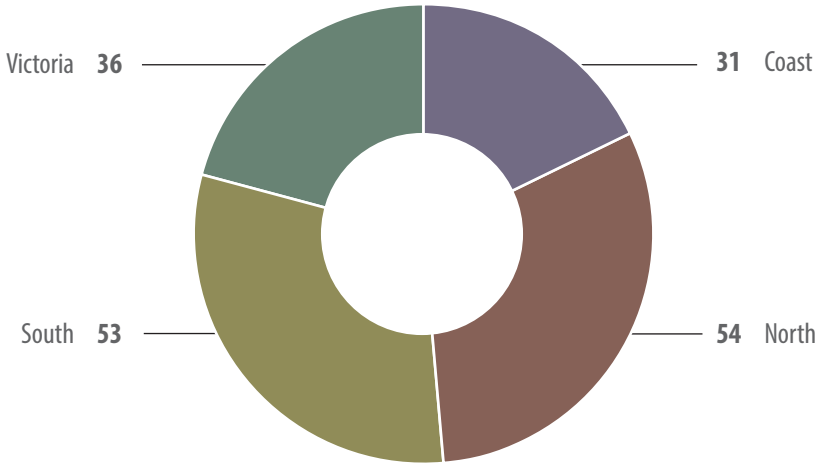


Figure 2. Number of all 174 projects by geographical location of the principal investigator for fiscal year 2020–2021.

FLNRORD Research Program members actively collaborate with the federal government, provincial universities, and national and international research organizations (Table 1).

Table 1. Research Collaborations and Partnerships

Provincial Ministries and Agencies	Alberta Ministry of Environment and Parks; BC Parks; BC Oil and Gas Commission; BC Timber Sales; GeoBC; B.C. Ministry of Environment and Climate Change Strategy
Municipal	Union of BC Municipalities; Various municipalities; Various regional districts; Capital Regional District
Federal	Canadian Forest Service; Environment and Climate Change Canada; Fisheries and Oceans Canada (DFO); Geological Survey of Canada; Parks Canada
Academic Institutions	Carleton University; College of New Caledonia; Simon Fraser University; Thompson Rivers University; University of British Columbia; University of Calgary; University of Northern British Columbia; University of Ottawa; University of Victoria; Vancouver Island University; Western University
Non-governmental Institutions and Organizations	Bulkley Valley Research Centre; BC Lake Stewardship Society; Columbia Basin Trust; Hakai Institute; San Juan Roundtable (First Nations, Industry, DFO, local community groups); South Coast Resource Stewardship; Sunshine Coast Community Forest; Nature Conservancy of Canada; Wells-Barkerville Community Forest
First Nations	Haida Gwaii Management Council; Pacheedaht First Nation; Skidegate Band Council
Industry and Private Sector	Canfor Corporation; Conifex Timber; Ecora Engineering and Resource Group; Pacific Climate Impacts Consortium; Teck Resources; Tolko Industries; West Fraser Forest Products; Western Forest Products
International	U.S. Geological Survey; University of Melbourne

Science Policy Integration

During the 2020–2021 fiscal year, the Research Program continued to implement the Science and Policy Integration Strategy to enhance the use of research findings produced by the program in policy. This work focussed on fostering opportunities to enhance training opportunities, communication, and collaboration.

Training Opportunities

- An online course titled Policy Development Fundamentals for Researchers was launched in May. This course provides information on increasing the incorporation of research knowledge in the decision-making process. The one-hour course is aimed at new research scientists and also at more senior researchers within the natural resources ministries. It is available on the Learning System.
- A workshop on Theory of Change was presented to researchers as a tool for planning and assessing research to effectively inform decision-making. Theory of Change is a logic model approach that describes a change process through the causal relationships between a research project and its intended results (outputs, outcomes, and impacts). The workshop was delivered online in two sessions of 1.5 hours each. This workshop was attended by 30 people.

Communication Opportunities

- Six talks were presented as part of the Science Policy Talks series. These talks provided an opportunity for researchers, policy makers, and managers to share the challenges and opportunities of using scientific information in decision-making.
- Four online presentations were delivered as a part of the Science Talks series. These talks had the purpose of disseminating research findings produced in-house and fostering collaboration among researchers.

Collaboration Opportunities

The terms of references for the Science to Policy Working Group (SPWG) were developed and approved by executives. The purpose of the SPWG is to provide a platform that facilitates the successful incorporation of research findings produced by FLNRORD Research Program scientists and other relevant science into the policy process related to the *Forest and Range Practices Act* (FRPA). Initial meetings of the SPWG are planned for the next fiscal year.

Update on First Nations Collaborations

The Research Program continued building research collaborations with First Nations during fiscal year 2020–2021. An update on research activities accomplished during the year is provided below.

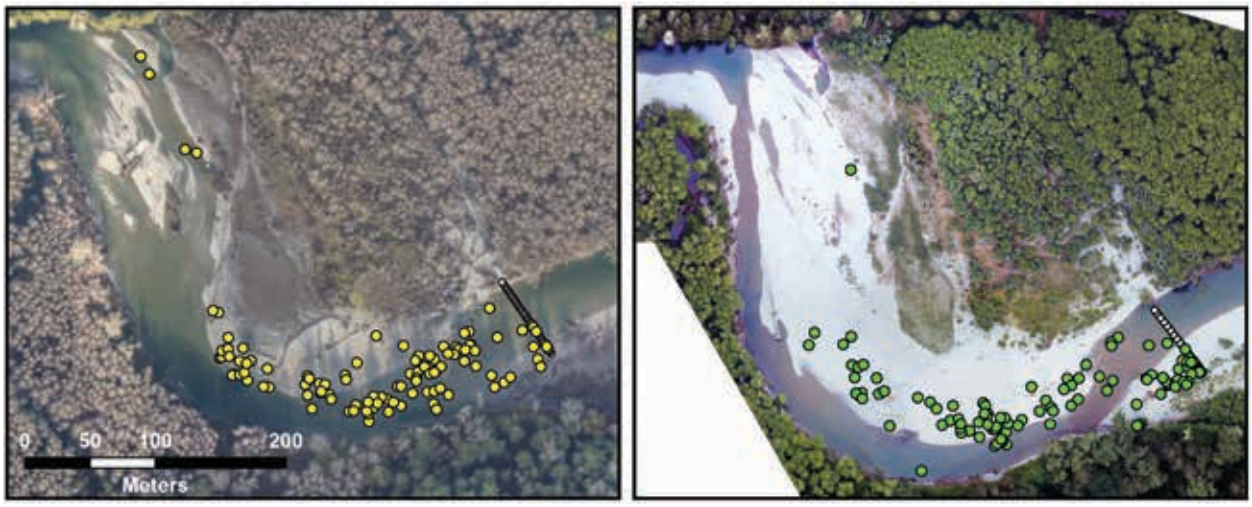
San Juan River Sediment Dynamics: West Coast Region and Pacheedaht First Nation Research Collaboration

As a part of the ongoing process-based restoration on the San Juan River of southwest Vancouver Island, initiated by Pacheedaht First Nation in 2014, research activities continue to analyze sediment dynamics in the river. The San Juan River watershed has some of the most landslide-prone areas in the province, and the river has been severely impacted by historical logging practices. The restoration is being supported by the San Juan Roundtable, composed of Pacheedaht First Nation, Fisheries and Oceans Canada (DFO), forestry companies, local community groups, and FLNRORD representatives. The Pacheedaht requested hydrology and geomorphology assistance from FLNRORD West Coast Region (WCR) to understand how process-based restoration might best proceed. The Water Protection and Research Sections began a joint research project in 2015–2016 to inform policies for river restoration, forestry, and fish management to provide tools for evaluating river behaviour and to inform improved forestry and fish restoration practices.

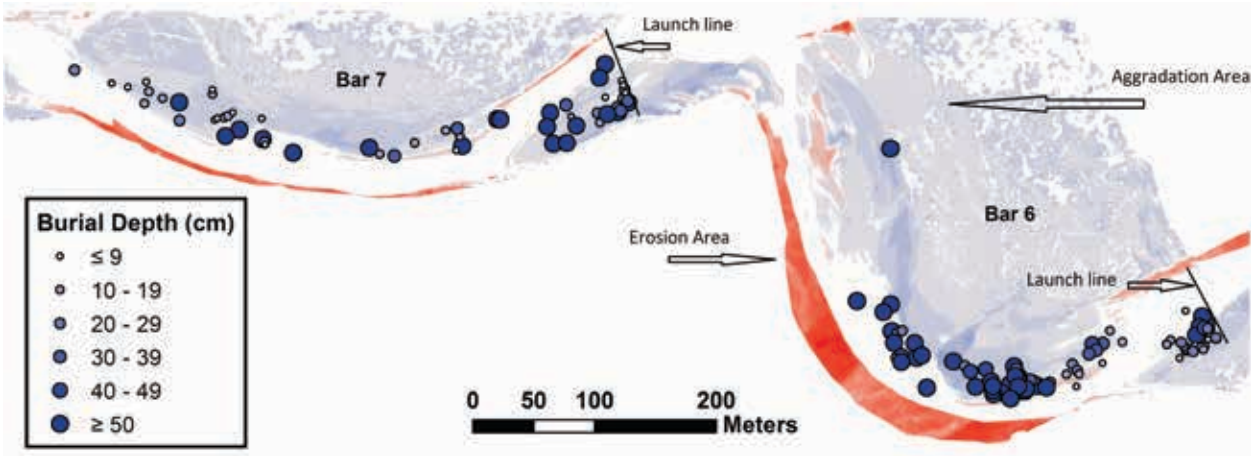
Pacheedaht First Nation and FLNRORD have collaborated at all stages of the research project. FLNRORD developed the initial research goals in discussions with the San Juan Technical Group, composed of representatives from Pacheedaht, DFO, and the WCR. Restoration plans were developed jointly, with input from WCR scientists and Pacheedaht biologists and foresters. Our improved understanding of sediment transport led to the Pacheedaht biologists questioning whether gravel scour in Chinook salmon spawning areas is limiting spawning success. We are now investigating sediment erosion specifically in areas where Chinook salmon lay their eggs.

This project provides tools to evaluate river behaviour and informs improved land management and fish restoration practices. The physical characteristics and stability of the channel, and the nature of sediment and sediment transport within the river, are key components of fish habitat in the river. Chinook salmon spawning redds located at the downstream end of pools are particularly at risk in a destabilized river. Detailed understanding of these physical characteristics is critical to prescribing successful restoration practices.

Initial findings on the river sediment dynamics suggest that annual floods destabilize the entire bed of the river, likely resulting in high losses of salmon eggs within the river gravel. The long-term channel mapping shows that, despite the near-elimination of logging-related landslides, there is continued channel instability. More detailed investigations are being conducted to further define gravel scour in salmon spawning areas.



Maps of sediment-tracer launch sites (row of white dots near right of each map) and recovery locations (yellow and green dots), San Juan River, in 2017 and 2018.



Coastal Experimental Watersheds – Multi-scale, Active Adaptive Management for Ecosystem-based Management in the Great Bear Rainforest: A Collaboration with Nanwakolas First Nation

Coastal Experimental Watersheds (CEWs) are designed to develop data and tools for evaluating the operational and ecological implications of, and advance the scientific foundations for, the legal land use orders addressing ecological integrity in the Great Bear Rainforest. CEWs integrate retrospective study, baseline data development, modelling, experimental field work (active adaptive management), and extension activities. Field experiments are being planned collaboratively with Nanwakolas Council and licensees within Knight Inlet. Experimentation is focussed on quantitative responses to watershed, sub-watershed, and riparian buffer manipulation of salmonid populations and habitat, headwater communities, stream geomorphology and fluvial processes, water quality and quantity, and riparian and upland vegetation communities. These studies are designed to coincide spatially and support fish and wildlife monitoring programs of Nanwakolas Council's member Nations.

In the last fiscal year, the development of GIS-based metrics at multi-order (1–7) watershed levels was completed, and the update of the web-based extension tool was initiated. Our research staff and representatives of the Nanwakolas Nation completed fieldwork to assess experimental design parameters. The parameters have been refined, and the initial pilot work with the Nanwakolas Nation representatives is scheduled for the next fiscal year.

Analysis and extension tools derived from this project support the adaptive management framework committed to through government-to-government agreements in the Great Bear Rainforest. Research results will reduce uncertainty about ecological outcomes of management decisions on the land base and will inform decision-making for land use planning within the Great Bear Rainforest by communities, forest licensees, and provincial and First Nations resource managers (Nanwakolas First Nation and Coastal First Nations), particularly in the context of the 2021 and 2026 amendment reviews of the land use orders.

Using the Biogeoclimatic Ecosystem Classification with Terrestrial Ecosystem Mapping as a Framework for Management of Culturally Important Plants – Model Development for the shíshálhswiya and the Great Bear Rainforest

This project is examining the potential to integrate emerging technologies (e.g., lidar) with new statistical modelling approaches and cultural knowledge to enhance the utility of the Biogeoclimatic Ecosystem Classification (BEC) and the Terrestrial Ecosystem Mapping (TEM) systems within resource management activities, particularly stewardship of culturally important plants. The study has two focal areas: the Great Bear Rainforest (Great Bear Rainforest south), supporting implementation of the objective for Aboriginal Forest Resources, and the shíshálhswiya (Sechelt), supporting the Foundation Agreement between the shíshálh Nation and the Province of British Columbia toward joint land and resource management for mutual stewardship interest.

FLNRORD researchers from both the Coast Area and the Thompson-Okanagan Region continued their focus on the shíshálhswiya subproject over the past year. Our research staff and members of shíshálh Nation's resource management team completed field sampling together to collect data for five focal understorey species to characterize vegetation communities and site conditions. In the last year, the models predicting presence and abundance of two focal species were updated using feedback provided by the joint FLNRORD–shíshálh Nation landscape unit planning team (LUPT). The research team reported and presented findings to the LUPT. Also, work planning was initiated with Nanwakolas Nation to extend sampling into the Great Bear Rainforest to assess the utility of the models and methods across geographic areas and BEC units. This sampling will take place in the new fiscal year.

Climate Change Research

From a total of 145 research projects, 17 have an explicit focus on climate change. Research topics include climate change indicators; impacts for ecosystems and hydrologic regime shifts; soil carbon storage; maximization of carbon sequestration and best practices for conservation; groundwater inventories, dynamics, and conservation; and others.

In addition, research projects on risks associated with the impacts of climate change – such as landslides and wildfires, mitigation strategies, and studies that provide a baseline for identifying climate change impacts (e.g., studies on sediment dynamic in rivers, forest pine beetle ecosystem monitoring, and aquatic and wildlife population assessments, among others) – contribute to strengthening the Ministry's capacity to prepare for and respond and adapt to climate change.

An important research development and contribution from the Research Program is the Stand-Level Drought Risk Assessment Tool.

Stand-Level Drought Risk Assessment Tool

The Stand-Level Drought Risk Assessment Tool provides the opportunity to integrate climate change into forest management, primarily timber supply analysis as well as harvesting and retention decisions. The tool projects the risk of tree mortality from future climate change-driven moisture stress. It can also be used to inform silvicultural practices to reduce the impacts of drought and has the potential to become part of forest management policy that considers climate change. The tool supports FLNRORD's Climate Change Strategy and the Omineca Climate Action Plan.

The Stand-Level Drought Risk Assessment Tool was developed using site-level absolute soil moisture regime/water balance modelling coupled with long-term climate data and climate projections to evaluate current and future risk of tree mortality from moisture stress. Current efforts are focussed on expanding coverage from the Prince George, Williams Lake, and Cranbrook Timber Supply Areas.

Climate Change Modelling and Monitoring

The ClimateBC and ClimateNA (for North America) programs use historical weather data and global circulation models to project future climate conditions. ClimateBC is used extensively by researchers, resource managers, industry, consultants, and academia, with over 1400 subscribers and 1650 citations. It generates monthly climate data at the spatial scales necessary for resource management and underpins many FLNRORD climate adaptation initiatives such as Climate-Based Seed Transfer (CBST), Climate Change Informed Species Selection (CCISS), Drought Risk Assessment Tools, future projections for Biogeoclimatic Ecosystem Classification (BEC), and various regional water tools. This year, through a collaboration of the Research Program and the University of British Columbia, a major upgrade to ClimateBC was produced. ClimateBCV7.1 includes the latest generation of global climate model simulations used in the 2021 Sixth Assessment Report of the Intergovernmental Panel on Climate Change. A web application (cmip6-BC) was developed to provide guidance and tools for using this new version of ClimateBC.

Forest Genetics Group

The forest genetics group is focussed on improving the value, resilience, and conservation of British Columbia's forest genetic resources to maintain healthy, productive forests and help mitigate the impacts of climate change on them. Work focusses on six areas: adaptive physiology, cone and seed pests, genetic worth and timber supply, deployment and genetic diversity, breeding values, and realized genetic gain trials. Some of this past year's accomplishments include releasing second-generation interior spruce to seed orchards, as well as deploying over 2500 lodgepole pine grafts for the Province of British Columbia's orchard expansion project. These additions to orchards will provide much-needed seed and will help the Province achieve its reforestation commitments. The program is also developing two new breeding programs for ponderosa pine and interior redcedar; these species are expected to play a bigger role in future climates. In addition, a comprehensive plan for future releases of improved stock was developed to help better prepare orchards for future expansion and improve the integration and efficiency of forest genetics and orchard management for the province. For more information on this work, visit Forest Genetics.

FPInnovations Collaboration

Since 2016–2017 FLNRORD has implemented the Clean-Tech Innovation Strategy (CTIS) for the British Columbia forest sector to provide more strategic and focussed investments for research. All research programs are required to support the strategy's three themes: Enhanced Economic Viability, Environmental Sustainability, and Aboriginal and Community Technical Support. FLNRORD invests $2.2 million annually through a shared cost arrangement in FPInnovations (FPI) research. The investment is matched with federal and/or industry contributions.

Over the past four years, FLNRORD has supported 58 FPI projects. Most (67%) of this investment supports projects under the Enhanced Economic Viability theme, followed by the Aboriginal and Community Technical Support (20%) and Environment Sustainability (13%) themes.

FPI research, supported by FLNRORD investment, includes operational projects (e.g., steep slope harvest, nine-axle vehicles, and partial cutting), development of strategic bioproducts (e.g., cellulose F and cellulose nano-crystal applications, bioconcrete, 100% recyclable and compostable packaging), and the development of innovative engineered wood products (e.g., new timber bridge, four engineered products pre-commercialization).

In addition to the $2.2 million annual contribution to FPI, FLNRORD's Innovation, Bioeconomy and Indigenous Opportunities Branch has a contract with FPI to support the development of the Forest Biomass Supply Information System (FBSIS). The work includes biomass inventory analysis at the level of timber supply areas, and validation trials on biomass supply estimates at the cutblock.

In 2021–2022, FLNRORD plans to allocate 48% of the investment to projects under the Enhanced Economy Viability theme to develop six strategic bioproducts: biosourced construction additives for green building, an asphalt initiative, a biorefinery-biocomposite initiative, functionalized cellulose coating, thermoforming thermomechanical pulp for sustainable mouldable packaging, and regenerated cellulose-based materials (spun fibre, novel engineered wood product opportunities from low-grade British Columbia fibre, next-generation timber forest resource bridges). For more information, visit FPInnovations.

Wildfire Research

The Research Program has active communication with the BC Wildfire Service and is constantly looking for opportunities to leverage resources and support research efforts. In the last year, 11 projects internally funded looked into (1) assessing post-wildfire silvicultural effects, including post-wildfire carbon and habitat values, and analyzing silvicultural techniques for post-fire regeneration, (2) developing technologies for predicting wildfire-associated hazards and estimating burn severity and recovery rates, and (3) monitoring wildfires in real time.

A promising collaborative research contribution is near real-time wildfire progression monitoring with Sentinel-1 synthetic aperture radar (SAR) time series. Sentinel-1 SAR time series, capable of penetrating clouds and smoke, in combination with a deep-learning framework for real-time wildfire progression monitoring, are used to detect burned areas automatically. This technique can detect wildfires and register their temporal progression with the potential to facilitate wildfire emergency response and rapid response for mitigation calls.

Research and Innovation – BC Wildfire Service

The BC Wildfire Service's Research and Innovation business area was established in 2018. The team is focussed on research that will generate knowledge and actionable insights alongside iterative and agile innovation trials, with a view to strengthening and modernizing the delivery of the BC Wildfire Service mandate of wildfire management and natural hazard emergency preparedness and response in British Columbia.

Four core research areas support the Research and Innovation team in achieving its priorities. All projects are aligned to these themes, though some are multi-disciplinary. The research areas are:

- Health, wellness, and safety of staff
- Social/human behavioural research
- Wildland fire science
- Equipment and technology innovation

The Research and Innovation team also focusses on building partnerships, such as with the Office of the Chief Forester's Research Program. The team relies on the diverse expertise and capacity of its partners:

- Canada Wildfire
- FPInnovations
- Thompson Rivers University Provincial Research Chair in Predictive Services, Emergency Management and Fire Science
- Canadian Interagency Forest Fire Centre, Fire Science Committee

The Research and Innovation team also works with universities, third-party research organizations, and other groups to address priority research questions.

Research Portfolios and 2020–2021 Research Examples

The Research Program is organized into six research portfolios: ecosystem stewardship, ecosystem health and disturbance, water, species and habitats, timber supply and silviculture, and forest bioeconomy. During 2020–2021, researchers from every portfolio conducted research projects (Figure 3); published research in peer-reviewed journals, field guides, or technical reports; gave presentations at workshops and conferences; and worked with graduate students.

Each research portfolio is led by an interdisciplinary team that represents regional- and provincial-level research needs. Each portfolio has a three- to five-year strategic plan and prepares an annual two-page summary of current and emerging research priorities, as well as an annual report of research achievements.

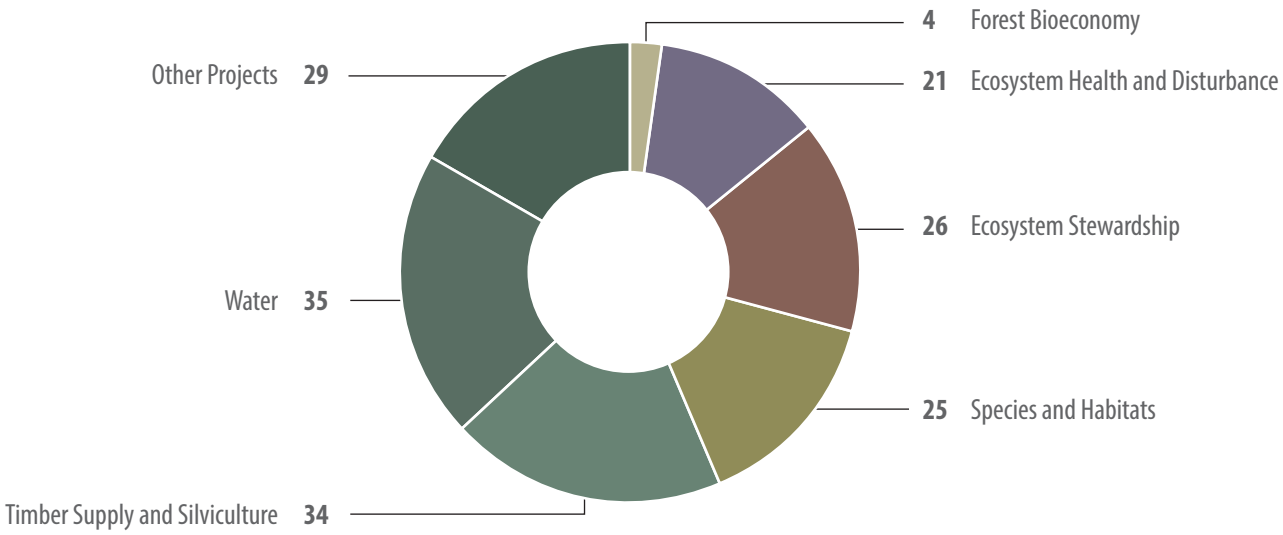


Figure 3. Total number of research projects under way in fiscal year 2020–2021 by portfolio.

Research initiatives:

- Determine the vulnerability of ecosystems to resource development and climate change
- Foster ecosystem resilience and adaptive capacity through management
- Build adaptive capacity by providing flexible tools and comprehensive information to support management and decision-making

ECOSYSTEM STEWARDSHIP

The intended outcome of this research portfolio is improved ecological knowledge for sustainable delivery of ecosystem services. This knowledge has strategic importance for supporting management decisions that maintain or enhance ecosystem resilience in the context of increasing uncertainty from social, economic, and environmental changes.

Biogeoclimatic Ecosystem Classification (BEC)

The BEC system is an important resource for managing the complexity of British Columbia's terrestrial ecology. It is the cornerstone of many stewardship and inventory decision-making processes, including tree species selection, stocking standards, timber supply review, and cumulative effects assessments. It supports habitat and forage mapping that is important to wildlife and range management, species distribution predictions, and high-resolution ecosystem map production. Ongoing updates are based on extensive field sampling for site-level classification and description and for landscape-level biogeoclimatic mapping. Recent accomplishments include updated guides and mapping for the southern Thompson-Okanagan Region, Kootenay-Boundary Region, and Engelmann-subalpine fir woodlands of the Skeena Region. Efforts have also been made to include regional First Nations in classification development and field work.

Climate Change Informed Species Selection (CCISS)

Widespread changes in the suitability of commercial tree species for survival and productivity are expected under climate change. Temperate tree species have increasing suitability, whereas boreal species have declining suitability. CCISS is a web-based decision tool for forestry professionals to incorporate projected climate changes into the selection of future climate-adapted tree species that are appropriate at a site-series level, and it will be a key aid in upcoming forest landscape planning. This tool has been

updated to include the most recent climate modelling available from the Coupled Model Intercomparison Project Phase 6 and aligns with the recent release of the Intergovernmental Panel on Climate Change's Sixth Assessment Report. Climate-related changes in suitability are expected for lodgepole pine, Douglas-fir, and western redcedar.

British Columbia Soils

Digital soil mapping has revolutionized soil surveys globally. Ministry researchers and university collaborators have a solid reputation in this field and in the production of high-quality spatial soil mapping products. Research includes database harmonization, digital terrain analysis, and machine learning for predictive mapping and product validation. This work has enabled a substantive contribution to the Global Soil Organic Carbon Map and continues to support British Columbia's online Soil Information Finder Tool. Current work is focussed on improving soil carbon distribution mapping and enhancing understanding of potential carbon sequestration deficit from various soil types, climates, and land uses.

Research on site productivity and soil conservation continues under the Long-term Soil Productivity Study, now at 20 years post-treatment for all installations in British Columbia. The rising concerns about wildfire in the province under altered climates have spurred research into fire severity effects on soil ecology and carbon sequestration. Other recent soil projects have examined post-harvest nitrogen losses across a range of soil fertility, and the nitrogen gains possible with pure and mixed stands of red alder. All of these studies support the incorporation of soil information into a better understanding of disturbance effects, efficacy of silvicultural treatments, inherent constraints on stand productivity, and long-term impacts on carbon sequestration.

Forest and Landscape Dynamics

Applied research aimed at answering management questions is key to ensuring environmental stewardship of our landscape. How are northern ecosystems being affected by climate change, and what does that mean for climate change adaptation strategies? How do we best manage stands heavily infested by beetles to promote ecosystem recovery? Where will forests transition to grasslands as predicted by climate change? Can we reduce wildfire risk with alternative planting or silvicultural prescriptions? How does old growth recover from disturbance? What are the carbon dynamics of old-growth forests, and what does that mean for climate change mitigation?

A collaborative initiative involving First Nations, licensees, and government is applying research-informed adaptive management in the Great Bear Rainforest. Researchers are also trying to understand the impact of forest management on ecosystems to inform future decisions, such as the effects of partial cutting on stand structure as well as on carbon sequestration and storage, wildlife habitat, bird abundance, and rare lichen colonization. Current forest carbon research shows that one way to adapt to climate change is to promote a diversified mix of species and age classes to better weather the storm of climate unpredictability.

ECOSYSTEM HEALTH AND DISTURBANCE

The intended outcomes of this research portfolio are to determine the factors, processes, and impacts of natural and anthropogenic, biotic, and abiotic disturbances; develop predictive tools for impact analysis and planning; and improve management practices for responding to these disturbances. Land managers, First Nations, and resource specialists will use the information and tools to enhance terrestrial ecosystem resilience and respond to the threats related to climate change and cumulative effects of resource development. There were 21 projects funded through this research portfolio in 2020–2021.

Abiotic Landscape Change and Detection

Landslides

- Assessment of ecological changes and subsequent restoration following landslides
- Assessment of landslide-generated sediment distribution in streams
- Assessment of the tsunami hazards from landslides

Remote sensing

- Detection of landslides using spaceborne synthetic aperture radar (SAR) and optical satellite data
- Use of remote sensing to characterize environmental change

Soils

- Assessment of soils and physical conditions affecting the response of new forests to anthropogenic disturbance in a changing climate
- Maintenance of the Long-term Soil Productivity Study installations and monitoring changes

Wildfire

- Assessment of post-wildfire landscape changes to improve hazard prediction
- Assessment of post-wildfire carbon and habitat values

Forest Insect and Pathogen Impact and Management

- Tree rings collected from sites in the south and from the most northern range of western spruce budworm were analyzed to understand differences and changing distribution and impact of this defoliator at the two extremes of its range.
- Western balsam bark beetle is the major cause of subalpine fir mortality in British Columbia. Climate change, drought, and aging forests have caused increasing rates of mortality of these ecosystems over the past two decades, with western balsam bark beetle as the primary driver. However, other insects and disease are now playing a more prominent role in the decline of subalpine fir forests. Data from this long-term study will form the basis of a hazard rating system, best management practices, and revised estimate of losses for applicable timber supply reviews.
- Research is ongoing on the effectiveness of Armillaria root disease control to promote successful conifer regeneration and growth and focusses on gauging the effectiveness of stump removal and other practices to guide silvicultural practices.
- Research is under way to improve estimates of the effects of insects and disease on young stand growth and yield, especially as they relate to management practices, weather, and climate.

Research initiatives:

- Assess abiotic changes to the landscape in a changing climate
- Explore improved methods for change recognition
- Improve hazard prediction and mitigation
- Assess the impacts of abiotic changes to landscape values
- Improve estimates of the impacts of forest health damage in young stands at rotation
- Predict climate change impacts to pest and fire behaviour across British Columbia landscapes
- Mitigate and adapt to changing pest and wildfire risk
- Inform management practices to reduce the occurrence of predictable disturbances

WATER

The intended outcomes of this research portfolio are to improve hydrologic, geomorphic, and aquatic ecosystem knowledge for sustainable resource stewardship and to inform public safety. Long-term projects increase scientific understanding of watersheds, surface water, groundwater, and geomorphic risks, as well as the effects of forest disturbance and regrowth and of climate change on water quality and quantity and public safety. This work is strategically important to support policy, decision makers, and practitioners. This portfolio supports a broad array of projects that cannot be detailed in an annual summary, so highlights from some long-term research installations and short-term projects are provided. Each of these projects supports one or more of our research initiatives.

Carnation Creek Channel Morphology and Environmental Flow Needs

Initiated more than 46 years ago to assess the influence of forest development on coastal watershed processes and salmon populations, this project continues to provide long-term understanding of forestry effects as well as data to explore new questions. A recently completed study quantified aquatic habitat to improve our understanding of environmental flow needs. It did so through 2D hydrodynamic modelling using the 45 years of channel survey data from Carnation Creek to investigate how historical changes in stream channel geomorphology have affected the quantity of aquatic habitat across eight study areas. A primary focus of this study was the analysis of habitat changes (via 10 habitat/channel geomorphology metrics) against eight commonly used environmental flow management thresholds.

Upper Penticton Creek Watershed Experiment

The Upper Penticton Creek (UPC) Watershed Experiment was established in 1984 as Interior British Columbia's only long-term paired-watershed experiment. Since then the primary focus of research at this site has been to better understand local hydrologic processes at both the stand and small watershed scales, and how these are affected by clearcut logging relative to an unlogged control. Research has included field-based studies and modelling. Results clearly show that clearcutting 50% of small, snow-dominated watersheds typical of the Okanagan Plateau changed snow accumulation and melt patterns, stream flow timing and magnitudes, physical water quality, and usable fish habitat. Research at UPC also provided a better understanding of the water balance, soil moisture and nutrient fluxes, groundwater, and aquatic community structure. The information gained at UPC has supported provincial policies, management guidelines, forest stewardship plans, and watershed risk assessments. The unlogged control watershed, the environmental monitoring network, and the established infrastructure at the site continue to provide opportunities for professional and public education and for research directed at emerging issues, such as the effects of young forests on stream flow and hydrologic recovery and the influence of climate change on the hydrologic regime.

Remote Sensing of Snow, Water, and Ice

Detailed mapping of seasonal snow, surface water, and glaciers directly improves our understanding of both natural and anthropogenic changes to the water cycle. In these projects, remote sensing data from airborne and satellite platforms are used to map these features over large areas and over time. Drones, airborne lidar, and satellite images are also being used to develop novel research methods. Meaningful contributions include (1) rapid quantification of industrial water use in the oil and gas sector, (2) monitoring of lake temperatures from thermal imagery, (3) mapping and quantification of glacier retreat throughout the province, (4) rapid mapping response for flood events, (5) cost-effective mapping of daily snow cover over large areas, and (6) quantification of water stored as snow in select watersheds for seasonal water availability and future infrastructure requirements.

These data also have the potential to improve provincial water datasets such as the Freshwater Atlas and contribute to the increasing interest in soil moisture changes over time. Methods developed and tested will also contribute to the evolution of the provincial snow monitoring program and leverage current weather station network data from the Climate Related Monitoring Program, including the Forest Ecosystem Research Network, funded partially by the Research Program, for validation and modelling. This project aims to continue refining methods across large areas to proactively respond to climate change and industrial pressures on the water cycle.

Landslide and Flooding Response to Wildfire

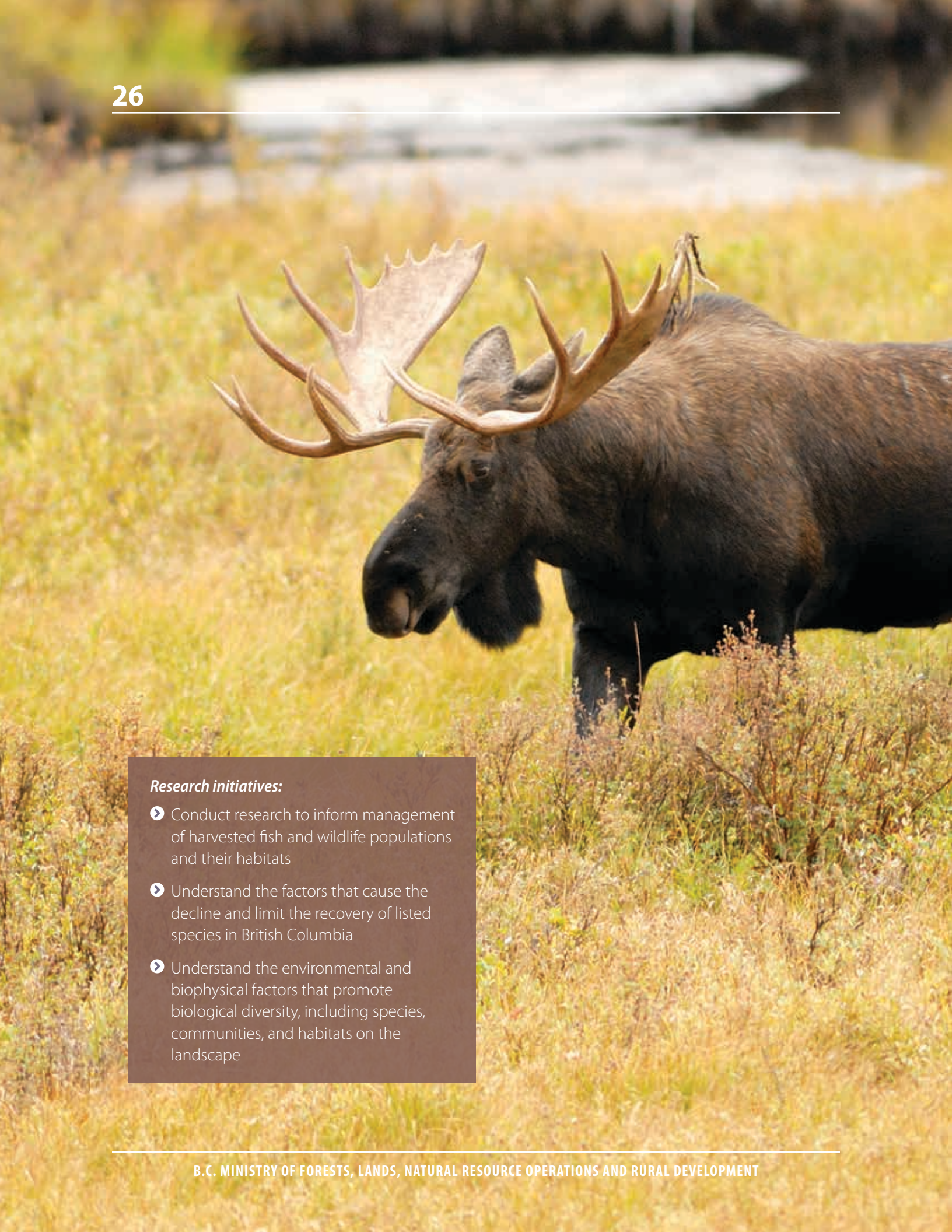
Ministry policy is to assess wildfires that may present geohazard risks to the public and important resources. Most knowledge of post-wildfire hazards originates from the United States; the applicability of these findings to British Columbia terrain and climate conditions is not well known. To improve the accuracy of post-wildfire geohazard assessments, historical wildfires in coastal British Columbia are studied to determine landslide frequency and location of landslides. Preliminary findings indicate that post-wildfire landslides are generally infrequent, but specific conditions of terrain and precipitation events can result in major landslide events.

Groundwater Research

Groundwater is recognized under the new *Water Sustainability Act*, but much research is required to fully understand groundwater. In particular, groundwater–surface water interactions is a key area. A project in the Upper Bulkley River is exploring this linkage. Also, springs and their source areas are a focus in northeastern British Columbia. Environmental flow needs in streams that are influenced by tides are being explored in the lower Fraser Valley. Another project in northeastern British Columbia is exploring groundwater to support the transboundary agreement with Alberta, Northwest Territories, and Yukon. A project has been completed on gaining a better understanding of the aquifers in the Terrace area.

Research initiatives:

- Develop predictive tools, long-term datasets, and guidance on changes to water quality, quantity, and timing caused by climate change, surface development, range use, and cumulative effects
- Develop, test, and improve predictive tools and observation networks for instream flow requirements to maintain aquatic ecosystem health
- Develop tools for predicting landslides, floods, and sediment supply and for determining the effects of wildfires on post-fire erosion and flooding



Research initiatives:

- Conduct research to inform management of harvested fish and wildlife populations and their habitats
- Understand the factors that cause the decline and limit the recovery of listed species in British Columbia
- Understand the environmental and biophysical factors that promote biological diversity, including species, communities, and habitats on the landscape

SPECIES AND HABITATS

The intended outcome of this research portfolio is improved conservation and management of fish and wildlife populations and habitat, locally and provincially. Research focusses on the response of animal populations and their habitats to the cumulative effects of climate change and human uses of natural resources. This strategic knowledge supports guidance and tools to inform immediate decision-making and the development of scientific understanding, so that policies can respond to emerging pressures on fish and wildlife populations and their habitats.

Understanding Factors that Influence Terrestrial and Aquatic Wildlife

A wide range of species are studied, including managed species such as mule deer, moose, grizzly bear, and furbearers (Pacific and American martens and wolverine), and stocked fish species such as rainbow trout, steelhead, kokanee, and sockeye salmon. Research on listed species included the barred owl, northern spotted owl, marbled murrelet, sooty grouse, coastal northern goshawk, white sturgeon, westslope cutthroat trout, western painted turtle, and western toad.

Mule deer

These are a primary source of food security for interior Indigenous peoples and the most important game animal in British Columbia in terms of licence sales and expenditures. A study of survival, mortality, and migration in southern British Columbia was established by putting GPS collars on 19 fawns and 40 adults in five areas. Extensive research was also initiated in this part of the province to examine mule deer responses to wildfire and habitat.

Moose

A long-term study is under way to assess whether landscape changes from the mountain pine beetle outbreak and associated salvage logging are related to moose population declines. Results are generally inconsistent with this landscape-change hypothesis, which assumes that cow survival is the primary driver of population change. To date, observed survival rates are largely within the range of other stable populations. Understanding factors affecting population trends and habitat use inform land management and support collaborative moose recovery efforts.

Grizzly bear

Most grizzly bear populations are limited by human-caused mortality, but the effect of food quality and quantity is not clear. A study on Southern Interior grizzly bear demography found that hunted populations can increase by 7–8% per year when berry crops are abundant and bear population density is below the ecosystem carrying capacity. Mapping tools for huckleberry and buffalo berry occurrence, yield, and selection by grizzly bears are resources to improve habitat management.

Barred and northern spotted owls

Recovery of northern spotted owls in southwestern British Columbia relies on the Spotted Owl Management Plan for a 294 700-hectare area, the captive breeding program, and removal and translocation of competing barred owls from spotted owl range. To analyze the efficacy of this removal work, backpack satellite tags were placed on nine translocated barred owls, four barred owls resident in the translocation site, and four barred owls in control areas with no translocation.

Kokanee and sockeye salmon

A collaborative and comprehensive evaluation of the ecology and habitats of deep-spawning kokanee and sockeye salmon was initiated to inform resource management decisions. Deep-spawning kokanee stocks are rare and very little is known about their behaviour and habitats. Methods include short-set gillnetting for catch and release, collecting underwater remote-camera imagery, deploying sensor networks, mapping, and modelling.

White sturgeon

There is an active recovery initiative for the endangered Nechako River population of white sturgeon. A conservation hatchery plays a critical role in recovery efforts, yet identifying an appropriate number of fish to release is difficult due to data limitation. FLNRORD is the statutory decision maker for freshwater fish releases, and thus, authorizing fish releases carries decision risk for the Province. A radio telemetry program is providing critical insights into downstream movements and survival of these hatchery-origin fish. The inferences gained from the program thus far have allowed the program to implement additional measures to work toward recovery.

Steelhead

Persistent low marine survival has resulted in many populations of steelhead being at low abundance for the last 20 years, particularly on Vancouver Island. There are many hypotheses to explain this trend, but data are lacking to identify dominant causal mechanisms. Here, we use pop-up Argos satellite tags to track the movements and mortality locations of steelhead kelts in the open ocean. Further, we attempt to infer cause of mortality by analyzing diving behaviour and temperature shifts at depth.

Habitat and Resource Management Practices

Research on the effects of forest management practices on wildlife habitat values continues at long-term silvicultural research installations.

Small headwater lakes

A comprehensive study was initiated to assess linkages between forest harvest practices on headwater stream inflows and fish diet in lakes. Work will assess the linkages among organic matter drift, fish diet, lake biotic productivity, and forest harvesting.

Baseline index monitoring

Other aquatic habitat research included baseline index monitoring of spawning activities to assess fisheries impacts on Fraser River sediment management and to assess impacts from fisheries and habitat alterations on juvenile sturgeon rearing in confirmed habitats.

Molecular Ecology Methods

Molecular ecology methods can assess species distribution change in response to factors such as human disturbance, invasive species, and hybridization. Studies of Pacific marten on the coast and American marten in the Interior use snagged hair for genetic identification of individuals for modelling. An environmental DNA assay system for the listed western painted turtle and its common competitor, the red-eared slider, is being tested for its value in supporting western painted turtle recovery. Genetic diversity analyses, differentiation, and habitat connectivity are used to compare the adaptive capacity of declining populations of western toads on Haida Gwaii and Vancouver Island to the thriving populations on the western British Columbia mainland. Sampling and genotyping of 110 populations of the listed westslope cutthroat trout determined that 94% are over 95% pure and thus are a high priority for conservation. Preliminary analyses of the genetic variation of true wild stock populations of rainbow trout are also being conducted for conservation.

TIMBER SUPPLY AND SILVICULTURE

The intended outcome of this research portfolio is increased volume and value of timber and fibre. Establishing and stewarding forests and maintaining timber supply to support the economy and communities are more challenging with the more frequent and severe disturbances and climatic extremes associated with climate change, and with increased demands among competing values. This work has strategic importance for increasing the volume and value of the timber supply while fostering resilient forests that will support economic prosperity and environmental sustainability in the short, medium, and long term.

Research initiatives:

- Develop and improve existing resource models to better estimate timber supply and range productivity and to support integrated decision-making
- Develop innovative and improved management practices that enhance timber supply and range productivity while managing for carbon sequestration, reducing environmental risks, and maintaining site productivity
- Enhance, maintain, and conserve forest genetic resources that maintain or enhance timber supply and site productivity

Uniform Shelterwood Silvicultural Systems for Even-Aged Douglas-fir (EP 1104.01)

This long-term research project was initiated in the Cariboo Region in 1990 to provide a viable alternative to the clearcut silvicultural system in the SBSdw subzone due to Douglas-fir plantation failure from frost damage in these systems. Three of the silvicultural systems tested were successful at establishing and growing primarily Douglas-fir regeneration of sufficient density and size to meet stocking targets in a 20-year period on most sites. The three systems were (1) a regeneration cut (30 m^2/ha residual basal area [RBA]) in 1991, (2) a regeneration cut in 1991 followed by a second regeneration cut (15 m^2/ha RBA) in 2001, and (3) a preparatory cut (40 m^2/ha RBA) in 1991 followed by a regeneration cut (20 m^2/ha RBA) in 2001. Both natural and planted Douglas-fir regeneration grew better as basal area retention decreased, primarily due to increased light and probably due to soil moisture and nutrients. Frost and frost damage were strongly reduced in the partial cuts. A technical report on the seedfall, regeneration, and vegetation responses over time is available.

Developing Climate-sensitive Tree and Stand Simulator (TASS) Models Using Transfer Functions

The Province of British Columbia's wide-ranging lodgepole pine provenance data were used to develop a mortality transfer function to examine climate change impacts to lodgepole pine growth and yield. Survival of lodgepole pine decreased exponentially with increased temperature transfer distance and was most pronounced for trees from the warmest climates. Survival within a stand was greater for taller trees and trees with greater annual height increments. This suggests that climate change will have a negative impact on survival, particularly for lodgepole pine in southern British Columbia and especially as the climate warms. The addition of climate sensitivity to growth and yield projections provided by TASS is a critical part of Timber Supply Reviews and Allowable Annual Cut determinations.

Post-fire Regeneration Experiment – Gustafson Installation

Reforestation strategies following salvage logging of fire-damaged ecosystems in the IDFdk3 variant are based on standard reforestation practices. A trial established in 2018 has been used to investigate seedling establishment and growth with (1) salvage logging with no site preparation, (2) salvage logging with site preparation, (3) no-harvest underplant, and (4) salvage logging with high retention coarse woody debris. Growing-season drought, competing vegetation, and frost events negatively impact interior Douglas-fir in large openings or stand-replacing wildfires in the IDFdk3. Management practices that best expedite post-fire Douglas-fir regeneration in drier ecosystems are urgently needed. Early results indicate that seedling growth may benefit with high retention of coarse woody debris, which could help support the modification of post-fire silvicultural practices that facilitate interior Douglas-fir regeneration and growth in the IDFdk3.

Endemic Species of Ectomycorrhizal Fungi Underpin the Extraordinary Productivity of Temperate Rainforests

Differences in the endemic ectomycorrhizal fungal community between Sitka spruce and western hemlock may help explain the superior growth of spruce on productive sites in the CWHvm subzone. Higher nitrogen content for endemic as compared with cosmopolitan fungal species (4.8% vs 3.9%, respectively), but no difference in overall sporocarp nutrition between Sitka spruce and western hemlock, indicated that fungal species attributes are independent of the host tree, and differences in conifer productivity may be more aligned with the abundance of endemic species. Identification of key endemic species underpinning conifer productivity in temperate rainforests will strengthen principles and guidelines on retention forestry and old-growth management areas.

Long-term Soil Productivity (LTSP) Study in the Interior Douglas-fir (EP 1148)

The North American-wide LTSP study follows a set protocol of treatments and measurements to elucidate the long-term effects of soil compaction and organic matter removal on ecosystem productivity following clearcut harvesting. As part of the British Columbia network of LTSP installations in the province, Douglas-fir and lodgepole pine establishment and growth in response to soil chemical and physical properties in Kamloops (IDFdk subzone) and East Kootenay (IDFdm subzone) have been examined since 2000. Lodgepole pine survival after 15 years was 82% compared with 70% for Douglas-fir across all treatments. Reduced nutrients but higher seedling survival were greatest with full organic matter removal. Research continues to be focussed on sustainable harvest and silvicultural management and on the impact of forest carbon stocks across the LTSP installations.

Research initiatives:

- Support development of the bioeconomy: fibre access, product innovation and development, green economy information and marketing development, and supply chain analysis
- Measure and manage our carbon footprint: carbon accounting analysis and system support, offset project opportunity development, economic cost/benefit analysis, and climate change risk assessment
- Determine non-timber values associated with product opportunities or climate change risks
- Address specific forest sector operational research requirements related to forest harvest operations, engineering, and road development/ maintenance, and to Indigenous peoples

FOREST BIOECONOMY

The intended outcome of this research portfolio is enhanced knowledge of alternative forest resources and products, including carbon, in support of the emergent bioeconomy and climate-focussed forest management initiatives. Government and industry need operational, technical, and resource management science and information to reduce investment uncertainty associated with new technology and developing markets. This strategic work is complemented by Ministry-funded research by FPInnovations.

Estimating Wood Product Substitution Ratios Using Market Responses to Supply and Demand of Alternative Building Products

Analyses of climate change mitigation through forest management are very sensitive to assumptions about how business-as-usual harvested carbon is used to replace products with higher emissions. The existing model of wood product substitution versus concrete oversimplifies the market responses to changes in supply and demand of wood products.[1] Therefore, advice to decision makers on climate change mitigation strategies (e.g., carbon benefits associated with substituting wood products for more emissions-intensive alternatives) is based on highly uncertain assumptions and little consideration for actual market effects.

The purpose of this subproject is to develop a quantitative methodological framework integrating supply and demand economics with life cycle carbon accounting of building products and applying it to estimate empirically the product substitution ratios for wood products between 1988 and 1997. The subproject will be divided into three main components: the development of the methodological framework, the application of the empirical framework to softwood lumber specifically, and the application

[1] Howard, C., C.C. Dymond, V.C. Griess, D. Tolkien-Spurr, and G.C. van Kooten. 2021. Wood product carbon substitution benefits: a critical review of assumptions. Carbon Balance Manag. 16(1):1–11.

to secondary wood products. Beginning in the late 1980s, U.S. market prices for sawn lumber, structural panels, and other wood products began to steadily increase, providing an opportunity to understand historic market responses and to empirically estimate the substitution ratios and resulting carbon effects between wood products and more emissions-intensive substitutes (e.g., concrete, steel).

Forest Carbon Succession Extension to LANDIS-II

The Province of British Columbia has led the development of the Forest Carbon Succession (ForCS) extension to LANDIS-II. This landscape-scale model has the advantages of being able to model climate change with the appropriate inputs, simulate multi-species and multi-age stands. By being part of an international community model, development costs are shared, and subject matter expertise can be employed for different aspects of the model (e.g., wildfire). This model is freely downloadable with user guides and is opensource.

This latest project has led to improvements to the growth-modelling algorithm in the model and added the ability to simulate partial harvesting of cohorts. Current improvements under way include exploring parallelization to speed up simulation times, adding land use change functionality, and adding the ability to read in wildfire and harvest maps from other models. More information can be found at Landis-II-Foundation.

BRITISH COLUMBIA

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