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GENOMICS FOR THE BLUE ECONOMY:

PAN-CANADIAN GENOMICS ENTERPRISE SUBMISSION

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PAN-CANADIAN GENOMICS ENTERPRISE SUBMISSION

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Blue Economy Strategy: Pan-Canadian Genomics Enterprise Submission

The pan-Canadian Genomic Enterprise:

- Genome Canada
- Genome Alberta
- Genome Atlantic
- Genome British Columbia
- Genome Prairie
- Genome Quebec
- Ontario Genomics

The pan-Canadian Genomics Enterprise is a federated ecosystem of Genome Canada and six provincially and regionally based Genome Centres that invest in mission-driven research and innovation (R&I) in genomics and biotechnology. We bring together provincial and regional players to create national solutions that provide economic and social benefits for all Canadians. The Genome Enterprise connects ideas and people across public and private sectors to innovate new applications for genomics, invests in large-scale science and technology to fuel innovation, and translates discoveries into applications and solutions across key sectors of national importance, including the environment, fisheries & aquaculture, energy, health, mining, agriculture and forestry.

KEY TERMS:

DFO – Fisheries and Oceans Canada
eDNA – Environmental DNA
ISED - Innovation, Science and Economic Development Canada
NRC – National Research Council
One Health – An approach to designing and implementing programmes, policies, legislation and research in which multiple sectors communicate and work together to achieve better public health outcomes.
PCGS – Pan-Canadian Genomics Strategy
ROI – Return on Investment

Executive Summary & Recommendations

In this submission to the Blue Economy Strategy Consultation, the Pan-Canadian Genomics Enterprise calls for centering genomics as a cross-cutting foundational technology to drive success of any future Canadian oceans strategy. This is set forth in five main recommendations.

"GENOMICS HAS ENORMOUS POTENTIAL TO IMPROVE CANADIANS' LIVES AND TO ADVANCE POST-PANDEMIC ECONOMIC RECOVERY. INVESTMENTS, LIKE THE ONE WE ARE MAKING TODAY IN GENOMICS RESEARCH, HELP KEEP CANADIANS HEALTHY AND HELP KEEP OUR INDUSTRIES PRODUCTIVE, SUSTAINABLE AND COMPETITIVE GLOBALLY."

THE HONOURABLE FRANÇOIS-PHILIPPE CHAMPAGNE, MINISTER OF INNOVATION, SCIENCE AND INDUSTRY

1. Genomics is already an identified key component of Canada's 'Build Back Better' strategy as highlighted in the 2021 Federal Budget with the announcement of a $400M Pan-Canadian Genomics Strategy with $136.7M going to Genome Canada to "kickstart" the strategy through mission-driven programming. The Pan-Canadian Genomics Strategy will be a cross-government initiative involving multiple parts and

A NATIONAL APPROACH TO SUPPORT GENOMICS RESEARCH CAN LEAD TO BREAKTHROUGHS THAT HAVE REAL WORLD APPLICATIONS. THERE IS AN OPPORTUNITY TO IMPROVE CANADIANS' HEALTH AND WELL-BEING, WHILE ALSO CREATING GOOD JOBS AND ECONOMIC GROWTH. LEVERAGING AND COMMERCIALIZING THIS ADVANTAGE WILL GIVE CANADIAN COMPANIES, RESEARCHERS, AND WORKERS A COMPETITIVE EDGE IN THIS GROWING FIELD.
FEDERAL BUDGET 2021

levels of government intended to improve Canada's socio-economic well-being. As such, genomics should be situated a core strategic driver of a 10-year Blue Economy strategy.

Recommendation 1

Identify and leverage genomics as a fundamental pillar and core component of a successful, long term and sustainable Blue Economy.

2. Genomics has the capacity to deliver impacts in the Blue Economy that are felt at different levels, ranging from international ocean environmental benefits (e.g. through e-DNA surveillance); to national economic and social benefits (e.g. through genomics informed bioprospecting); to provincial, regional and community employment and well-being benefits (e.g. through regional and community-led genomics-based aquaculture approaches). This extends to the relationships with Canada's Indigenous communities and how benefits arise within Indigenous frameworks. In addition, genomics can provide benefits that range from the immediate (existing technologies to leverage and apply in new ways now), to the long-term (game-changing innovations for a Blue Economy of the future).

Recommendation 2

Engage closely with the pan-Canadian Genomics Enterprise as the Blue Economy and Pan-Canadian Genomics Strategies take shape to ensure optimal alignment and coherence for mutual benefit and maximized impact.

3. Genomics is a cross-cutting and foundational technology that can inform multiple components of a Blue Economy Strategy, as well as align with the needs and mandates of relevant departments and agencies across the federal government (Figure 1). This capacity as a foundational technology makes genomics similar to other foundational elements of modern innovation strategies such as AI and Big Data – both of which when combined with genomics in the innovation landscape deliver exponential impacts for Canada and Canadians.

Recommendation 3

Ensure that the Blue Economy strategy is regularly updated to take into account new innovation and new opportunities for rapidly growing and applied science and technologies like genomics to address big ocean challenges and to align with the evolution of international ocean and water strategies. This will be key to a sustainable and successful Blue Economy strategy.

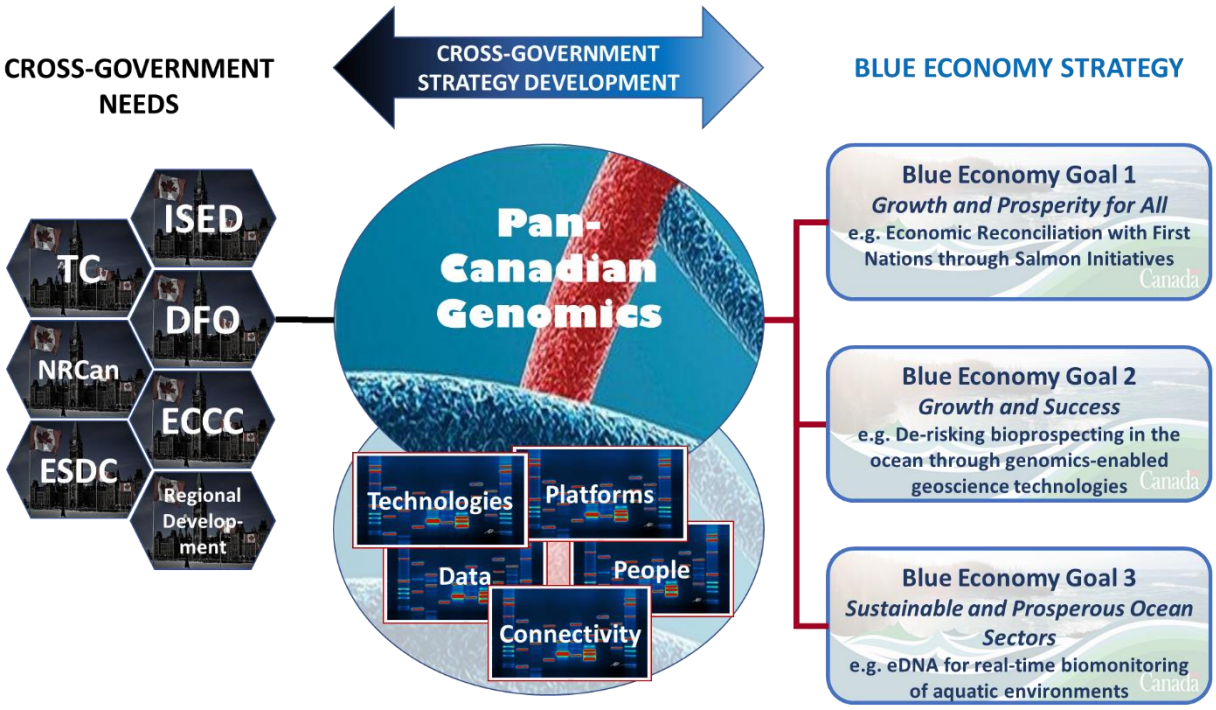


Figure 1. Genomics is a foundational component of cross-government Blue Economy Strategy.

4. Canada's Genomics Enterprise has been driving impactful research, development, training and innovation across Canada's genomics ecosystem for over 20 years. This provides a significant long-term investment in platforms, technologies, people, data and connectivity that the Blue Economy can build on.

Recommendation 4

Position genomics-enabled innovation as core to the development of high-quality jobs (high skilled, high paying, transferable) in Canada's coastal regions and Indigenous communities centrally in the Blue Economy Strategy – leveraging existing Pan-Canadian Genomics Approaches that are already achieving this.

5. Genomics technologies expand the reach of the Blue Economy strategy into Canada's broader innovation value chains. For example, by connecting inland agriculture with aquaculture through genomics technologies (e.g. plant-based fish feed), or linking offshore bioremediation with mining and energy environmental sustainability on land. This connection can increase the ROI from investments in the Blue Economy, as well as leverage investments in other parts of the broader innovation economy in Canada.

Recommendation 5

Leverage the interaction between Canada's marine and freshwater resources, platforms and innovations for sustainability, economic growth and targeting climate change in the Blue Economy Strategy.

Context

Canada's vision for a sustainable Blue Economy will see the growth of ocean sectors through innovation. It will provide good jobs and be inclusive, advance reconciliation with Indigenous peoples, respect regional differences and needs, and contribute to a clean and healthy ocean. A strong Blue Economy will also be an important part of our economic recovery from the impacts of COVID-19 and our collective effort to build back better.

Platform technologies like genomics, AI and robotics can enhance industry/private sector competitiveness and high value knowledge-based job creation in a Blue Economy. Leveraging the economic value-add and the cross-sectoral economic opportunities associated with genomics can provide a core ingredient to a successful Canadian Blue Economy Strategy.

In Canada, we have a pan-Canadian Genomics Enterprise with over 20 years of experience in building genomics ingredients into impactful people, programs, technologies and companies that bring the *transformative power of genomics* to Canadian prosperity and wellbeing. In a sense, Genomics can be seen as the 'butter' that binds together, enhances the outcomes/flavours, and complements other ingredients in the recipes of Canadian innovation-driven benefits for a future Blue Economy. While alone genomics will not provide the return, as an essential part of the recipe, it will ensure the outcomes for the Blue Economy Strategy reach their maximum potential.

Genomics and its role in the Blue Economy

GENOMICS AS A FOUNDATIONAL TECHNOLOGY FOR THE BLUE ECONOMY

With the announcement in the 2021 Federal Budget of a Pan-Canadian Genomics Strategy (PCGS) it is clear that Canada has centred genomics as one of the foundational elements to underpin and support innovation and economic growth across the system, in a similar way to 'Big Data' and 'Artificial Intelligence'.

This centring provides two clear opportunities for the Blue Economy sector and strategy. First, there is an opportunity to create alignment between the Blue Economy strategy and the PCGS to ensure that as genomics foundational technologies, platforms, data, people and connectivity are created and mobilized through the PCGS, it is aligned with and informs the Blue Economy strategy to ensure maximum impact is realized. Second, that the developments that occur in Genomics inside the Blue Economy (such as new approaches to bioprospecting in the ocean, bioremediation of environmental damage, etc.) are able to spill-over to other sectors for further impact, and that other sectors that are advancing genomics innovation can spill over into the Blue Economy (such as agricultural genomics on high protein foodstuffs, or a One Health approach to addressing antimicrobial resistance).

ADDRESSING THE BLUE ECONOMY CONSULTATION THEMES

The Blue Economy Strategy consultation document is built around three themes and genomics is reflected in all three. For each of these themes we have also provided a sample of the existing approaches genomics provides to inform the development of the Blue Economy Strategy, with specific pertinent examples highlighted in text boxes.

A. Focusing Canada's Blue Economy on Growth and Prosperity for All

The Blue Economy will only be a success if it is able to build a future economy that addresses equity issues across Indigenous communities, coastal regions and builds inclusive growth of high-quality jobs and industries that meet the needs of all.

Genomics and the Canadian Genomics Enterprise are already engaged in delivering on building the **participation of Indigenous communities** in the integration of genomics technologies with Indigenous ways of knowing and communities' own self-determined goals to address critical challenges and opportunities related to food security and commercial, recreational and subsistence fisheries. This demonstrably leads to economic and wellbeing outputs for Indigenous Communities (See Box 1). Incorporating genomics as a foundational technology to align with Indigenous innovation and development can ensure that the Blue Economy doesn't leave Indigenous peoples of Canada behind or reapply colonial relationships to communities.

Box 1. Advanced Economic Reconciliation for First Nations through the Blue Economy

Since 2019, the Strategic Salmon Health Initiative research team in BC partnered with the Broughton Nations (ʻNamgis, Mamalilikulla, and Kwikwasut'inuxw Haxwa'mis) and Okanagan Nations Alliance (ONA) to develop the capacity, literacy, and infrastructure to create the first Indigenous-led genomics laboratory in Canada at the kɬ cp̓əlk̓ stim̓ Laboratory.

The anticipated intellectual property transfer of the SSHI technology has empowered the ʻNamgis First Nations to champion several multi-million-dollar research projects to implement an independent fish health monitoring program in BC.

Supported by the BC Salmon Restoration and Innovative Fund, the projects include Independent BC First Nations' Genomic Lab Project (Phase 1 & 2), and the Implementation of the Broughton First Nations Indigenous monitoring and inspection plan totalling $2.0 M and $7.3 M, respectively.

Coastal communities across Canada are highly reliant upon the Blue Economy, and Genomics is also providing **regional development opportunities** in terms of new innovative jobs and industries that can provide the labour force of the future with high quality jobs that bring transferable innovation skills. For example, the support for Kelly Cove Salmon (Cooke Aquaculture) for Genomics support in salmon survival and health, has been building high quality innovation jobs into the Atlantic Canada economy (Genome Atlantic, 2014).

Removing the barriers that are experienced by those traditionally excluded from economic growth (equity deserving groups) will help to ensure that the strategy for the future Blue Economy in Canada will provide benefit to all Canadians. Genomics as a foundation for building high quality jobs, driving innovation and increasing community wellbeing, is committed to building equity into all future activities (Genome Canada, 2020). This means that a foundational element of a future strategy will be driven by equity, including how to engage equity deserving groups in designing and reaping benefits from genomics technologies in the future.

B. Positioning Canada's Blue Economy for Growth and Success

Growth in the Blue Economy will be intimately tied to the sustainability and resilience of the Oceans. This will include being able to monitor oceans to identify how the environment is changing, in particular in relation to driving sustainable innovation and economic development in the ocean. Genomics can be a significant tool in this part of a future Blue Economy through technologies such as environmental DNA screening (eDNA), fish stock management addressing climate change and providing strategies to reduce environmental risks as portions of the Ocean Economy innovate and grow.

Box 2. Adding environmental genomics to the biodiversity assessment toolkit

The offshore oil and gas industry is critical to the Newfoundland and Labrador economy, yet these operations must be carried out with good environmental stewardship practices.

A current barrier to growth and development is the length of time it takes to carry out environmental assessments (sometimes five years or more), increasing both the costs and business risks associated with new projects. Genome Atlantic has partnered with Petroleum Research Newfoundland and Labrador (PRNL), eDNAtec's Centre for Environmental Genomics in St. John's, NL, and the Department of Fisheries and Oceans on a $1.3 million R&D project aimed at tailoring environmental DNA (eDNA) for use in the ocean environment and comparing this approach to traditional biomonitoring techniques.

One such technology that aligns with this is the use of **eDNA in 'de-risking' offshore oil and gas exploration** (Box 2). By being able to use a study of eDNA for assessment of new projects and sites, genomics tools can significantly reduce the environmental and financial risks faced in offshore exploration. This kind of approach is also fostering growth in the Blue Economy by bringing together innovators, large-scale private sector partners and regional and federal decision maker partners to build alliances to drive economic growth in coastal and ocean communities.

Genomics is also **driving growth and reducing risk in aquaculture** for Canada, for example in addressing climate change for Atlantic Salmon (Genome Atlantic, 2018) and Blue Mussels (Genome Atlantic, 2020) – which are significant contributors to jobs in Atlantic provinces.

Canada's **One Health** approach to addressing human health challenges through understanding health across biological systems is also likely to form a key component of growth and success for the future Blue Economy. For example, there are already genomics studies addressing the presence of Norovirus in BC Oyster populations to try and predict and manage likely human health outbreaks (Genome BC, 2019).

In the future it is also possible to consider longer-term benefits of genomics in alignment with AI and Big Data in developing **real-time monitoring systems for ocean health** through developing new eDNA monitoring technology that can automatically collect and send large amounts of data to AI-enhanced analysis of Ocean biodiversity.

C. Advancing Sustainable and Prosperous Ocean Sectors in Canada

As the ocean sector grows through the period of the Blue Economy Strategy, it will be vital to ensure that innovation keeps pace and drives increased and sustainable growth. As already noted, genomics is working closely to de-risk offshore energy exploration, but it is also providing the tools to manage environmental challenges associated with growing use of the oceans by all types of industry.

Sustainability and environmental resilience form the basis for the genomics technologies related to **bioremediation**. These are able to be used in ocean and land environments, but the ability to transfer technological breakthroughs to the Blue Economy will be vital for sustainable growth. For example, genomics work is already informing Canadian policies on oil spill remediation as part of the new 'Alternative Response Measures' component of the Canadian Oceans Protection Plan (GenICE, 2021). The GenICE project (Box 3) provides an example of how genomic bioremediation knowledge can ensure that economic growth for ocean industries does not come at the expense of environmental sustainability.

Box 3. GenICE: Microbial Genomics for Oil Spill Preparedness in Canada's Arctic Marine Environment

Thanks to reduced sea ice cover and ice-free summers, the Northwest Passage has never been so busy. Shipping has increased by 166% since 2004, while cruise ships and tourism have increased by 500 per cent in the past five years. With this increased activity, the risk of accidental releases of diesel or bunker fuel or other transportation-related contaminants has grown. In addition, climate change has focused attention on Arctic oil exploration and fears of an oil spill in the Arctic Ocean.

Current decisions by major oil companies suggest that drilling for oil in the Canadian Arctic is at least a decade away, giving scientists a window of opportunity to develop emergency preparedness plans for future exploration activities that may take place. Drs. Casey Hubert and Gary Stern are leading a team that will use microbial genomics to generate credible, science-based evidence on the role and potential of bioremediation to deal with oil spills in the cold, ice-laden Arctic Ocean. Policies and strategies informed by the research will enable an improved capacity for environmental protection through safer shipping and oil exploration in the Arctic.

Other **genomics technologies that are in use to drive Blue Economy growth**, beyond those in aquaculture identified already, include using genomics to understand marine pipeline (and infrastructure) corrosion by microbes (Genome Atlantic, 2017); building the biofuels sector that is starting to become part of the ocean transport discussion (Genome Prairie, 2009); and the connectivity of genomics technologies with other ocean technology advancements and innovations through the Ocean Supercluster (Ocean Supercluster, 2020) and NRC's Ocean Program (NRC, 2021).

ADDRESSING THE BLUE ECONOMY CONSULTATION 'BIG QUESTIONS'

The consultation document identifies five 'big questions' that are relevant to those developing the strategy. While much of our response has already addressed parts of these questions, we provide short responses to the questions that reflect the role of genomics and the pan-Canadian Genomics Enterprise specifically below.

How do we ensure that our oceans opportunities are equitably shared?
From the Genomics Enterprise, it is clear that it is possible to build innovative Blue Economy approaches with genomics that respect the self-determined goals and needs of Indigenous communities while honouring reconciliation approaches. Bringing foundational technologies and training to communities affected by the Blue Economy and being deliberate in targeting the needs of equity deserving communities, Genomics innovations can support bringing resources, jobs and wellbeing to those most in need of it in Canada's Blue Economy.

Are there other ideas that you think would help us develop Canada's Blue Economy Strategy?
Genomics as a foundational technology is now being developed into a Pan-Canadian Genomics Strategy. By ensuring that the Blue Economy Strategy develops with an appreciation of the integration it can and should have with the PCGS, DFO and the Blue Economy Strategy can both leverage and influence other parts of Canada's innovation portfolio for mutual benefit.

Are there additional themes that you think the Government should explore?
It is clear that there are significant linkages between marine and freshwater innovation in the realm of genomics and other foundational technologies. It will be important for a Blue Economy Strategy to leverage the freshwater innovation system.

Do you have ideas that could strengthen Canada's leadership role in oceans health and developing a sustainable Blue Economy?
Utilizing the connections and networks of the pan-Canadian Genomics Enterprise can bring a new set of stakeholders and partners to the Blue Economy. In particular in terms of international leadership around Blue Economy innovation and technology development and deployment. This will also create a leadership role within Canada for the ocean innovation system to integrate with the other components of Canada's innovation system.

How can our Blue Economy Strategy support the Sustainable Development Goals of the United Nations 2030 agenda?
One of the major benefits of aligning the Blue Economy strategy with a foundational technology such as genomics is to create connections across a broad range of potential goals. In relation to the 17 identified UN 2030 Sustainable Development Goals, this allows an expansion from the clear alignment with Goal 14 on 'Life Below Water' (the goal specifically linked to ocean health and sustainability) to extend connections to 12 of the 17 goals.

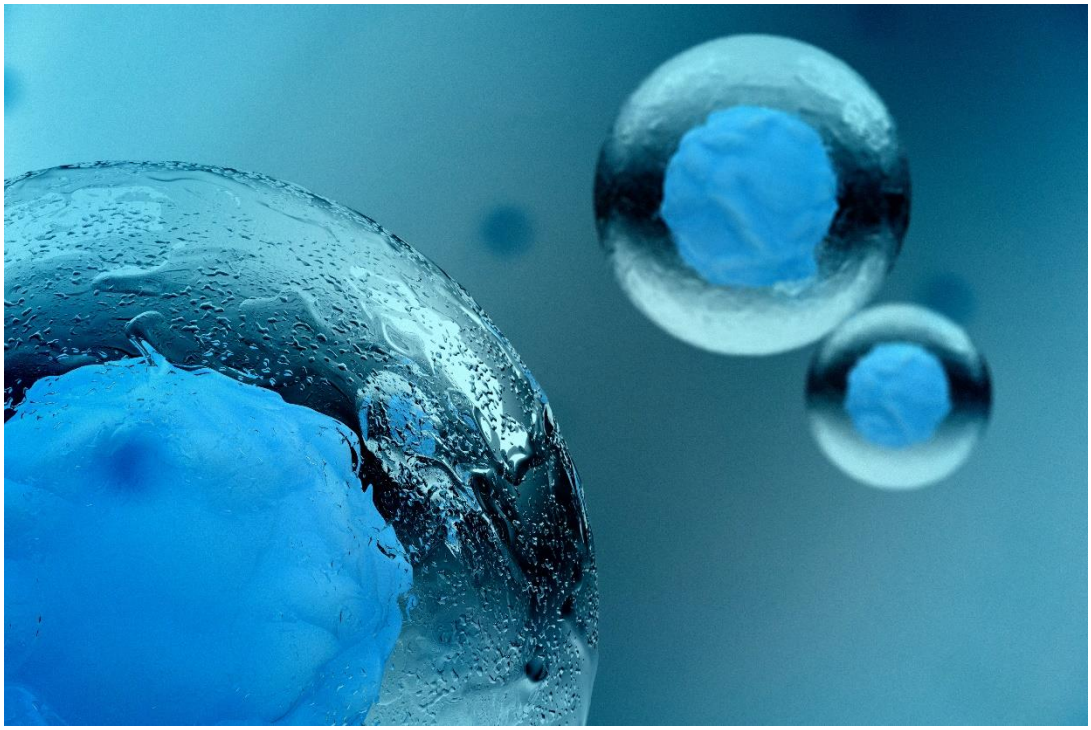
For example, aligning genomics innovation for regional development immediately connects Goals 8, 9 and 11 to the Strategy. Linking genomics technologies around health, energy, sustainability and food security encompasses Goals 2, 3, 6, 7, 12, 13 and 15. While the

connectivity of the genomics enterprise across stakeholder groups, communities, policy-makers and internationally brings Goal 17 squarely into the realm of a Blue Economy strategy.

Understanding that the Blue Economy is tied to outcomes beyond ocean health can ensure that Canada is seriously integrating its innovative strategies into global benefit and sustainable development.

Closing Statement

The pan-Canadian Genomics Enterprise, comprising Genome Canada and the regional Genome Centres, fully endorses this consultation process for creating an effective, impactful and equitable Blue Economy in Canada. The Pan-Canadian Genomics Enterprise plays a unique national leadership role in Canada, bringing together stakeholders from academic science, innovation, policy and industry. This national convening and coordinating role allows the Enterprise to drive genomics approaches through the value chain to deliver impacts for Canada and Canadians. We are ready to contribute to efforts towards realizing value of genomics as part of the core technologies supporting a future Blue Economy so that Canada can "***build back bluer and better"***.



UTILIZING THE POWER OF GENOMICS TO BUILD BACK BLUER AND BETTER

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Appendices

The following appendices provide illustrative examples of existing genomics research and innovations that can tangibly support the delivery of a ten-year Blue Economy Strategy. They highlight that this work is across the Pan-Canadian Genomics Enterprise, as well as the connections to multiple government departments aligned with the Blue Economy.

APPENDIX A. WORK IN FIRST NATIONS AND INDIGENOUS FISHERIES

A1. Strategic Salmon Health Initiative (SSHI) Through Genome BC

Genome British Columbia, the Pacific Salmon Foundation, and Fisheries and Oceans Canada embarked on a remarkable 8-year partnership aimed to discover the microbes that may be undermining the productivity and performance of our Pacific salmon in British Columbia. Researchers developed and applied genomic technologies that enabled the identification of microbes, understand the transmission dynamics and historical presence of detected microbes, their evolutionary history, and the potential role of exchanges between wild and cultured salmon.

The innovative diagnostic and monitoring tool (Salmon FitChip) developed by the SSHI team has caught the attention of regulators, industry, and First Nations communities. Since 2019, the SSHI research team partnered with the Broughton Nations (ʻNamgis, Mamalilikulla, and Kwikwasut'inuxw Haxwa'mis) and Okanagan Nations Alliance (ONA) to develop the capacity, literacy, and infrastructure to create the first Indigenous-led genomics laboratory in Canada at the kł cp̓ə̓lk̓ stim̓ Laboratory. The anticipated intellectual property transfer of the SSHI technology has empowered the ʻNamgis First Nations to champion several multi-million-dollar research projects to implement an independent fish health monitoring program in BC. Supported by the BC Salmon Restoration and Innovative Fund, the projects include *Independent BC First Nations' Genomic Lab Project (Phase 1 & 2*), and the *Implementation of the Broughton First Nations Indigenous monitoring and inspection plan* totalling $2.0 M and $7.3 M, respectively.

Links to the GBC funded projects:

- **https://www.genomebc.ca/projects/inventory-and-assessment-of-health-risk-of-microbes-in-bc-phase-1**
- **https://www.genomebc.ca/projects/inventory-and-assessment-of-health-risk-of-microbes-in-bc-phase-2a**
- **https://www.genomebc.ca/projects/inventory-and-assessment-of-health-risk-of-microbes-in-bc-phase-2b**

Information on the ʻNamgis First Nations projects funded by British Columbia Salmon Restoration and Innovation Fund here:

- **https://www.dfo-mpo.gc.ca/fisheries-peches/initiatives/fish-fund-bc-fonds-peche-cb/projects-projets-eng.html**
- **https://www.mycomoxvalleynow.com/58520/premier-says-steps-being-made-in-wild-salmon-protection-in-broughton-area/**
- **https://www.syilx.org/fisheries/hatchery/lab/**

A2. FISHES: Fostering Indigenous Small-scale fisheries for Health, Economy, and food Security

- **Status:** Active
- **Competition:** 2018 Large-Scale Applied Research Project Competition: Genomics Solutions for Agriculture, Agri-food, Fisheries and Aquaculture
- **Sector:** Fisheries and Aquaculture
- **Genome Centre(s**): Génome Québec, Ontario Genomics
- **Project Leader(s**): Louis Bernatchez (Université Laval), Jean-Sébastien Moore (Université Laval), Dylan J. Fraser (Concordia University), Stephan Schott (Carleton University)
-

Project Description: The FISHES project will develop and apply genomic approaches in concert with Traditional Ecological Knowledge to address critical challenges and opportunities related to food security and commercial, recreational and subsistence fisheries of northern Indigenous Peoples in Canada (Inuit, Cree and Dené communities). The project will develop genomic resources for six species important to northern communities and use these resources to identify genetically distinct populations, assess their vulnerability to future climatic conditions, quantify their contributions to mixed-population harvests, and measure the contribution of fish from developing hatchery programs to subsistence harvests. FISHES will support the co-generation of knowledge to foster the development and co-management of sustainable fisheries and will also contribute to our ability to forecast the response of key fisheries to rapid global and socio-economic changes in northern Indigenous communities.

- **http://fishes-project.ibis.ulaval.ca/about-fishes/**
- **http://fishes-project.ibis.ulaval.ca/wp-content/uploads/sites/16/2021/04/FISHES_wbt-report_2021_04_13.pdf**

In addition, the FISHES project is now being connected with Genome Quebec's 'DNA-Water Mission' through direct alignment of citizen science with Indigenous communities in Quebec.

- **http://www.genomequebec-education-formations.com/missionadn**

APPENDIX B. eDNA FOR OCEAN MONITORING

B1. Assessing Freshwater Health Through Community Based Environmental DNA Metabarcoding

- **Status:** Active
- **Competition:** Genomic Applications Partnership Program
- **Sector:** Environment
- **Genome Centre(s):** Ontario Genomics
- **Project Leader(s):** Mehrdad Hajibabaei (University of Guelph)
- **Receptor Leader(s):** Elizabeth Hendriks (World Wildlife Fund Canada (WWF-Canada)); Laura Maclean (ECCC - Environment and Climate Change Canada)

Project Description: With a growing economy, increasing population, and climate change, Canada faces increased pressures on its precious resource: freshwater (20% of the world's freshwater). Current methods for monitoring the health of our watersheds remain slow, laborious, expensive and imprecise. Canada's geographic diversity and low population density makes monitoring networks a challenge to maintain. We need more efficient, comprehensive monitoring tools to inform governments, communities and industries about the true consequences of economic development on freshwater quality, to support rapid and effective protection of vulnerable ecosystems.

The WWF- Canada and Environment and Climate Change Canada (ECCC) are working with Dr. Mehrdad Hajibabaei of the University of Guelph to validate and implement a new technique called environmental DNA metabarcoding, which uses bulk environmental samples for identification of species through species specific genomic sequences (DNA 'barcodes') using high-throughput sequencing technologies. The project will generate biodiversity data for freshwater benthic macroinvertebrates, the small animals that live at the bottom of streams, rivers. The technique will be used to analyze bulk samples collected by community-based monitoring efforts across a wide range of Canadian watersheds. Sampling by community groups will be coordinated by WWF-Canada and its partner organizations such as Living Lakes Canada.

Implementation at this scale will be a world first, supporting the wider adoption of these technologies within existing environmental monitoring and assessment applications, including ECCC's Canadian Aquatic Biomonitoring Network (CABIN) which engages over 1,400 users, including federal, provincial and territorial government agencies, First Nations, academia, industry, NGOs and environmental consulting firms.

Many of these organizations already use biomonitoring to understand and manage the impacts of resource projects such as mines, hydro dams and energy projects. By providing access to this new genomics-based technique, and by demonstrating its reliability in assessing river health, we can broaden the reach and impact of existing community-based monitoring programs, ultimately leading to better informed decisions.

B2. Advancing Environmental Genomics in the Marine Environment

- **Status:** Active
- **Competition:** Regional Priorities Partnership Program (RP3)
- **Sector:** Environment
- **Genome Centre(s):** Genome Atlantic
- **Project Leader(s):** David Finn (Petroleum Research Newfoundland and Labrador), Mehrdad Hajibabaei (eDNAtec), David Cote (Fisheries and Oceans Canada)
- **Fiscal Year Project Launched:** 2019-2020

Project Description: The offshore oil and gas industry is critical to the Newfoundland and Labrador economy (Government of Newfoundland and Labrador 2017), yet these operations must be carried out with good environmental stewardship practices. A current barrier to growth and development is the length of time it takes for environmental assessments to take place, which frequently exceed five years—increasing both the costs and the business risks associated with new projects. Petroleum Research Newfoundland and Labrador (PRNL) connects major oil and gas companies to research trends and initiatives. PRNL has identified genomics as a key area of research with wide range potential for applications in oil and gas industry and will play a key role in providing guidance and advice to the other project participants to ensure industry needs are being met.

Through support from PRNL's member oil and gas companies, eDNAtec's Centre for Environmental Genomics Applications opened in St. John's, N.L., in mid-2017 and is the only research centre of its kind whose sole mandate is to advance environmental DNA analysis technologies for the use of environmental biomonitoring purposes. In partnership with Fisheries and Oceans Canada (DFO), samples will be obtained from the Newfoundland and Labrador coastal, continental shelf, and open water regions and analyzed using both traditional biomonitoring methods and environmental DNA analyses. These comparative studies are a crucial next step towards the refinement of laboratory methods and the widespread adoption of the environmental genomics techniques by both industry and regulatory agencies.

B3. Optimizing the eDNA Approach to Monitor Biodiversity in Canada's Marine Protected Areas

- **Status**: Active
- **Competition:** Genomic Applications Partnership Program
- **Sector:** Environment
- **Genome Centre(s):** Génome Québec
- **Project Leader(s):** Jennifer Sunday (McGill University)
- **Receptor Leader(s):** Emily Rubidge and Ryan Stanley (Department of Fisheries and Oceans, Canada)
- **Fiscal Year Project Launched:** 2020-2021

Project Description: Canada is investing in its large Marine Protected Area (MPA) network, spanning approximately 805,000 km2, to preserve marine biodiversity and promote healthy, functional, and resilient marine ecosystems. However current biodiversity sampling methods are inadequate to monitor biodiversity within a network of this size. The project team proposes to use environmental DNA (eDNA) metabarcoding to evaluate and optimize marine monitoring survey designs. The results of this project will be the first quantitative evaluation of eDNA survey design in a marine setting and will provide a foundation for decisions in monitoring investment using this technology in the Canadian MPA network.

APPENDIX C. DE-RISKING OFFSHORE EXPLORATION

C1. Validation and Integration of Genomics Solutions for Offshore Oil Exploration in Nova Scotia and Beyond

- **Status:** Active
- **Competition:** Genomic Applications Partnership Program
- **Sector:** Energy
- **Genome Centre(s):** Genome Atlantic, Genome Alberta
- **Project Leader(s):** Casey Hubert (University of Calgary), Todd Ventura (Saint Mary's University)
- **Receptor Leader(s):** Adam MacDonald (Nova Scotia Department of Energy)

Project Description: This project focuses on de-risking exploration and development in offshore Nova Scotia (NS) by the validation and integration of new genomics-based technologies with traditional exploration approaches. The primary goals of the proposed GAPP project are to (1) further decrease risk in oil exploration in offshore NS; (2) attract offshore petroleum exploration and development investment to NS in a globally competitive sector; and (3) differentiate Nova Scotia Department of Energy and Mines' geoscience package by including innovative genomics solutions and showcasing them to the world. The main deliverable will be integration of different omics data layers with geochemistry and other geoscience into an easily accessible and marketable database for mapping target sites to enumerate the existence and type of reservoir leakage at prospective target sites. By providing novel, genomics-enabled data the province will significantly increase interest from oil majors and simultaneously produce intellectual property (IP) and potential for commercialization via spin off companies or licensing of the IP to industry service providers.

APPENDIX D: SELECTED OTHER PROJECTS OF INTEREST

Breeding Better Oysters

A $3.8 MILLION, 4-year project puts a New Brunswick company at the FOREFRONT of oyster breeding technology & aims to increase profits for oyster farms in ATLANTIC CANADA.

L'Étang Ruisseau Bar (ERB)
Shippagan, New Brunswick

SELECTIVE BREEDING
through **genomics**
shortens production time by

20%

Genomics will increase ERB's annual production by more than 60% by 2027

Project Funders & Partners

Genome Canada, Genome Atlantic, Génome Québec, ERB, Ministère de l'Économie et de l'Innovation du Québec, Atlantic Fisheries Fund, Université Laval, University of Chile, Mitacs Canada, NRC-IRAP.

Ambitious Targets Demand A NEW Approach

- New Brunswick aims to increase oyster production by 10%/year.
- Having a reliable source of superior, faster-growing oyster seed is key to meeting those targets and will benefit the entire East Coast industry.

Genome Atlantic has worked with ERB to help shape the proposal, assemble the research talent, source the required funding, and manage the funded project.

GenomeAtlantic
Life Sciences. Life Solutions.

CONTACT US TO FIND OUT MORE
902.421.5646
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WEBSITE: www.genomeatlantic.ca

Climate-Proofing Blue Mussels

An $800,000 venture to create the genomic tools for a blue mussel selective breeding program that will protect the shellfish against climate change & preserve Prince Edward Island's dominance in the North American market.

BLUE MUSSELS ARE CANADA'S TOP FARMED SHELLFISH PRODUCT

80%

of mussels sold in North America are from P.E.I.

Mussels and the P.E.I. economy

- $60 million in direct economic growth
- Employs 1,500 people
- $11 million in salaries

CLIMATE CHANGE will test the blue mussel's biological limits, putting a lucrative industry at risk.

Genomic tools are critical to protect and sustain the industry:

- Selective breeding for disease & temperature resistance
- Faster growth (proven 12% growth gains in selectively bred aquatic species) for sustainable, increased production

Project Funders & Partners

Genome Atlantic, Genome Canada, Atlantic Fisheries Fund, Government of Prince Edward Island, Atlantic Aqua Farms, Prince Edward Island Mussel Farms, Prince Edward Aqua Farms, PEI Marine Science Organization

Selective breeding **through genomics** could DOUBLE annual blue mussel production in P.E.I. within 10 years (from 50M lbs. to 100M lbs.)

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