GenomeCanada

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Submission from the Canadian Genomics Enterprise to Environment and Climate Change Canada's 2030 Biodiversity Strategy Consultation

Introduction

As outlined in the discussion paper ***Towards a 2030 Biodiversity Strategy for Canada***, Canada's nature is important for the world and is essential for human survival, security, prosperity and well-being. It provides us with a stable climate, breathable air, food supply, clean water and protection from disease and disaster. Considering that Canada holds 28 per cent of the world's boreal forest, 20 per cent of the world's total freshwater, 24 per cent of the world's wetlands, and is home to an estimated 80,000 wild species, it is more important than ever to halt and reverse nature loss.

As cutting-edge genomics research and innovation advance exponentially, a greater range of tools and techniques are available and coming online to aid in the preservation of global and national biodiversity. Genomics can be used to identify biodiversity markers, mitigate human-made impacts to the environment and create a community more resilient to climate change. In this process, Genome Canada acknowledges that both slowing and reversing biodiversity loss requires an array of collaborations and partnerships, including with First Nations, Métis, and Inuit peoples in communities from coast to coast to coast. It also requires real transformative change, innovation and a proper accounting for the true value of nature in decision-making across all sectors.

ABOUT US

Genome Canada is an independent, federally funded not-for-profit organization and a national leader for Canada's genomics ecosystem. Working in partnership, and across sectors, we invest in, and coordinate genomics **research**, **innovation**, **data** and **talent** to generate solutions to today's biggest challenges. Genome Canada works closely with the Canadian government to address federal priorities for genomics. We also coordinate with a **pan-Canadian network of Genome Centres**, which enables us to reflect regional and provincial priorities. This network is key to our impact, facilitating regionally focused programs, proactive business development and strong industry connections across the country.

The Canadian Genomics Enterprise—comprised of Genome Canada and the six regional Genome Centres—has 22+ years of deep expertise and experience working across the Canadian genomics ecosystem to lead high-impact, challenge-driven genomics research and innovation initiatives that: deliver tangible impacts for Canadians; complement federal science, technology, and innovation efforts; and address federal priorities, such as climate action, green growth in traditional sectors, food and energy security and future pandemic preparedness.

Canada has world-leading expertise in biodiversity genomics. Leveraging this capacity through the application of genomics tools and technologies will be key to accelerating Canada's efforts to meet its national and international biodiversity targets. For this reason, we recommend that genomics science and technology should be explicitly referenced and included as a key enabling solution in the 2030 National Biodiversity Strategy. Funders like the Wellcome Trust, countries like the United Kingdom and regional blocs such as the European Union[1] are investing significantly in large-scale genomics initiatives, collaborations and life sciences data commons to

[1] **https://wellcome.org/press-release/ambitious-project-map-genomes-all-life-british-isles-funded-wellcome; https://biodiversitygenomics.eu/;** and **https://biofair.uk/**.

support their biodiversity goals and strategies. Canada will have to do the same if we are to meet the targets set at COP15.

Key considerations

1. Science and data must be supported as key enablers of the success of the strategy. **In particular, genomics tools and technologies can *accelerate* meeting several of the targets[2] for Canada's 2030 National Biodiversity Strategy and help achieve our national and global biodiversity goals**. Genomics can contribute both short and long-term solutions leading to actionable insights and evidence-based policy and regulation.

2. Success will require a **whole-of-government science-based approach to biodiversity conservation policy**. Key science-based government departments (SBDs) must work together (Department of Fisheries and Oceans, Environment and Climate Change Canada, Natural Resources Canada, Agriculture and Agri-Food Canada, National Research Council Canada, other SBDs) with extramural research and innovation partners like Genome Canada and the regional Genome Centres to ensure genomics and environmental data set linkages and integration to support biodiversity policy development.

3. **We can help Canada lead the world in applying genomics tools, technologies and genomics-enabled climate change models to meeting biodiversity conservation targets**. The Canadian Genomics Enterprise has a critical mass of large-scale (e.g., the **Canadian BioGenome** and **BIOSCAN-Canada** projects) and targeted (e.g., the **Bison Integrated Genomics** project) biodiversity genomics research initiatives.[3] We also support talented, world-leading researchers and private sector partners in biodiversity genomics and have pan-Canadian expertise in creating federated data ecosystems and data hubs that can be leveraged to support the strategy's goals and Canadian global leadership in this space.

4. **We strongly support the Digital Sequence Information (DSI) Framework agreed to at COP15.** This acknowledges the importance of DSI for sustainable development and also emphasizes the need for further capacity-building initiatives and scientific cooperation to enhance access and use of DSI worldwide.

Six recommendations

The following are six recommendations to inform the development of Canada's 2030 National Biodiversity Strategy. These represent six key areas where genomics can accelerate Canada's efforts in meeting its national and international biodiversity goals.

1. Ecosystem and species monitoring and management to prevent biodiversity loss and promote conservation.

[2] Throughout the submission, we refer to how genomics can support specific Kunming-Montreal Global Biodiversity Framework (KMGBF) targets **https://www.cbd.int/gbf/targets/**. Appendix B also captures this information in narrative format.
[3] See Appendix A for a comprehensive list of projects referenced throughout the submission.

2. Supporting reduction in extinction rate and risk of species and maintaining and safeguarding the genetic diversity within populations of wild and domesticated species.

3. Preserving Indigenous traditional ecological knowledge related to biodiversity and supporting Indigenous community needs.

4. Supporting green growth.

5. Ensuring adequate data and knowledge for informed evidence-based decision-making.

6. Enhancing the understanding of the ethical, economic, environmental, legal and social aspects of genomics to ensure the responsible equitable and effective development, uptake and implementation of genomics research and innovation.

The strategy speaks about monitoring and methods for biodiversity protection but should also highlight the specific value-add role of genomics. Genomics is a *key* tool in monitoring eco-regions and bio-geographical structures, which is critically important given the reality that ecosystems and species cross jurisdictional borders and are not confined to economic or political regions. Key areas where genomics tools and technologies provide accelerated, agile, and precision solutions include:

1. **Ecosystem and species monitoring and management to prevent biodiversity loss and promote conservation.**

    a. The success of Canada's biodiversity strategy will require developing baseline knowledge of genetic diversity in an ecosystem to inform monitoring and management practices to slow the current rate of biodiversity loss and promote conservation.

    b. Genomic sequencing and banking of genomics data[4] to characterize species and populations sets the baseline and references for characterizing the evolving genetic diversity of an ecosystem and within a species (ecotypes). Examples of species include trout and caribou (Targets 2, 4, 6, 8). Genomics can be also used to derive important ecological information from soil that leads to the characterization of soil microbiome diversity, which in turn is linked to soil health, water quality, agricultural production, animal health, and human health.

    c. Genomics-based bio surveillance is much more accurate, less invasive and substantially faster than morphological-based methods and can be applied on a global scale. A key tool is eDNA monitoring and surveillance[5]:

        i. With species genetic biodiversity baseline information in hand, genomics tools such as eDNA[6] can be used to monitor change rapidly and in real time and gather precise information which feeds into ethical and environmental regulation, policy and permit decisions in an iterative and nimble way. eDNA includes the cutting-edge concept of "airborne DNA" that focuses on the detection of species from their genetic remnants in the air. This has the potential to be used for the detection of

[4] Project examples 5, 8, 9, 30-35.
[5] **Environmental DNA for Biodiversity and Ecosystem Monitoring: Molecular Ecology: Vol 30, No 13 (wiley.com)**.
[6] Project examples 1, 3, 4, 18, 22, 28, 29.

rare and endangered species, track shifts in the makeup of species assemblages due to climate change and provide early warning of invasive species. With the use of such tools, we don't need species to be present at time of detection in order to monitor ecosystem change.

2. **Supporting reduction in extinction rate and risk of species and maintaining and safeguarding the genetic diversity within populations of wild and domesticated species.**

   a. Recovery progress for species is low and information for assessment is lacking. With the right tools and standards, genomic information can be used to track species recovery in precise and non-invasive ways.

      i. Tools like **iTrackDNA's eDNA kits** will allow for the detection of various species from environmental samples and eliminates the need for direct observation, which is logistically and economically more cumbersome.

      ii. Tracking species at risk also benefits from understanding the genetic structure within discrete populations, as seen in the **Use of genomics to manage and protect caribou populations** project. Only through genetic analyses were groups able to protect and manage the endangered populations of that species and its habitat in a manner consistent with sustainable development and supported by up-to-date knowledge, for the stability of the tundra ecosystems and for the food security and economy of Northern communities.

   b. Addressing sustainable harvesting and trade of wild species (target 5): Genomics tools can provide information on population sizes, changes, health/disease status, and resiliency which contribute to understanding the sustainability and safety of harvesting and trade. In addition, leveraging genomics can support rapid identification of species at the point of trade and in harvesting investigations.

   c. Preserving wildlife population health (targets 6, 2): Genomics can be used to non-invasively monitor the impact of stressors (including climate-based stress) on different species in order to preserve wildlife population health. The same tools can identify, minimize, and mitigate invasive species, pests, and pathogens that threaten Canada's species, ecosystems and biodiversity (project examples 26, 36-38).

   d. The combination of genotype and environment associations with artificial intelligence can help develop predictive models of species adaptation to climate change and assess genomic vulnerability.

   e. Genomics can also: (i) measure the impact of restoration efforts, (ii) identify connectivity and demographics of populations within and among species in a certain habitat or ecosystem, and (iii) allow consanguinity and genomic variability analyses and evaluation of potential impacts to avoid the extinction of endangered species.

   f. Genomics information can provide guidelines to support ecosystem restoration and/or reintroduction and rehabilitation of species to environments altered by natural disasters, climate change, industry or disease.

   g. Taxonomic analysis of individuals from a given species is insufficient as it provides an

incomplete picture of subtle variations. The challenge in detecting rare species could result in the loss of individuals or species already in danger of extinction.

3. **Preserving Indigenous traditional ecological knowledge related to biodiversity and supporting Indigenous community needs.**
   a. Dealing with chronic wasting disease[7] is a major priority for Indigenous communities and hunters. Genomics can be a tool to support food security in Indigenous and remote communities, as well as food traceability as it allows unambiguous detection of food origin and identification of species related to illegal activities.

   b. There is an active real-time connection between Indigenous peoples, the environment and biodiversity because they are actively using natural resources for community benefit and social/economic utility. These communities have an inherent and urgent interest in understanding what is available for their communities to thrive. Meaningful engagement with communities to understand their needs in wildlife conservation and management discussions are being undertaken through the **Canadian BioGenome** project following protocols established through **The Role of Genomics in Fostering and Supporting Arctic Biodiversity: Implications for Wildlife Management, Policy and Indigenous Food Security** project.

4. **Supporting green growth.**
   a. Canada is a resource-rich country and genomics can be a tool to help Canada sustainably harvest these resources while meeting environmental and biodiversity goals.

   b. Agile, lower-cost tools such as eDNA kits will be increasingly necessary to comply with what industry expects will be increasingly stringent regulations around new and existing natural resource development.

   c. Genomics can support environmental assessments related to biodiversity conservation and industrial goals.

GENOME ATLANTIC

Advancing environmental genomics in the marine environment

Energy Research and Innovation Newfoundland and Labrador (ERINL) has recognized the value of genomics to support the growth of the offshore oil and gas industry while supporting environmental goals. ERINL has partnered with eDNAtec's Centre for Environmental Genomics Applications (with a mandate to advance environmental DNA analysis technologies for the use of environmental biomonitoring purposes) and Fisheries and Oceans Canada (DFO), to obtain samples from the Newfoundland and Labrador coastal, continental shelf, and open water regions and analyze them using both traditional biomonitoring methods and environmental DNA analyses. These comparative studies will support the refinement of laboratory methods and the widespread adoption of environmental genomics techniques by both industry and regulatory agencies.

[7] Project example 16.

d. Genomics can support Canada's agri-foods[8] and natural resource industry's ability to adopt sustainable practices through multiple avenues such as identification and mitigation of invasive species[9] and emerging pathogens (project examples 37, 38, 40); genomics-informed breeding—pest and pathogen resistance, climate adaptation and resilience (project examples 13, 39); new treatments for disease (project examples 41, 42); biopesticides and biocontrol agents, biofertilizers, bio preservatives and bioremediation and bioaugmentation (project examples 43-47). These measures can increase production, reduce waste, increase efficiencies, minimize pollutants (including fertilizers, pesticides, antibiotics, etc.), and decrease the overall environmental and carbon footprint of industrial operations (targets 5, 6, 7, 8, 10, 16).

e. Genomics can also contribute significantly to nature-based solutions, actions that aim to protect, manage and restore ecosystems sustainably.[10] Using genomics, scientists can select species and/or populations which are bred for certain desirable characteristics or resilient to the environmental conditions in specific areas (targets 8, 11).

f. Biodiversity data can make an important contribution to synthetic biology and its role in the sustainable use of resources, the development of bioproducts, and the circular economy.

5. Ensuring adequate data and knowledge for informed evidence-based decision-making.

a. The strategy talks about the effective and targeted actions to halt and reverse biodiversity loss. Such actions must be guided by the best available information and will require mobilizing data and all forms of knowledge and ways of knowing. Genomics can be key to support evidence-informed decision-making.

b. Data on the status of Canada's biodiversity is fragmented and the unstructured information cannot be effectively translated into policy- and decision-making. There is a strong need for a comprehensive observation network in Canada in addition to comprehensive and consistent data collection.

c. In order for political leaders and policy makers to make informed decisions on the protection of biodiversity, they need access to—and an understanding of—the biodiversity data available, but there is currently no such central resource. A successful strategy will require an *integrative biology-based approach*: the collaboration between all levels of biology, from the very small scale (genomics) to the very large scale. Genomics can produce models that predict how species or communities might adapt to climate change, but not without the help of other disciplines.

[8] See **Climate-Smart Agriculture and Food Systems – Genome Canada** new challenge initiative.
[9] Project examples 4, 25, 26, 27.
[10] **https://www.iucn.org/our-work/nature-based-solutions**.

d. Canada's biodiversity targets highlight the need for a comprehensive observation network that considers Canada as a whole and coordinates the various local, regional, and provincial efforts. Genomics can support an essential biodiversity variables (EBV) framework as demonstrated by the **GEOBON** initiative that has facilitated the development and enhancement of more than 20 national biodiversity observation systems (representing most of the Earth's major biomes), developed operational products (e.g., global change detection maps of forest cover; compendium of marine environmental databases), and provided high quality observations, information, and data to scientists, decision-makers and the public at various scales and models that support improved policy assessments and scenarios at multiple scales.

e. The Canadian Genomics Enterprise constitutes a pan-Canadian network of researchers, private partners and industries, and as such, can provide important insights and support meeting this objective. The urgency with which our biodiversity must be protected presents an opportunity to bring together this existing capacity into a coordinated national network and/or initiative that can be leveraged to tackle existing and emerging issues head-on.

f. Canada's biodiversity strategy and the utilization of genomics-enabled insights will have to balance how long it takes to develop baseline knowledge of genetic diversity in an ecosystem and slowing the current rate of biodiversity loss. In California, the government has invested in "Bio Blitzes" to urgently get immediate baseline information from ecosystems in partnership with researchers. This initiative helps to understand how the ecosystem is changing and supports long-term policy for ecosystem management and fire and flood prevention.

g. Sometimes, the ecosystem cannot go back to the way it was. This may be due to inherent changes to the environment (e.g., climate), or because we don't completely understand what was there before the disturbance. Genomics can support both traditional and novel approaches to ecosystem restoration.

h. Genomics data generation and sequencing information will contribute to our understanding and implementation of bio-prospecting (mining, oceans, forestry, agriculture) which is the basis for a circular bioeconomy (target 10).

i. For many species and ecosystems, Canada currently has limited samples to reference after disturbances such as natural disasters to identify pre-existing genetic diversity. To effectively react to catastrophic events (both natural and anthropogenic in nature), biobanking and information on population and ecosystem genomic diversity is necessary to inform restoration and rescue efforts. Proactive work to capture existing genomic diversity information prior to these events is crucial to safeguard Canada's biodiversity.

6. Enhancing the understanding of the ethical, economic, environmental, legal and social aspects of genomics to ensure the responsible equitable and effective development, uptake and implementation of genomics research and innovation.

a. Many societal issues pertaining to biodiversity can be explored through GE^{3}LS research: genomics and its ethical, environmental, economic, legal, and social aspects and related knowledge mobilization activities and public engagement. Building on this

research, the Canadian Genomics Enterprise invests time, resources, and effort to effectively mobilize knowledge to drive the adoption of genomics solutions and build genomics public awareness. We work together with stakeholders to: (1) support evidence-based policy- and decision-making and engage in policy dialogue to inform and shape policy and regulations affecting societal uptake of genomics; (2) collaborate with communities and end-users, and co-create equitable and accessible genomic solutions with them: and (3) promote genomics literacy and awareness in Canada through traditional and social media, events and strategic partnerships.

i. An example of this kind of work can be seen with the **FISHES** pan-Canadian initiative and the adaptation and deployment of **Mission e-DNA** in Indigenous communities. Led by Génome Québec and the Fonds de recherche du Québec, Mission eDNA-First Nation ran in seven classes in two high schools located in the Eeyou Istchee (Cree) communities of Waskaganish and Eastmain. The pilot project was made possible thanks to the support of the communities' Chiefs and Councils, as well as the Eeyou Marine Region Wildlife Board. Génome Québec worked with a local consultant and coordinator to adapt teaching materials to foster interesting and culturally relevant engagement with science.

b. Genomics collaborations are also an opportunity to learn from and collaborate with traditional ecological knowledge.[11] Investigation into ethical, economic and sustainable management of wild species (target 9), can be seen in the **BEARWatch** project, which is combining leading-edge genomics with comprehensive social science, developed and implemented within a framework of collaboration with Northern communities, Indigenous organizations and territorial and other levels of government, to provide data for tracking changes in polar bear populations. The key insights for polar bear management and for tracking the changing ecosystems of the Canadian Arctic, helps situate Canada as a world leader in genomics-based, community-oriented research for wildlife management.

j. Biodiversity genomics research can inform decision-making tools, natural capital accounting, and sustainable management of wildlife, invasive species, agriculture, aquaculture, fisheries and forests (target 14).

By its nature, genomics and its associated tools and resources have and will continue to play important roles in the environmental, economic, sociocultural, and governmental aspects of Canada's biodiversity objectives. The power of genomics in detecting, managing, and understanding species (animal, insect, microscopic or plant) will only become more evident and accessible as time goes on. In addition, genomics cuts across several other sectors of vital importance, including agriculture, forestry, and human health. Each of these fields impact biodiversity and in turn, biodiversity has important implications for how these sectors will evolve over time. As a unifying technology that impacts all these areas, we strongly encourage the federal government to explicitly incorporate genomics science and technologies into its strategy for protecting biodiversity.

[11] Project examples 5, 7, 17.

GENOME ALBERTA, ONTARIO GENOMICS

The role of genomics in fostering and supporting arctic biodiversity: implications for wildlife management, policy and indigenous food security

Wildlife genome information is extremely valuable for environmental decision-making, yet much remains unused for this purpose. This project draws together partners with expertise across disciplines, cultures and organizations, building upon team strengths in Arctic observation and monitoring, biology, conservation, cyber-cartography, data management, genomics, geography, Indigenous knowledge, the legal and policy sciences, and resource management. Together the team will co-develop a suite of genomics knowledge-mobilization tools that will support environmental decision-making. The focus is on supporting end-users with responsibilities for or interests in the areas of biodiversity monitoring, conservation, and the co-management of wildlife that are key to the social, cultural, physical and economic well-being of Northern Indigenous peoples.

The team will develop decision support tools building on an assessment of genomics data availability (can it be located, is it obtainable?) and accessibility (is it useable by non-experts and for decision-making and policy development?), and will consider the potential and the practical, economic, legal and ethical issues of mobilizing genomics for decision-making—including those pertaining to Indigenous perspectives and rights, and national and international frameworks and commitments that may influence policy at different levels of government. Project activities and outcomes will support conservation, natural resource management, and the sustainability of Arctic wildlife. Outcomes will also support Canada's efforts to protect Arctic species and ensure food security for Arctic People. The project can serve as a model for mobilizing genomics in different regions of Canada and in other nations.

Appendix A: Examples of projects, with reference numbers used in text

Ref #	Example	Type	Lead Centre
1	**Advancing Environmental Genomics in the Marine Environment**	Genome Canada-funded project	Genome Atlantic
2	**Conservation Genomics of the Endangered North Atlantic Right Whale**	Genome Canada-funded project	Genome Atlantic
3	**Sampling the Sea: eDNA Technology for Atlantic Canada's Blue Economy**	Video	Genome Atlantic
4	**Tracking invasive earthworms through eDNA: a proof of concept.**	Centre-funded project	Genome Atlantic
5	**BIOSCAN-Canada**	Genome Canada-funded project	Ontario Genomics
6	**Caribou Genomics: A National Non-Invasive Monitoring Approach for an Iconic Model Species-At-Risk**	Genome Canada-funded project	Ontario Genomics
7	**BEARWATCH: Monitoring Impacts of Arctic Climate Change using Polar Bears, Genomics and Traditional Ecological Knowledge**	Genome Canada-funded project	Ontario Genomics
8	**Centre for Biodiversity Genomics**	Organization that houses BIOSCAN & iBOL	Ontario Genomics
9	**The International Barcode of Life (iBOL)**	Genome Canada-funded project	Ontario Genomics
10	**Bison Integrated Genomics**	Genome Canada-funded project	Genome Prairie, Genome Alberta
11	**Enhancing the Value of Lentil Variation for Ecosystem Survival (EVOLVES)**	Genome Canada-funded project	Genome Prairie
12	**4DWheat: Diversity, Discovery, Design and Delivery**	Genome Canada-funded project	Genome Prairie, Ontario Genomics
13	**DivSeek Canada: Harnessing Genomics to Accelerate Crop Improvement in Canada**	Genome Canada-funded project	Genome British Columbia, Genome Prairie
14	**Uniting Indigenous knowledge and genomics for biodiversity**	News post	Genome Canada
15	**The Role of Genomics in Fostering and Supporting Arctic Biodiversity: Implications for Wildlife Management, Policy and Indigenous Food Security**	Genome Canada-funded project	Genome Alberta, Ontario Genomics
16	**Systems Biology and Molecular Ecology of Chronic Wasting Disease**	Genome Canada-funded project	Genome Alberta
17	**FISHES: Fostering Indigenous Small-scale fisheries for Health, Economy, and food Security**	Genome Canada-funded project	Génome Québec, Ontario Genomics

Ref #	Example	Type	Lead Centre
18	iTrackDNA: Non-Destructive Precision Genomics for Environmental Impact Tracking in a Global Climate Change Era	Genome Canada-funded project	Génome Québec, Genome British Columbia
19	Validation of the use of the EcoToxChip test system for regulatory decision-making	Genome Canada-funded project	Génome Québec
20	ATRAPP – Algal Blooms, Treatment, Risk Assessment, Prediction and Prevention Through Genomics	Genome Canada-funded project	Génome Québec
21	Use of Genomics to Manage and Protect Caribou Populations	Genome Canada-funded project	Génome Québec
22	Optimizing the eDNA Approach to Monitor Biodiversity in Canada's Marine Protected Areas	Genome Canada-funded project	Génome Québec
23	CoAdapTree: Healthy trees for future climates	Genome Canada-funded project	Genome Alberta, Genome British Columbia, Génome Québec
24	Extracting Signal from Noise: Big Biodiversity Analysis from High-Throughput Sequence Data	Genome Canada-funded project	Ontario Genomics
25	BioSurveillance of Alien Forest Enemies (BioSAFE)	Genome Canada-funded project	Genome British Columbia, Génome Québec
26	TRIA-FOR: Transformative risk assessment and forest resilience using genomic tools for the mountain pine beetle outbreak	Genome Canada-funded project	Genome Alberta, Ontario Genomics
27	Protecting Canada's forests against invasive alien species by next generation biosurveillance	Genome Canada-funded project	Genome British Columbia, Génome Québec
28	Using eDNA for Pacific Salmon Stock Assessments	Centre-funded project	Genome British Columbia
29	Constructing a complete mitogenome and nuclear rDNA reference library for BC's freshwater fish to enable defensible eDNA metabarcoding data for regulatory and industry purposes	Centre-funded project	Genome British Columbia
30	Understanding the algal microbiomes living on alpine snowfields in south-western B.C.	Centre-funded project	Genome British Columbia
31	The Canadian BioGenome Project	Genome Canada-funded project	Genome British Columbia
32	Developing an effective, accessible, and affordable SNP genotyping set for the advancement of noninvasive grizzly bear monitoring in British Columbia	Centre-funded project	Genome British Columbia
33	Landscape-level genetic diversity for resilient future forests	Centre-funded project	Genome British Columbia
34	KelpGen: Genomic Tools for Preserving and Restoring Canada's Kelp Forests	Centre-funded project	Genome British Columbia

Ref #	Example	Type	Lead Centre
35	Genomic differentiation among Northern Goshawks of coastal BC	Centre-funded project	Genome British Columbia
36	Genomics-Based Forest Health Diagnostics and Monitoring	Genome Canada-funded project	Genome British Columbia
37	Complex Gill Disease Initiative (CGDI)	Genome Canada-funded project	Genome British Columbia
38	Genomic Analysis of Wetland Sediment as a Tool for Avian Influenza Surveillance and Prevention	Centre-funded project	Genome British Columbia
39	Spruce-Up - Advanced spruce genomics for productive and resilient forests	Genome Canada-funded project	Genome British Columbia, Génome Québec
40	Building on past success: leveraging genomic data from cereal pathogens to develop a biovigilance strategy	Centre-funded project	Genome British Columbia
41	Vaccinomics for animal disease	Centre-funded project	Genome British Columbia
42	PeptAid - Antimicrobial Peptides to Replace Antibiotics in Farm Veterinary Practice	Genome Canada-funded project	Genome British Columbia
43	Genomics of viruses and microbial symbionts of spotted wing Drosophila	Centre-funded project	Genome British Columbia
44	Long-term impacts of biosolids on soil microbial communities during mine tailings reclamation	Centre-funded project	Genome British Columbia
45	Synthetic Biology Solutions for Detoxification of Oil Sands Process Affected Water (OSPW)	Centre-funded project	Genome British Columbia
46	Genomics Solutions for Ecosystem Reclamation Following Mine Closure	Centre-funded project	Genome British Columbia
47	Valorization of pulp & paper residues as slow-release nutrient amendments for enhanced bioremediation of mine influenced water and disturbed mine and forestry sites	Centre-funded project	Genome British Columbia

Appendix B: Addressing the Kunming-Montreal Global Biodiversity Framework (KMGBF)

HOW GENOMICS WILL CONTRIBUTE TO KMGBF GOALS AND TARGETS[12] [13]

Target 6: Impacts of alien species on biodiversity and ecosystems are eliminated, minimized, or reduced.

- Management of invasive alien species will be facilitated by using the proper tools, including standardized eDNA assays, which allow the precise and non-invasive detection of invasive or alien species from environmental samples. (**iTrackDNA**, **Project Optimize**)

Target 7: By 2030, the negative impact of pollution from all sources is reduced to levels that are not harmful to biodiversity and ecosystem function.

- The presence and nature of environmental toxins can be detected through genomics-based assays (**EcoToxChip**, **ATRAPP**).

Target 9: The management and use of wild species are sustainable.

- Genomic tools such as eDNA assays (**iTrackDNA**, **Project Optimize**) can help manage wild species by detecting their presence in non-invasive ways. Genomics is also important for the identification of distinct populations within a species (**caribou genomics**, **FISHES**) that might require different management practices. Diversity of non-visible species is also important, as microbes and insects are essential to the health of our soils and waters. Genomics-based assays are a simple and cost-effective way of detecting species in various samples without the risk of faulty visual identification.

Target 10: Areas under agriculture, aquaculture, fisheries, and forestry are managed sustainably.

- The sustainable management of aquaculture and fisheries requires a detailed understanding of the species concerned and source populations. Complete genomes and SNP-based assays (**FISHES**) are powerful tools that can be used to track genetic diversity within a species and through an understanding of species' adaptability, ensure the sustainability of aquaculture and fishery practise.
- Genomics also plays an important role in the economic components of biodiversity targets. Proper management of fisheries through a better understanding of fish biology and genomics can ensure the long-term viability of industries and careful management of stock populations. In addition, genomics can be used to trace the food in grocery stores and markets to ensure that the proper species are being sold and that efforts by fisheries to maintain critical populations are conducted properly.
- The proper management of our forests also benefits from genomics through the study of key species and how we can make them more resistant to existing and future changes to their environment (**CoAdapTree**).

[12] Appendix B was prepared by Danielle Bilodeau and Diana Iglesias of Génome Québec.
[13] **15/4. Kunming-Montreal Global Biodiversity Framework (cbd.int)**.

Target 13: Effective legal, policy, administrative, and capacity-building measures are taken to ensure equitable sharing of benefits that arise from the utilization of genetic resources and associated traditional knowledge.

- Genomic research projects funded by the Genomic Enterprise must include a plan for the sharing of data and findings resulting from their studies. In addition, all major projects must have a social research component to address barriers to uptake and implementation of tools and knowledge by the end users (all government levels, communities, etc.). As a specific example, the **caribou genomics** project worked closely with the Minister of the Environment, the Fight Against Climate Change, Wildlife and Parks to develop tools for use by the provincial government to ensure the proper protection and management of caribou populations.

Target 20: Strengthen capacity building and technical and scientific cooperation.

- One of the best ways to ensure technical cooperation is the use of standardized tools. Existing and emerging genomics-based technologies such as the eDNA detection kits developed by the **iTrackDNA** team require precise standards for sampling, the use of the tools, and the interpretation of the results. This allows users from across a province or across the country to compare results effectively and ensure decisions are made with the best available data.

Target 21: Ensure data, information and knowledge are accessible to decision makers, practitioners, and the public.

- Locally, Genome Centres are also examples of collaborative networks and community outreach efforts, which are in line with the socio-cultural aspects of Canada's biodiversity targets. As an example, Génome Québec's **Mission ADN-eau** has been teaching students about environmental DNA since 2019. This half-day event invites students to collect water samples which are then submitted for sequencing to identify the different species present in that environment. Later, the results are shared with the students, and they are encouraged to reflect on the consequences of their findings and consider why certain rivers might have more microorganisms than others, or why a specific species of fish isn't found in certain bodies of water. Importantly, what this data means for the health of the environments sampled is a key point of discussion with the participants.
- Genome Canada funded projects have also launched their own initiatives for involving various communities in their research, either by encouraging citizens to contribute samples (**ATRAPP**), or by empowering communities to conduct their own monitoring of biodiversity through training and access to resources (**iTrackDNA**).

Goal A: Connectivity and resilience of ecosystems, abundance of native wild species + halting of human induced extinction, maintenance of genetic diversity within populations of wild and domesticated species.

- Genomics allows for precise wild species management through non-invasive tracking of environmental DNA (**iTrackDNA**) and tracking of interspecies diversity with SNP chips (**caribou genomics project**).
- Invasive species can also be tracked through eDNA, and a better understanding of the genomics of these species can help identify tools and strategies to control them. In addition, invasive species have the ability to carry new pathogens with them and thereby introduce new threats to Canadian health. Genomics can help here as well by quickly identifying new pathogens, and by understanding their genome be one step closer to controlling their impact on human health.

Goal B: Biodiversity is sustainably used and managed, and ecosystem functions are valued, maintained, and enhanced, with those in decline being restored.

- In considering the role of genomics in biodiversity monitoring, management, and conservation, it will be important to consider an integrative approach. This involves the integration of Traditional Knowledge and ensuring that Indigenous communities are involved in every aspect of Canada's efforts in protecting and maintaining its biodiversity.
- Genomics provides tools to determine baseline values and changes in biodiversity between and within species currently in our environment (**FISHES, Project Optimize, caribou genomics**). By understanding this diversity, we can take appropriate measures to protect it, restore it, and measure the effect of these actions over time, not only for the different species involved, but also on the ecosystem functions, thereby facilitating quick decision-making.

Goal C: Benefits from utilization of genetic resources and traditional knowledge are shared fairly and equitably, while ensuring traditional knowledge associated with genetic resources is properly protected.

- Existing projects have and continue to demonstrate how the acquisition and use of genetic resources can be conducted in an equitable manner (**FISHES, iTrackDNA**)
- In all research fields, Génome Québec is increasingly asking research teams to consider Indigenous Peoples in the planning and execution of research objectives, as well as the dissemination of results. We have a lot to learn from Indigenous Peoples on respectful interactions with nature and it is critical that they be involved in every step of a national biodiversity strategy.

HIGHLIGHTED PROJECTS

FISHES[14] (2018–2025)

- **F**ostering **I**ndigenous **S**mall-scale fisheries for **H**ealth, **E**conomy, and food **S**ecurity.
- Using a combination of genomics and Traditional Ecological Knowledge, this project addresses critical challenges and opportunities related to food security and Commercial, Recreational, and Subsistence fisheries of northern Indigenous Peoples in Canada.
- The team is developing genomic resources for 6 species of fish important to northern communities and using this data to identify distinct populations and assess their vulnerability to future climate changes.
- FISHES supports the cogeneration of knowledge to foster the development and co-management of sustainable fisheries, increased food security, and enhanced social well-being.

iTrackDNA[15] (2021–2025)

- Applies innovative solutions on a large scale through 1) development and validation of genomics enabled tools; 2) eDNA field kit validation in collaboration with four remote First Nations; and 3) development of a socio-ecological framework to address policy, governance and economic research and recommendations on eDNA applications in Canada.
- Fills a critical gap in eDNA resource development by supporting national eDNA standard creation, and experimental evaluation of factors affecting eDNA and eRNA detection in various environmental conditions.

[14] **FISHES-project (ulaval.ca)**.
[15] **iTrackDNA**.

EcoToxChip[16] (2016–2023 and 2023–2026)

- During the LSARP-funded project, the team developed a PCR-based tool which uses a set of carefully selected genes in order to quickly and reliably screen chemicals and complex environmental samples.
- In subsequent GAPP funding, the project team is working with ECCC and aims to advance the existing EcoToxChip system to make it more accessible, while also being consistent and reliable for informing regulatory decisions.

ATRAPP[17] (2016–2022)

- **A**lgal blooms, **T**reatment, **R**isk **A**ssessment, **P**rediction and **P**revention through genomics
- During this LSARP, the team identified key biomarkers and established methods for the detection and quantification of 26 types of cyanotoxins. They also developed a model that can use chemical and genomic data to predict total toxin concentration and time until first day of toxicity.
- The team is now in discussions with the *Centre d'expertise en analyze environmental du Québec* and a private company to use identified biomarkers in the commercialization of a test for the detection of proliferating microbes in water.
- Findings from this project have led to policy recommendations which have been incorporated in the *Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec*'s new plan for sustainable agriculture.
- Through 2 citizen science initiatives[18,19], the team has assembled a large network of concerned citizens eager to contribute to research on issues related to freshwater ecosystems.

Use of Genomics to Manage and Protect Caribou Populations[20] (2018–2022)

- Through this GAPP, the researchers published a complete caribou genome using sequencing data from 150 individuals. 700 additional caribou samples were used to identify polymorphisms from distinct populations.
- Sequencing data was used to generate a SNP chip with over 63,000 sites and Québec's *Ministère de l'Environnement et de la Lutte contre les changements climatiques* has since used the chip to analyze over 2,000 samples as part of their mandate to protect and manage the endangered populations of the species.

Optimizing the eDNA approach to monitor biodiversity in Canada's Marine Protected Areas (Project Optimize)[21] (2021–2023)

- In this GAPP, researchers are working to optimize the monitoring of species in Canada's MPAs using eDNA metabarcoding.
- The team is generating an evidence-based decision support tool for use by Fisheries and Oceans Canada that will estimate the cost of eDNA biodiversity monitoring and assist in the selection of an optimal sampling design.

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[16] **Technology - EcoToxChip**.
[17] **ATRAPP**.
[18] **Adopte un lac - Faculté des arts et des sciences - Université de Montréal (umontreal.ca)**.
[19] **Dessine-moi un lac - Faculté des arts et des sciences - Université de Montréal (umontreal.ca)**.
[20] **Protéger les caribous grâce à l'ADN | Le Journal de Montréal (journaldemontreal.com)**.
[21] **PROJECT OPTIMIZE - Home (weebly.com)**.

CoAdapTree: Healthy Trees for Future Climates[22] (2016–2022)

- Through this LSARP, researchers have identified genes for climate adaptation and disease tolerance in Douglas-fir and lodgepole pine.
- Two CoAdapTree SNP arrays were developed for the same species that detect genes associated with climate adaptation, and disease, drought, or cold hardiness.

Mission AND-eau[23] (2019-present)

- Since 2019, Génome Québec has been working with teachers and students from local schools to collect environmental DNA from Québec's waterways. In the process, participants are educated on DNA, sequencing, and how individual species can be identified by trace amounts of material left behind in the environment.

Resources

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[22] **CoAdapTree | Tree Breeding | Project | UBC Forestry**.
[23] **Mission ADN eau - Accueil — Génome Québec**.

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