



## ARCHIVED - Annual Performance Report 2010-2011

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# Genomics R&D Initiative

ANNUAL PERFORMANCE REPORT 2010-11

*The Genomics R&D Initiative is a national program that coordinates federal science departments and agencies in the field of genomics to support key national interests in human health, agriculture and food safety, environment and natural resources management.*



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# Executive Summary



The \$19.9 million/yr **Genomics R&D Initiative (GRDI)** sustains federal genomics research in support of key federal public policy objectives in areas of national interest to strengthen innovation, promote competitiveness, and ensure sustainability for the benefit of all Canadians, under the mandates of the National Research Council of Canada (\$6M/yr), Agriculture and Agri-Food Canada (\$6M/yr), Health Canada and the Public Health Agency (\$4M/yr), Natural Resources Canada (\$2M/yr), Environment Canada (\$1M/yr) and Fisheries and Oceans Canada (\$0.9M/yr).

Since the implementation of GRDI in 1999, participating departments and agencies have increased their human resource capacity in federal laboratories as well as enhanced the tools, equipment, infrastructure and networks required to undertake genomics R&D and participate in broader, high-impact programs through extensive collaborations with Canadian and international organizations. Investments from the GRDI have allowed public sector scientists to explore promising research avenues towards Canada's economic goals and social wealth and have delivered tangible results that are already helping in many areas important to Canadians. Federal scientists excel in strategically selected areas of genomics research and the GRDI was assessed in its independent formative evaluation as well as its impact evaluation completed in 2010 as well-managed, effective and efficient. Phase IV of the GRDI ends in March 2011. In a climate of limited resources for government operations, the GRDI forms an integral component of the genomics research program of federal laboratories.

The GRDI has been funded for three-year cycles: Phase I (1999-02), Phase II (2002-05), Phase III (2005-08), and Phase IV (2008-11). Fiscal year 2010-11 was the third and last year of Phase IV programs. The overall GRDI program framework for Phase IV is presented in the following section, entitled **Phase IV GRDI Impact Areas**. Fiscal year 2010-11 was also a year of planning activities for Phase V of the GRDI.

This Annual Performance Report for 2010-11 follows the Results-based Management and Accountability Framework (RMAF) for the GRDI, which formalizes common measurement criteria according to requirements of the Treasury Board Secretariat. It presents the GRDI program profile and impact areas, its links to departmental objectives and program activity architecture, its relevance to the Federal S&T Strategy, and the research program plans and activities. It then reports on performance for 2010-11 in terms of management, collaborations (**Tables 3 and 4**), capacity building, research and development (summarized in **Annex 3** of Appendix A and illustrated by the summary statistics of outputs in **Annexes 2, 4 and 5** of Appendix A), and outreach.

# Acronyms

<b>AAFC</b>	Agriculture and Agri-Food Canada	<b>NRC</b>	National Research Council
<b>ADM</b>	Assistant Deputy Minister	<b>NRCan</b>	Natural Resources Canada
<b>CanSeq</b>	Canadian Canola Genome Sequencing Initiative	<b>OGD</b>	Other Government Departments
<b>CCGI</b>	Canadian Crop Genomics Initiative	<b>PCR</b>	Polymerase Chain Reaction
<b>cDNA</b>	complementary DNA	<b>PFC</b>	Perfluoroalkyl compounds
<b>CFIA</b>	Canadian Food Inspection Agency	<b>PHAC</b>	Public Health Agency of Canada
<b>CFS</b>	Canadian Forest Service	<b>qPCR</b>	Quantitative real time polymerase chain reaction
<b>DFO</b>	Fisheries and Oceans Canada	<b>R&amp;D</b>	Research and Development
<b>DGGE</b>	Denaturing Gradient Gel Electrophoresis	<b>RMAF</b>	Results-based Management and Accountability Framework
<b>DNA</b>	Deoxyribonucleic Acid	<b>RNA</b>	Ribonucleic Acid
<b>EC</b>	Environment Canada	<b>S&amp;T</b>	Science and Technology
<b>GHI</b>	Genomics and Health Initiative	<b>SNP</b>	Single Nucleotide Polymorphism
<b>GRDI</b>	Genomics R&D Initiative	<b>STAGE</b>	Strategic Technology Applications of Genomics in the Environment
<b>HC</b>	Health Canada	<b>STEC</b>	Shiga toxin-producing Escherichia coli
<b>HIV</b>	Human immunodeficiency virus	<b>US-EPA</b>	US Environmental Protection Agency
<b>HQP</b>	Highly qualified personnel	<b>US-FDA</b>	US Food and Drug Administration
<b>ISAV</b>	Infectious salmon anemia virus		
<b>LOI</b>	Letter of intent		
<b>mRNA</b>	Messenger RNA		
<b>mtDNA</b>	Mitochondrial DNA		
<b>NML</b>	National Microbiology Laboratory		



# Phase IV GRDI Impact Areas

*The strategic focus of GRDI research is to contribute solutions to issues of key importance to Canadians – protecting and improving human health, developing new treatments for chronic and infectious diseases, protecting the environment, and managing agricultural and natural resources in a way that is sustainable. Focusing on the specific role of federal government research, it supports evidence-based decision making, policy development, formulation of standards and regulations, and facilitates the development of Canadian commercial enterprises.*

## IMPROVED PUBLIC HEALTH AND WELLNESS

### PLANNED RESULTS

*Improve knowledge and understanding of human infectious and chronic diseases for public health-related applications including the development of improved or new diagnostic tools*

*Realize crop value improvements in cereals, canola and legumes related to seed development and metabolism (oil content, starch quality, anti-nutritional compounds)*

### IMPACT AREAS

Phase IV GRDI tackles research on issues such as developing new treatments for cancer, heart disease, and a vast range of other acute and chronic diseases; developing vaccines; and understanding how to limit the spread of diseases and potential pandemics. New drugs, nutraceuticals, improved crop yield and nutritional value, and functional foods are the result of genomics-based research towards successful health outcomes.

### PLANNED ACTIVITIES

#### *Infectious diseases*

- Understand the molecular basis of critical pathogenic and genetic diseases
- Conduct molecular epidemiology of infectious diseases

- Create point-of-care devices for the diagnosis of organisms causing hospital-acquired infections and food and water contamination
- Understand responses to hepatitis C and HIV antiviral treatments
- Clarify the role of vitamin D related to severe influenza infection in seniors
- Develop bacteriophages to prevent common bacterial infections
- Evaluate the role of bacterial pathogens in cystic fibrosis patients

#### *Chronic diseases*

- Identify and develop a broad range of targeted therapeutic agents to create the next generation of efficient cancer therapies
- Study interferon-induced hepatic injury
- Identify biomarkers for exposure to mutagenic carcinogens and inhaled contaminants, and effects in cancer, atherosclerosis and asthma development

#### *Food supply*

- Decipher the genes that control seed development, carbon partitioning, protein quality, oil quality, starch quality, and the accumulation of anti-nutritional compounds in cereals (wheat, corn), oilseeds (*Brassica*) and legumes (soybean) to improve their productivity and resilience
- Study nutraceutical compounds such as phytosterols, anthranides, and glucans for medical applications

## TOWARDS ENVIRONMENTAL SUSTAINABILITY

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### PLANNED RESULTS

*Realize crop value improvements in cereals, canola and legumes related to adaptation to environmental stresses (diseases, pests, drought, cold, and poor soil conditions)*

*Increase knowledge for forest generation and protection methods, and for addressing environmental impact considerations, through a focused effort on species and traits that are of economic importance to Canada*

*Develop and use genomics tools to generate increased understanding of population genetics and structure, as well as of behavioural, physiological and immunological responses to the environment, for the sustainable management of aquatic resources*

*Develop genomics applications to understand and remediate environmental contamination and to preserve biodiversity*

### IMPACT AREAS

Phase IV GRDI tackles research on issues towards environmental sustainability outcomes such as developing more productive and resistant crops for sustainable agriculture; controlling plant and animal pests and diseases in an environmentally sustainable manner; adapting crops, forests and fish species to respond to climate change related challenges; and protecting endangered species.

### PLANNED ACTIVITIES

#### *Agriculture*

- Improve the productivity and resilience of Canadian canola crops to meet increasing national and global demands for food and industrial applications (biofuels)
- Develop crops with increased resistance to diseases and insect pests
- Design strategies to engineer increased tolerance to heat, cold and frost in crops

#### *Forestry*

- Identify genetic markers for the selection of spruce trees with desired attributes of wood quality and adaptation
- Understand forest host-pathogen genetic interactions to improve sustainable pest control
- Develop and transfer molecular diagnostic tools for the detection and surveillance of forest diseases and pests and phytosanitary certification

#### *Fisheries and aquaculture*

- Develop conservation genomics for species of importance to Canada (Atlantic salmon, beluga whales, capelin, Dolly Varden chars)
- Study the migratory fitness of wild salmon
- Identify redfish species and stock structure
- Study salmon diseases (anemia virus, parasites, louse)

#### *Environment*

- Conduct molecular characterization of microbial communities in contaminated soil
- Investigate the toxic effects of environmental contaminants on aquatic microbial communities
- Develop conservation genomics of selected wildlife species (birds, mammals)
- Apply genetic markers to resolve species identification and population structure of aquatic invasive species
- Study emerging infectious diseases in native birds and amphibians

## EVIDENCE-BASED DECISION MAKING

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### PLANNED RESULT

*Support federal regulatory decisions under the mandates of participating departments and agencies*

### IMPACT AREAS

Phase IV GRDI research is developing: diagnostic tools for the detection, surveillance and management of food-borne and water-borne pathogens (salmonella, *Escherichia coli*), human, aquatic, animal and plant pests and diseases, including quarantine species; detailed characterization of new products (food, pharmaceuticals, medical devices, etc.) to allow their responsible introduction and ongoing monitoring; and forensic tools to monitor fish resources for the sustainable management of fishery openings and access to global markets. Many of the impact areas already described under the above sections also support evidence-based decision making.

### PLANNED ACTIVITIES

- Develop monitoring tools for the management of two important fisheries (beluga and salmon)
- Implement the use of genetic information for mixed-stock fishery management
- Understand population genetics and structure of economically important species to guide management decisions
- Develop diagnostic tools for the management of aquatic animal diseases, important for both the wild fisheries and the aquaculture industry
- Develop and use DNA profile for threatened Northern abalone as evidence to successfully prosecute poachers in court and facilitate out-of-court settlements
- Validate genomics-based procedures to ensure more accurate data for submission under the *Canadian Environmental Protection Act* New Substances Notifications Regulations
- Improve 'early warning' signals to industry regulators with DNA-based techniques used to link environmental exposure of specific substances to potential toxic effects

- Provide species identification for improved decision-making under the *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act*, and the *Convention on International Trade in Endangered Species of Wild Fauna and Flora*
- Evaluate gene expression changes in human cell lines following exposure to wireless telecommunication signals emitted by cellular phones
- Investigate molecular-level effects of environmental contaminants (priority substances and emerging contaminants) on wild species to improve environmental risk assessment/monitoring
- Detect the presence of genetically modified organisms in aquatic ecosystems
- Detect pathogenic micro-organisms in wastewater

## FORMULATION OF POLICIES, STANDARDS AND REGULATIONS

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### PLANNED RESULTS

*Support of key federal public policy objectives under the mandates of participating departments and agencies*

*Position the Canadian regulatory system for health to enable innovation while minimizing the risks to Canadians through a focused genomics R&D program aimed at strengthening research in priority areas such as genetic information, biotechnology products, human genomics and microbial genomics, related to human, animal and environmental health*

*Develop genome-science applications to support regulatory activities in key areas such as environmental risk assessment and management; enforcement and compliance; pollution detection, monitoring and prevention; conservation biology and wildlife genetics; technology forecasting and assessment; and the sustainable development and responsible use of bio-based products and industrial processes*



## IMPACT AREAS

Responsible commercial applications that generate wealth for Canadians are enabled by effective regulatory approaches. Phase IV GRDI generates knowledge to support the formulation of policies, standards and regulations related to the responsible introduction and ongoing monitoring of new products such as pharmaceuticals, medical devices, and food commodities; traceability (animals, plants, food, fish); environmental monitoring and remediation; food additives and labelling. Many of the impact areas already described under the above sections also support the formulation of policies, standards and regulations.

## PLANNED ACTIVITIES

- Develop a molecular risk assessment strategy for toxin-producing *E. Coli*
- Understand gene expression patterns linked to dietary fibre and “resistant carbohydrates” to shape a new Health Canada definition for dietary fibre
- Conduct molecular characterization of microbial communities in contaminated soil to validate a new national guidance document under the *Canadian Environmental Protection Act*
- Integrate systems biology approaches in HC regulatory toxicology assessments
- Develop methods for the evaluation of how effluents and chemicals affect aquatic microbial communities, in collaboration with the British Columbia Ministry of the Environment, to be included in risk assessment processes under the Georgia Basin Action Plan and the Chemical Management Plan

## SUPPORT FOR CANADIAN COMMERCIAL ENTERPRISES

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### PLANNED RESULT

*Develop commercially relevant advances in areas of genomics R&D related to human health (e.g. genetic testing, diagnostics, microbial genomics applications, treating and preventing human diseases such as cancer and cardiovascular disease, and pathogen detection)*

### IMPACT AREAS

Phase IV GRDI scientists collaborate with Canadian companies to support their R&D efforts for the generation of wealth to support Canada's economy.

### PLANNED ACTIVITIES

- Conclude a licensing agreement with a Canadian biotech company for the commercial development of antibodies developed by GRDI scientists for cancer treatment
- Collaborate with a commercial partner for the validation of *Salmonella* detection technology developed by GRDI scientists and commercialization to diagnostic laboratories
- Implement the *Canadian Canola Genome Sequencing Initiative* Collaborative Research Agreement between GRDI scientists, Genome Alberta and four industry partners (Cargill Limited, Dow AgroSciences Canada Inc., KWS SAAT Ag and RAPOOL-Ring GmbH) formalized in February 2009

# Genomics R&D Initiative (GRDI) – Program Profile

## Overview

Genomics is the science that studies DNA sequences and their functions in living organisms. The real potential for genomics to provide benefits lies in its power to enable the study of biological systems in their entirety. This provides the understanding of how genes and their products interact in a given environment and insights into how variation in genes impacts biological outcomes such as productivity, quality, and disease resistance.

Genomics has applications in all areas of life. It provides knowledge to support the development of products and processes to enhance the competitiveness of sectors that are key to the economic wealth of Canadian communities (health, agriculture, forestry, fisheries), to advance sustainable environmental technologies, and to improve the quality of life for Canadians now and in the future. Federal, provincial and municipal governments, as well as the private sector, are major consumers of knowledge and tools derived from these technologies.

The Government of Canada, recognizing its legitimate and necessary role in this area, has been a strong supporter of genomics research for over a decade and has funded federal research through the Genomics R&D Initiative (GRDI) since 1999.

The \$19.9 million/yr GRDI sustains federal genomics research in support of key federal public policy objectives in areas of national interest to strengthen innovation, promote competitiveness, and ensure sustainability for the benefit of all Canadians, under the mandates of the National Research Council of Canada (\$6M/yr), Agriculture and Agri-Food Canada (\$6M/yr), Health Canada and the Public Health Agency (\$4M/yr), Natural Resources Canada (\$2M/yr), Environment Canada (\$1M/yr) and Fisheries and Oceans Canada (\$0.9M/yr). The GRDI has been funded in three-year cycles as shown in Table 1. Phase IV of the GRDI ends in March 2011. In a climate of limited resources for government operations, the GRDI forms an integral component of the genomics research program of federal laboratories.

**Table 1: Funding Allocations (\$000)**

DEPARTMENT/AGENCY	PHASE I 1999-2002	PHASE II 2002-2005	PHASE III 2005-2008	PHASE IV 2008-2011
Agriculture and Agri-Food Canada	17,000	18,000	18,000	18,000
Environment Canada	3,000	3,000	3,000	3,000
Fisheries and Oceans Canada	2,500	2,700	2,700	2,700
Health Canada / Public Health Agency of Canada	10,000	12,000	12,000	12,000
National Research Council Canada	17,000	18,000	18,000	18,000
Natural Resources Canada	5,000	6,000	6,000	6,000
Medical Research Council <sup>1</sup>	500	-	-	-
<b>Total</b>	<b>55,000</b>	<b>59,700</b>	<b>59,700</b>	<b>59,700</b>

<sup>1</sup> Precursor to the Canadian Institutes of Health Research (CIHR) – one time allocation in fiscal year 1999-2000 to assist in the establishment and support of a Genome Canada Secretariat.

The strategic focus of GRDI research is to contribute solutions to issues of key importance to Canadians – protecting and improving human health, developing new treatments for chronic and infectious diseases, protecting the environment, and managing agricultural and natural resources in a way that is sustainable.

Focusing on the specific role of federal government research, it supports evidence-based decision making, policy development, formulation of standards and regulations, and facilitates the development of Canadian commercial enterprises.

Since the implementation of GRDI in 1999, participating departments and agencies have explored promising research avenues towards Canada's economic goals and social wealth and have delivered tangible results that are already helping in many areas important to Canadians.

To maximize the quality and relevance of research funded under the GRDI, each department uses a competitive program proposal and approval process including scientific peer reviews. Extensive research collaborations in Canada and internationally allow strong leverage of resources and expertise, and the pursuit of larger-scale multi-disciplinary discovery enterprises (as described in **Tables 2, 3 and 4**, and Management on page 13).

### **Governance**

An interdepartmental Assistant Deputy Minister (ADM) Coordinating Committee oversees the collective management and coordination of the federal GRDI. The Committee ensures that effective priority setting mechanisms are established within departments, and that government objectives and priorities are addressed. The Committee also ensures that common management principles are implemented and horizontal collaborations between organizations are pursued and undertaken. The committee includes members from each of the organizations receiving funding and guest representatives from Industry Canada and from Genome Canada. The Canadian Food Inspection Agency is also represented to plan for future phases of the GRDI.

An interdepartmental GRDI Working Group supports the work of the committee. The mandate of the working group is to provide recommendations and advice to the ADM Coordinating Committee regarding strategic priority setting and overall management of the GRDI. The working group also supports evaluation and reporting requirements related to the Initiative.

The National Research Council coordinates interdepartmental activities to manage the GRDI, including the development and implementation of the Results-based Management and Accountability Framework, and chairs both the Coordinating Committee and the Working Group.

### **Impact Evaluation**

An independent impact evaluation was completed for the GRDI in 2010. The main objective of this evaluation was to assess the performance and relevance of the Initiative according to the Treasury Board Policy on Evaluation with regard to the Initiative's targeted outcomes. The impact evaluation was contracted to an independent private consultant through an open competitive process, under guidance from the Interdepartmental Evaluation Working Group composed of two representatives from each of the participating departments and agencies, one with an evaluation function and one with a program function. This working group acted as the evaluation steering committee and provided feedback during the planning and implementation phases of the evaluation. The evaluation process was led by the Planning and Performance Management Directorate within the National Research Council's Strategy and Development Branch, who chaired the interdepartmental working group, administered the consultant's contracts, participated in the evaluation planning and completion, and recovered prorated costs from the participating departments using interdepartmental settlements.

The evaluation framework, the selection of methods and the associated level of effort were determined using a pilot risk-based approach developed by the National Research Council. The approach aimed to maximize the consultation of collaborators and users of R&D results who are external to the government as the 2006 evaluation focused more on stakeholders within the federal government. Overall, a total of 158 distinct individuals were consulted during the process, from Canadian governmental organizations (federal, provincial, municipal), universities, private companies, not-for-profit organizations and international organizations.

The evaluation findings confirm the continued relevance of the GRDI and recognize its considerable contributions to the development and application of new research methods, techniques, standard operating protocols and overall approaches. The findings show that the GRDI has been very successful in addressing and meeting the needs of its main stakeholders, both internal and external to participating departments and agencies. All lines of evidence provide strong support that the Initiative has positioned Canada, and GRDI researchers in particular,

as important contributors to genomics research at the national and international levels. They show that duplication of effort was avoided, and that processes were implemented to enhance the delivery and management of the Initiative. The findings also show that the GRDI has supported mandate-driven research that generated results that have not been achieved elsewhere, and answers specific needs that are not being fulfilled by the other genomics R&D being conducted in Canada. They show the strategic alignment of the GRDI with federal government and departmental objectives and priorities, an alignment particularly well suited to research that is conducted in support of regulation, or that addresses specific issues of importance within the Canadian context. Finally, the findings confirm the continued need for a horizontally managed initiative that supports genomics R&D within participating departments and agencies.

While the impact evaluation finds that the GRDI as a whole is relevant and effective, several recommendations have been presented to address areas for further improvement. In summary, these are:

- Develop opportunities to support specific interdepartmental genomics R&D projects with shared resources in high profile priority areas,

while continuing to build on the research capacity and expertise in their niche areas. As part of this effort, consider how to best distribute funding among participating departments in the shorter term (Phase V) as well as the longer term (future phases);

- Take steps to develop and implement a communication strategy aimed at increasing the visibility and profile of the Initiative, both within and outside of federal departments;
- Ensure that mechanisms are developed and implemented that further integrate users of R&D results in all stages of genomics R&D projects' life cycles to ensure proper alignment of scientific progress with targeted potential uses and expected impacts; and
- Continue to improve the tracking and reporting of performance and financial information, specifically to ensure that reliable information on total departmental investments and expenditures related to GRDI is available and understood.

The ADM Coordinating Committee and its supporting working group have developed a draft Management Response Action Plan to address the recommendations to ensure the long-term success of the GRDI.

## Results-based Management and Accountability Framework

A Results-based Management and Accountability Framework (RMAF) was developed for the GRDI in 2007 and guides the structure and content of this 2010-11 Annual Performance Report, which covers the last year of Phase IV funding.

The RMAF logic model reflects the overall objectives of the Initiative organized into four program areas: Management, Genomics R&D Capacity, Research and Development, and Outreach. The key performance indicators under each of these are:

- **Management** – Enhanced governance, coordination and partnerships.
- **Genomics R&D Capacity** – Increased number and training of Highly Qualified Personnel; advancements in state-of-the-art infrastructure; and increased participation in national and international genomics initiatives.

- **Research and Development** – Access to and sharing of technology and scientific knowledge; application of research results to develop innovative, new or improved methods, products, processes or technologies.
- **Outreach** – Increased awareness and understanding of genomics research results and applications.

An overview of the RMAF is provided in Appendix B, including the Logic Model and related tables of performance indicators.



## Links to Departmental Objectives and Program Activity Architecture

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Projects funded under the GRDI are focused on departmental mandates and government priorities, and are aligned with the strategies of their respective departments.

The Genomics and Health Initiative (GHI) is the largest horizontal R&D initiative of the National Research Council (NRC). Through its multi-disciplinary approach and research excellence NRC-GHI is supporting goal 2 of the NRC Strategy by making significant contributions to Canadian R&D priorities in health (chronic diseases and agri-food), in energy (biofuels), and for the environment (environmental technologies and bioproducts). GHI also contributes to goal 1 of the NRC Strategy by contributing to the competitiveness of industry by increasing the flow of technologies into high-impact areas of the Canadian economy. Support for these goals is achieved through the funding of research programs that are aligned with key industrial sectors and focused on the translation of scientific and technical knowledge into social and economic development. The initiative enables NRC to deliver on its mandate to translate S&T into value for Canada through partnerships with other government organizations, academia, and industry and to provide an integrated approach to S&T initiatives.

Agriculture and Agri-Food Canada (AAFC) provides information, research and technology, programs and policies to support Canada's agriculture, agri-food and agri-based product sectors. The GRDI directly supports all seven priorities of the department's Science and Innovation Strategic Action Plan: *Enhancing human health and wellness through food, nutrition and innovative products; Enhancing the quality of food and safety of the food supply; Enhancing the security and protection of the food supply; Enhancing economic benefits for all stakeholders; Enhancing environmental performance of the Canadian agricultural system; Enhancing the understanding of Canadian bioresources and protecting and conserving their genetic diversity; and Developing new opportunities for agriculture from bioresources.* Funding from the GRDI has enabled AAFC to strengthen the Canadian Crop Genomics Initiative (CCGI) through additional investments in plant genomics and in the formation of multi-disciplinary teams across Canada. Funding from the GRDI has been used to support the

advancement of technologies for 1) the development of sustainable food and feed supply from cereals, legumes, and oilseeds, and 2) the introduction of crop platforms for the generation of industrial and biofuel products. The CCGI catalyzes the formation of integrated S&T teams within AAFC and in partnership with universities, the private sector, non-governmental organizations and highly regarded international genomic institutes.

At Health Canada (HC), the GRDI constitutes a valuable investment to generate knowledge that is vital to the effective regulation of health related products. The Departmental Science Plan outlines genomics-related roles and responsibilities including providing leadership in policy and regulatory development, informing and engaging the public, ensuring an international position for Canada, and applying the benefits of genomics research to HC's mandate. Four themes guide research activities of the GRDI: generation, use and societal impacts of human genetic information; health and safety of biotechnology products; human genomic applications and impacts related to diagnostics and disease; and microbial genomic applications and impacts related to diagnostics and disease.

Within the Public Health Agency of Canada (PHAC), the projects funded by the GRDI also support the over-arching Strategic Outcome *Canada is able to promote health, reduce health inequalities, and prevent and mitigate disease and injury.* Research projects designed to develop new genomics-based methods to identify and evaluate the public health risk of pathogens directly align with several of the Agency's Program Activities. The development and application of leading-edge public health science and of tools to provide specialized laboratory testing and reference services that will contribute to better public health and improved responses to emerging health risks fall directly within the Program Activity of *Science and Technology for Public Health.* This Program Activity is further supported by projects directed at creating innovative genomic approaches to analyse risk and define best interventions to address the prevention of both infectious and chronic diseases. In addition, by the development and deployment of genomics-based pathogen surveillance technologies



within laboratories across Canada, the Agency is strengthening its surveillance and population risk assessment capacities. As a result, Canadians will benefit from enhanced disease prevention as well as faster, more effective responses to public health emergencies.

The Canadian Forest Service (CFS) of Natural Resources Canada (NRCan) promotes the sustainable development of Canada's forests and the competitiveness of the Canadian forest sector. The GRDI has developed the foundation for contributing to the NRCan Strategic Outcome *Economic Competitiveness* and to the Program Activity *Economic opportunities for natural resources*. It contributes to the CFS Program Sub-Activity: *Innovation Grows along the Entire Forest Value Chain – from Forest to Market*. It is positioned at the leading edge of unique technological platforms for tree and insect tissue culture, molecular diagnostics, population genetics, biological control products and functional genomics. Resulting from this foundation is a critical mass of data, infrastructure, and partnerships that is delivering important practical applications.

Environment Canada (EC) carries out its genomics research through the Strategic Technology Applications of Genomics in the Environment (STAGE) program. Under the aegis of this program, the department has focused funding on projects that support the departmental Science Plan. More specifically, the projects examine how genomics tools and methods can be used to support the department's policy, regulatory decision making, and

enforcement mandates. Projects address the following departmental priorities: *Risk Identification* (e.g. knowledge on the effects of environmental contaminants on the biodiversity and function of microbial communities); *Risk Assessment/Management* (e.g. more accurate data for submission and knowledge for assisting regulatory decisions); *Conservation Biology and Wildlife Management* (e.g. genetic markers for conservation and protection decisions); and *Improved Enforcement and Compliance* (e.g. sample identification and wildlife forensics). Genomics-derived tools are starting to be applied by end users (regulations, enforcement, conservation strategies etc.). However, not all areas of genomics are at the same stage of maturity and extensive validation of some genomics-based approaches and data are needed before being applied to the enforcement and regulatory mandates of the department.

The Biotechnology and Genomics Program of Fisheries and Oceans Canada (DFO) supports genomics research and development related to responsibilities for fishery management, monitoring fish habitat, sustaining fisheries and aquaculture, and protecting marine resources. Specific goals for genomics research and development within DFO research centres across Canada were developed for aquatic ecosystems and organisms in alignment with the department's mandate and strategic objectives. The Biotechnology and Genomics Program directly supports one of the three pillars of the Program Activity Architecture at DFO: *Economically Prosperous Maritime Sectors and Fisheries*.

## Relevance to the Federal S&T Strategy

The federal science policy framework is provided by the 2007 Federal Science and Technology (S&T) Strategy – *Mobilizing Science and Technology to Canada's Advantage* with its four core principles (promoting world-class excellence; focusing on priorities; encouraging partnerships; enhancing accountability) and its three policy commitments of creating Entrepreneurial, People, and Knowledge Advantages. Canada will achieve a Knowledge Advantage by focusing more of our energies and resources in the priority areas of environmental science and technologies; natural resources and energy; health and related life sciences and technologies; and information and communications technologies.

The S&T Strategy summarizes the role of research pursued inside federal laboratories as upholding regulatory, public policy, and operational mandates in important areas such as health care, food safety, and environmental protection, focusing activities in areas where government is best able to deliver results, and leveraging university and private-sector strengths.

The GRDI is highly relevant to the Federal S&T Strategy, given its strategic focus on supporting government evidence-based decision making, policy and regulatory development, and the development of Canadian commercial enterprises in the key areas of protecting and improving human health, developing

new treatments for chronic and infectious diseases, protecting the environment, and managing agricultural and natural resources in a way that is sustainable.

Programs funded under the GRDI are used to attract, train, and support highly skilled personnel including research scientists, visiting fellows, PhD students, technicians, and policy analysts, providing them access to world-class research infrastructure and networks.

Collaborative relationships are an important part of the GRDI to bring together the unique capabilities, interests, and resources of research partners and stakeholders. They are created among government-based science organizations, universities, industry, and other research institutes, both nationally and internationally, through the sharing of technology platforms and by collaborating in research areas that cut across traditional departmental sectors.

## Resources

All departments have levered the GRDI with allocations from their A-base resources and from successful collaborations. **Table 2** provides an overview of resources in 2010-11, showing that leveraged funds represented almost twice the GRDI investments.

Additional in kind leverage included the sharing of technology platforms, materials, and expertise with a variety of partners in research areas that cut across traditional departmental sectors.

**Table 2: GRDI and Leveraged Resources (\$000)**

DEPARTMENT/AGENCY	GRDI	LEVERAGED	GRDI + LEVERAGED
National Research Council Canada	6,000	17,962	23,962
Agriculture and Agri-Food Canada	6,000	7,997	13,997
Health Canada	1,635	1,000	2,635
Public Health Agency Canada	2,365	985	3,350
Natural Resources Canada	2,000	4,971	6,971
Environmental Canada	1,000	2,917	3,917
Fisheries and Oceans Canada	900	2,097	2,997
<b>Total</b>	<b>19,900</b>	<b>37,929</b>	<b>57,829</b>

## Research Program Plans and Activities

Projects of the GRDI support innovation and related regulations and policies in the key Canadian economic sectors of forestry, agriculture, fisheries, health, and life sciences. The overall GRDI program framework for Phase IV is presented in the section entitled **Phase IV GRDI Impact Areas**. Highlights of departmental plans and activities for 2010-11 (third and last year of Phase IV) are provided in the following sections and additional details may be found in **Annex 1** of Appendix A.

The NRC Genomics and Health Initiative supports five research programs focusing on canola productivity, treatment of brain tumours, near-patient diagnostic devices, cancer identification and treatment, and diagnostic tools for heart attack patients.

The AAFC Canadian Crop Genomics Initiative focuses on functional genomics of disease and insect resistance, tolerance to stress such as cold, platform technologies and enhanced quality attributes in cereals (wheat, oat and triticale), oilseeds (*Brassica* and *Arabidopsis*) and legumes (soybeans, pulses).

The GRDI activities at HC focus on identifying biochemical pathways perturbed by exposure to environmental hazards such as radiation from natural sources; consumer devices (e.g. cell phones); chemical carcinogens and endocrine disruptors with the objective of supporting HC's regulation of risks associated with environmental hazards. Also, genetic responses to different dietary fibres were identified and investigated to assist in policy decisions related to these nutritional components.

From the perspective of PHAC, genomics of humans and microbes has the potential to radically alter public health practices in the future, with new approaches for disease surveillance, disease prevention and improvement of health status that can effectively counterbalance health care funding pressures.

The GRDI at NRCan generates in depth scientific knowledge that is critical for the development of tailored solutions to specific forestry issues, such as evolving needs of Canada's forest industry and threats from insects, diseases and climate change, focusing on species and traits that are of economic importance. The following themes are supported: emerging environmental issues such as monitoring and response to pests and pathogens; relationships between genomes to study the genetic profiles and evolution of main pests, host defence mechanisms, host-pathogen interactions; and sustainable forestry and competitiveness towards improvements of tree growth, wood quality, and resistance to biotic and abiotic agents.

Environment Canada has strengthened its internal capacity in the area of the development and application of genomics-based approaches to address

environmental issues related to risk identification, risk assessment and management, conservation biology, wildlife management, and improved enforcement and compliance. Environment Canada is using this capacity to explore how best to use genomics to fulfill EC mandates to preserve and enhance the quality of the natural environment, including water, air, soil, flora and fauna; conserve Canada's renewable resources; and conserve and protect Canada's water resources. Environment Canada investigators participate in broad national and international efforts in genomics, and are acknowledged for their valuable expertise and scientific contributions.

Fisheries and Oceans Canada continues to focus research on three themes for genomics research and development: aquatic resource profiling, aquatic animal health, and aquatic ecosystem health. Following the department's competitive funding allocation process for Phase IV of the GRDI funding, researchers from all of the department's regions were actively engaged in conducting genomics research and development projects to advance the department's strategic objectives. Planning was initiated in all of the department's regions to identify high priority genomics projects for the future.

## Performance

This 2010-11 Annual Performance Report is presented using the performance indicator categories outlined in the GRDI Results-based Management and Accountability Framework, to outline progress on governance, coordination and science partnerships; research capacity; infrastructure; sharing of technology and scientific knowledge; public awareness of genomics; participation in national and international initiatives; and application of research results to develop innovative methods, products, processes or technologies.

### Management

Sound management is an important aspect of any government program. The GRDI departments and agencies have established practices to define priorities effectively, support departmental coordination, and select projects to specifically address the identified priorities.

At NRC, a call for proposals was completed in 2010-11 for a fifth phase of the GHI program. To ensure that the maximum possible benefit is derived from NRC

investments, GHI continues to employ a competitive project selection process that requires the submission of Letters of Intent (LOIs) and sending out full Project Proposals for external review of quality and relevance against pre-determined evaluation criteria. Of the nine LOIs that were developed into Full Proposals, three were approved by NRC Senior Executive Committee for implementation in 2011-12 (Surgical Simulation, Protein Therapeutics, and Next Generation Canola). Additionally, a small portion of funding was approved to continue work under a previous GHI-4 project (Biochips for Pathogen Detection) – with a focus on further developing a biosensor based on photonic wire technology.

At AAFC, Phase IV projects of the CCGI will be extended for an additional year of funding in 2011-12. A call for proposals for Phase V will be conducted in fall 2011. The proposals will undergo a peer review process and follow the same process used for A-base funded projects. The selected projects will begin in April 2012.

At NRCan, the competitive process for Phase V project selection began with a call for LOIs. Fifteen LOIs were received and reviewed by the CFS Genomics Management Committee for their alignment with NRCan genomics research priorities. Six LOIs were selected for the development of full proposals, which were reviewed by international peer reviewers and end users prior to the final project selection and funding allocations.

At DFO, a call for proposals was launched in 2010-11 in anticipation of renewal of the GRDI for a fifth phase. Thirty-three LOIs were submitted from DFO scientists from all six of the department's regions that conduct genomics research. The LOIs will be reviewed, with full proposals to be requested for the highest ranking LOIs. Factors to be considered in the evaluation will include consistency with the four themes of the DFO Aquatic Biotechnology & Genomics R&D Strategy and the ten priorities of the DFO Science 5-Year Research Agenda; clear objectives; appropriate collaboration; appropriate funding request; and adequate scientific contribution. Full proposals will then be further evaluated, and the highest priority projects approved in accordance with available funding.

At the interdepartmental level, the GRDI working group met on a monthly basis and the GRDI ADM Coordinating Committee met three times to plan future phases of the GRDI. At their meeting of June 28, 2010, the ADM Coordinating Committee decided that the GRDI should plan for a Phase V that would start transitioning into a redesigned model using existing resources. This transition would include the launch of pilot interdepartmental projects with shared resources, along two themes: 1) Improved ability to detect, diagnose and monitor organisms to ensure a sustainable supply of safe and healthy food and water for human consumption; and 2) Improved ability to detect, identify and understand Canadian biological diversity to prepare Canadian natural and managed resources and markets for global change. Under the shared priority envelope, the ADM Coordinating Committee also decided that a small investment would be made to provide initial support to common functions that would most benefit from interdepartmental integration (e.g. bioinformatics). Recognizing the importance of its regulatory role, the Canadian Food Inspection Agency (CFIA) would have the opportunity to participate in the shared priority projects.

In 2010-11, a new Performance Measurement Strategy was developed for the GRDI to ensure sound management of Phase V of the initiative and to

formalize the commitment of participating departments/agencies regarding common measurement and accountability requirements. This is consistent with the concept of modern comptrollership that focuses on results-based control systems.

## Collaborations

Collaborations are an important part of the GRDI as illustrated by **Tables 3** and **4**. **Table 3** shows GRDI interdepartmental collaborative activities during 2010-11 that are supported by GRDI funds in at least one of the collaborating departments/agencies.

**Table 3: Interdepartmental GRDI Collaborative Projects**

PARTNERS	RESEARCH AREA
AAFC – NRC	Beyond canola: genomics for the next generation of Canadian brassica crops
AAFC – NRC	Transcript profiling of S-methyl-cysteine biosynthesis in developing seeds of common bean
AAFC – NRC	Genetic mechanisms controlling the expression of seed maturation genes in soybean
AAFC – NRC	Harnessing information on disease resistance in pulses using genomics
AAFC – NRC	Associative expression and systems analysis of complex traits in canola
AAFC – HC	Functional genomics of soybean seed proteins-reducing exposure to allergens
EC – DFO	Identification of pathogenic larval parasites in fish
EC – AAFC	Assessing environmental risks of genetically modified organisms
EC – NRC	Microarray development – pyrosequencing facilities
EC – NRC	Pathogen detection and identification
EC – HC	DNA microarray studies on effects of perfluoroalkyl compounds (PFCs) on gene expression in birds
EC – HC	Nanotechnology research initiative
EC – DFO	Development and validation of a crustacean cDNA microarray and correlation of gene expression profiles
EC – DFO	Seabird population sampling
PHAC – HC	Risk assessment of non-O157 STEC <i>E. coli</i>
PHAC – CFIA PHAC – AAFC	High throughput genomic methods for molecular epidemiology of infectious diseases
PHAC – NRC	Bacteriophages as tools for the prevention of common bacterial infections
PHAC – NRC	microRNAs and infectious diseases

The following examples profile some of these collaborations. NRC has been successful in building a bench-top prototype device that uses biochip technology to dramatically shorten the time required for detecting and distinguishing bacterial pathogens in food products. This work is part of a collaborative project between the NRC and PHAC's National Microbiology Laboratory (NML) to develop a silicon chip that can rapidly detect and identify several strains (serotypes) of *E. coli* pathogens in a single measurement. If successful, this chip-based serotyping system will accelerate the difficult task of distinguishing those bacteria that cause serious infections from the many harmless strains. As part of the collaboration, NML provides samples of *E. coli* bacteria, as well as proprietary NML antibodies specific to these various strains. In turn, the NRC team is working to adapt the NML-provided assay protocol for use on the biosensor chips.

The development of rapid and improved detection methods leads to quicker and more accurate responses to disease outbreaks. This in turn reduces the number of Canadians that get sick, and ultimately reduces the financial burden on Canada's health care system. Even while the technology was still in development, NML and NRC were drawn together by a common vision of the technology's potential to address such needs. The formal collaboration arose from complementary expertise and requirements. The NRC team has particular strengths in the area of sensor design and fabrication, surface chemistry, antibody engineering and the development of the instrumentation and user interface. The NML team has

access to the required pathogens and secure facilities for pathogen handling, a well established suite of optimized strain-specific assays and protocols, and an extensive knowledge of work flow requirements for laboratories involved in pathogen detection. By working together collaboratively, all the necessary pieces were in place to demonstrate the technology for real-world use. Demonstration and deployment of the technology in a well-respected laboratory such as NML ensures that the technology has been designed for, and can address, real world issues in pathogen detection and identification. Beyond the current efforts, future work may include construction of a system that could be readily deployed at NML, or other similar laboratories, for use as a routine tool for pathogen identification.

A collaboration between DFO and NRC to characterize aquatic microbes around the Hibernia platform has involved extensive sample collection and experimentation by DFO and metagenomic analysis by the NRC, and technology transfer - specifically Denaturing Gradient Gel Electrophoresis - from the NRC to DFO's Aquatic Biotechnology Laboratory, including hands-on tutorials, equipment set-up, and protocol adjustments between the two laboratories.

**Table 4** shows the extent of collaborations with a wide variety of partners, for a total of more than 320 collaborations leveraging expertise and resources. Many projects involve non-governmental researchers from Canadian and international research organizations and universities.

**Table 4: Collaborations by Organization Type**

TYPE	NRC	AAFC	HC	PHAC	NRCAN	EC	DFO	TOTALS
Universities (Canadian and International)	46	19	14	25	11	40	9	<b>164</b>
Other International Research Organizations	13	5	4	9	4	16	0	<b>51</b>
Other Canadian Research Institutions	3	-	3	9	3	5	0	<b>23</b>
Private Sector	16	-	3	2	1	5	1	<b>28</b>
Other Public Sector Organizations	2	7	3	4	3	18	19	<b>56</b>
<b>Total</b>	<b>80</b>	<b>31</b>	<b>27</b>	<b>49</b>	<b>22</b>	<b>84</b>	<b>29</b>	<b>322</b>



The non-for-profit organization Genome Canada and its regional centres are supported by the Government of Canada (\$915M since 2000) to advance large-scale genomics research and enhance Canada's international position. This investment was leveraged to more than \$1.7 billion with co-funding from partners. Synergies developed between federal scientists active in the GRDI and academic scientists active under large-scale programs financed by Genome Canada continue to flourish.

Scientists funded by the GRDI continued to be key participants of the Canadian Canola Genome Sequencing Initiative (CanSeq) Collaborative Research Agreement between NRC, AAFC, Genome Alberta and industry partners (Cargill Limited, Dow AgroSciences Canada Inc., KWS SAAT Ag, Pioneer, Bayer, Euralis, Limagrain, Viterro and RAPOOL-Ring GmbH) that was formalized in February 2009. This large-scale collaboration ensured Canadian participation in a multi-national project that recently completed the genome sequence of the first Brassica species, *B. rapa* which will be released in 2011. This project will also develop a *B. napus* genome sequence and identify genome wide nucleotide variation in *B. napus*. *Brassica rapa* and *B. napus* are the canola species grown in Canada and the genome sequence will also help in improving cruciferous vegetables that belong to the genus *Brassica*.

Scientists funded by the GRDI from NRC and AAFC collaborated with European scientists at the John Innes Centre in the UK and at two German institutes (University of Giessen and the Max Planck in Cologne) on a genomics project: "Associative expression and systems analysis of complex traits in oilseed rape/canola (ASSYST)" that utilises high-throughput expression analysis to identify key factors controlling oil and fibre accumulation in canola seed.

Scientists at AAFC and HC collaborated on a project to identify the major allergens affecting North American patients suffering from soy allergy. This interdisciplinary network of scientists has enabled the development of tools to characterize and quantify allergenic proteins in seeds, an information that is crucial for the development of allergen-free soy-based food.

The NRC Canadian Forest Service (CFS) is a strong collaborator in the Genome Canada/Genome Quebec project *Arborea II*, which identifies genes linked to the natural variability of growth and wood properties in white spruce, a species of key economic importance. The research is being led by researchers at Université Laval and 30% of the project team members are from the CFS. The CFS collaborated with the Canadian Space Agency, NASA, *Arborea* and several other organizations to carry out a study on differential gene expression between trees submitted to gravity and those grown in the absence of gravity. Finally, the CFS is also collaborating in a Genome Canada/Genome BC/Genome Alberta project on mountain pine beetle system genomics.

Scientists from HC collaborate nationally and internationally with scientists and regulators to develop improved biomarkers and regulatory approaches for the risk assessment of chemical substances and consumer products.

Scientists from PHAC collaborate widely with academic partners at a variety of Canadian and international universities. Studies of food-borne pathogens have been conducted in partnership with scientists at HC, CFIA and AAFC. Researchers at the NRC have assisted in studies of the role of microRNAs in viral infections, and in the evaluation of bacteriophages as tools for the prevention of bacterial infections.

Funding from GRDI has fostered continued collaboration between EC scientists and the US-EPA on microbial source tracking research. The EC laboratory in Burlington and US-EPA Cincinnati laboratories have shared resources and expertise, and will continue to do so in the future to address common microbial water quality research needs of the two agencies. In particular, the two countries will need to collaborate to address transboundary issues related to water quality in the Great Lakes area where Canada and the United States share important source waters. Provincial and municipal agencies are also interested in GRDI research. For example, results can provide guidance to cities such as Toronto for decisions on options (e.g. bird control vs. wastewater upgrades) related to the management of their beaches. There is also a sense of urgency related to the implementation of Ontario's new source water protection regime stemming from

the Walkerton outbreak in 2000. Federal, provincial, and municipal partners on the Lake Ontario Collaborative Study to Protect Drinking Water are increasingly seeking research support from Environment Canada related to waterborne pathogen and microbial source tracking, to better understand the potential for waterborne pathogen threats at offshore drinking water intakes in Lake Ontario.

### Genomics R&D Capacity

In 2010-11, the GRDI supported the work of 595 scientific and technical staff, 66 post-doctoral fellows, 153 students (PhD, MSc, BSc, and Co-op), 1 visiting scientist, and 4 administrative officers, for a total of 819 active research and technical personnel. **Annex 2** of Appendix A provides additional detail presented by department.

Departments continued to invest in core infrastructure facilities for DNA sequencing, proteomics and microarrays. Funding was also allocated towards the purchase, maintenance and upgrading of laboratory equipment such as real-time PCR equipment, spectrometers, electrophoresis and hybridization stations.

For example, as part of NRC's efforts to enhance the development of protein-based cancer therapeutics, the NRC Biotechnology Research Institute acquired an ECISz® cell monitoring system through an investment of \$22,000 from the GHI-4 Cancer project. This system provides the team with automated, label-free and non-invasive monitoring of cell behaviour (motility, migration, morphology, or cell death) in real time. This acquisition enables the Cancer project team to monitor in real time the effect of a particular experimental treatment on the behaviour of a cancer cell. With the ECISz® system in place, the experimental work can be completed faster and more accurately, and can also be expanded to higher throughput, if required. This enables the team to assess their therapeutic candidates more efficiently.

### Research and Development

Research and Development is the central component of this Initiative, together with activities surrounding the conduct of R&D that are critical to ensuring relevance and impact, such as the transfer of knowledge, techniques and products to research partners and end-users, and the dissemination of research results. As part of the 2010-11 Report on Plans and Priorities, the participating departments established a collective set of planned results to:

- Develop commercially relevant advances in areas of genomics R&D related to human health (e.g. genetic testing, diagnostics, microbial genomic applications, treating and preventing human diseases such as cancer and cardiovascular disease, and pathogen detection);
- Realize crop value improvements in cereals, soybean and canola through improvements in areas related to adaptation to biotic and abiotic stresses (e.g. resistance to disease, tolerance to cold), as well as seed development and metabolism (e.g. industrial applications, health and nutrition benefits and enhanced end-use quality);
- Implement the sustainable management of aquatic resources through the use of genomics tools to: manage fishery openings; generate increased understanding of population genetics and structure; further understanding of behavioural, physiological and immunological responses to the environment; and through the management of aquatic animal diseases;
- Position the Canadian regulatory system for health to enable innovation while minimizing the risks to Canadians through a focused genomics R&D program aimed at strengthening research in priority areas such as genetic information, biotechnology products, human genomics and microbial genomics, related to human, animal and environmental health;
- Improve knowledge and understanding of human infectious and chronic diseases for public health-related applications including the development of improved or new diagnostic tools;

- Increase knowledge to support forest generation and protection, and to address environmental impact considerations, through a focused genomics R&D effort on species and traits that are of economic importance to Canada; and
- Develop genome-science applications to support regulatory and enforcement activities in key areas such as environmental risk assessment and management; enforcement and compliance; pollution detection, monitoring and prevention; conservation biology and wildlife genetics; technology forecasting and assessment; and the responsible and sustainable development and use of bio-based products and industrial processes.

The **Phase IV GRDI Impact Areas** section provides the strategic directions and high-impact research areas selected for 2008-11. A detailed account of the results achieved in 2010-11 against planned results as listed in the 2010-11 Report on Plans and Priorities is provided in **Annex 3**.

An important goal of the GRDI is to ensure that federal research scientists remain credible as part of the world's major scientific players in the rapidly evolving field of genomics. This is achieved through scientific publications and presentations at national and international conferences and workshops, and participation in committees, boards and networks. The following enumerates direct R&D outputs for 2010-11, while **Annex 4** of Appendix A provides additional detail broken down by department/agency:

- 198 publications in refereed journals;
- 79 publications in conference proceedings;
- 124 invited presentations;
- 13 technical reports;
- 26 other publications including books and book chapters;
- 114 presentations and posters at national and international conferences;
- 14 disclosures filed;
- 4 licenses issued;
- 10 patent applications;
- 8 patents issued;
- 11 material transfer agreements;
- 107 collaborative agreements;
- 5 genomics-related databases developed and launched;
- 16 bioinformatics programs or tools developed; and
- numerous genomic database deposits.

### Outreach

Direct and indirect public communications are an important aspect of the GRDI. External web sites and project wikis were developed; interviews to the media and press releases were given; community presentations, demonstration tours, citizen engagement events, and workshops involving external stakeholders and end-users were organized; public presentations and lectures in graduate seminar courses were given; brochures and factsheets were written; and GRDI scientists participated in science fairs and student mentorships. Additional information detailing department/agency activities is provided in **Annex 5** of Appendix A.

# Appendix A

## Supplemental Performance Details

### Annex 1 – GRDI Funded Projects by Department

#### National Research Council Canada

##### ***Biochips for the Understanding and Diagnosis of Human Disease***

This project aims to develop new tools for understanding the molecular processes underlying critical pathogenic and genetic diseases. The goal is to create small and efficient point-of-care diagnostic devices integrated onto a single silicone chip (biochip) with the capacity to rapidly detect specific pathogenic markers. In particular, this device will focus on diagnosing infectious agents responsible for hospital-acquired infections and threats to food and water safety.

##### ***Biorenewable Oil for Food and Fuel***

The goal of this project is to apply genomics-based approaches to improve the productivity, yield, oil content and resilience of Canadian canola crops in order to meet increasing national and global demands for this vital crop for both food (oil for cooking) and industrial / non-food applications (biofuels).

##### ***Identification of Proteins Targeting the Tumour Microenvironment for Therapeutic Applications***

The objective of this project is to tackle the complex treatment of cancer by identifying and developing a broad range of targeted therapeutics agents that can be used to create the next generation of promising and more efficient cancer therapies.

Under its GHI program, NRC also invests in health-related projects that do not have an explicit genomics component. These projects include:

##### **Heart Disease: Better Tools for Better Treatment:**

The objective of this project is to bring closer to clinical practice, a number of innovations for better diagnostic and imaging tools that can be employed in the management of heart disease.

#### Patient-Specific Virtual Reality Simulation

**Systems for Surgical Oncology:** The objective of this project is to develop a virtual-reality based rehearsal (training and planning) system, integrated with Magnetic Resonance Imagery, for patient-specific surgical oncology.

#### Agriculture and Agri-Food Canada

##### ***Biotic Stress***

Research in this area is ongoing to develop germ-plasm and varieties with resistance to economically important diseases and insect pests. Molecular biologists and entomologists are examining and developing a molecular basis for both antibiotic and antixenotic approaches to insect and pathogen resistance.

##### ***Abiotic Stress***

Parallel gene discovery programs in different systems are pursued to uncover novel and complementary avenues to engineering increased cold tolerance and increased frost resistance. Cold and heat tolerance and freezing resistance are important characteristics for almost all crops and are of crucial strategic importance to Canada as they have a significant bearing on yield potential and stability.

##### ***Quality attributes in cereals (wheat, oat, triticale), oilseeds (Brassica/Arabidopsis) and legumes (soybeans, pulses)***

Research in this area focuses on important aspects of seed quality and aims to decipher the genes that control seed development, carbon partitioning, protein quality, oil quality, starch quality, and the accumulation of anti-nutritional compounds. Compounds of nutraceutical interest under study include phytosterols, anthramides and glucans.

## Health Canada

### ***Development and validation of toxicogenomic tools, and integrated systems biology approaches in regulatory toxicology***

The objective of this research is to use systems biology approaches to determine the modes of action of specific toxicants and identify new biomarkers of exposure and effect. The results are being used to develop a framework for the integration of toxicogenomics into regulatory risk assessment.

### ***Environmental health applications of toxicogenomics and proteomics. Identification of exposure and effect biomarkers for mutagenic carcinogens in complex environmental matrices***

This research aims at identifying candidate biomarkers for exposure to complex mixtures and related adverse health outcomes.

### ***Molecular genomics applied to radiation risk assessment***

The objective of this research is to strengthen the scientific understanding of molecular processes involved in the interaction between various forms of radiation (including alpha-particles, UV light and radiofrequency fields) and biological tissues, to inform policy decisions related to radiation protection.

### ***Colon epithelial cell genetic responses to dietary fibre***

This research studies colon epithelial gene expression as a means of determining the relationship between a material's fermentability and the quality and safety of the source of fermentable material.

## Public Health Agency of Canada

- Host genomics of hepatitis C antiviral treatment response
- A molecular risk assessment strategy for non-O157 Shiga toxin-producing *Escherichia coli*
- Development of high-throughput comparative genomic methods for studying the molecular epidemiology of infectious diseases
- Identification and characterization of virus – host cell protein-protein interactions

- Influence of genetic variability in innate immunity pathways and micronutrient status on infectious disease outcomes with specific focus on severe influenza infection
- Bacteriophages and prevention of common bacterial infections
- MicroRNAs and infectious disease: a novel regulatory mechanism in host-pathogen interaction
- The application of multiplexed, parallel, high throughput, real-time PCR based pathogen detection system for HIV drug resistance testing
- Genetic variability and virulence studies in emerging antimicrobial resistant organisms
- Genomic analysis of “novel” chronic bacterial pathogens in cystic fibrosis patients
- Pyrosequencing and assembly of viral quasispecies

## Natural Resources Canada

### ***Genomics/proteomics for identifying commercially desirable tree genes***

This area of work aims at developing methods, tools and databases for the discovery of trees possessing commercially desirable attributes and for the conservation of genetic resources. Candidate genes for wood quality, growth and disease resistance are characterized and transferred to tree breeders and the scientific community. Research projects include:

- Discovery of genes controlling wood and fibre traits in white and black spruces and development of genetic markers for the selection of trees with desired attributes
- Functional genomics in spruce
- Genome scan to reveal gene islands underlying productivity and adaptation in spruce
- Isolation and identification of defense genes, and molecular markers associated with disease resistance of *Pinus monticola* to blister rust fungus
- Understanding tree defense response through genomics



### ***Understanding host-pathogen genetic interactions to improve sustainability and productivity***

This area of work aims at strengthening basic knowledge of forest pests and their pathogens. Genomics is used to understand pathogen modes of action, host specificity, host-pathogen interactions, ecology, and impact on host populations. The knowledge advances the search for new active ingredients and target sites for the next generation of biopesticides and new and improved biocontrol agents. Innovative molecular technologies for pest diagnostics and identification is also pursued and transferred to end-users in Canada and internationally for surveillance of diseases and pests, and phytosanitary certification. Research projects include:

- Proteomics regulation of virus/larva interactions
- Molecular screening for pathogens of indigenous and introduced coleopteran forest pests
- Comparative genomics of forest defoliators: from DNA to mitigation
- Genomics of fungal tree pathogens
- Emerald ash borer sensory genomics: mining for odorant receptors mediating host-finding and mate-finding
- Douglas-fir resistance to root disease and other stress agents

### **Environment Canada**

- Aquatic toxicogenomics of emerging substances: nanotechnology, biotechnology and urban effluents
- Development and validation of a crustacean DNA microarray and correlation of gene expression profiles with traditional toxicological end-points for contaminant exposure
- Validation of genomics tools for the prediction of environmental effects: response of fish to contaminated sediments
- Effects of contaminants on aquatic microbial diversity as indicated by expression profiling and proteomic analysis
- Identification of pathogenic larval parasites in fish and amphibians through barcoding
- Towards metagenomic characterization of microbial water quality in Canadian aquatic ecosystems

- Application of aquatic toxicogenomic tools for risk assessment of aquatic contaminant impacts on early life stage of fish and amphibians: an Okanagan lake case study
- Development and application of genomics techniques in assessing environmental risks of genetically modified organisms and microbial strains on the Domestic Substances List
- Conservation and genetic characterization of the western chorus frog (*Pseudacris triseriata*)
- Strategies for Ontario Canada Goose population harvest discrimination
- Molecular ecology and evolution of *Pasteurella multocida* strains isolated from large-scale avian cholera outbreaks across Canada
- Assessment and improvement of DNA microarray for the detection of pathogens and microorganisms in the environment
- Using gene expression analyses and the amphibian toxicity test system to evaluate genotoxicity of high-priority pesticides and other contaminants on aquatic wildlife
- Avian toxicogenomics – new tools for hazard assessment programs
- Characterization and sequencing of avian influenza viruses from birds in Newfoundland
- Establishing molecular assessment techniques for emerging infectious diseases in native amphibians; establishing PCR techniques for disease incidence and distribution assessments
- Development of non-invasive DNA genotyping of fecal samples from aquatic mustelids for application to contaminated site assessment
- Genetic structuring in seabird populations and the implication for the conservation of seabirds that are taken incidentally in British Columbia fisheries

### **Fisheries and Oceans Canada**

#### ***Genome-based monitoring to help in the management of two important fisheries***

- Using genetics to improve conservation of beluga whales (*Delphinapterus leucas*) in the western Canadian Arctic
- Genomics of migratory fitness in wild salmon

***Increased understanding of population genetic and structure of important economic fisheries***

- Conservation genomics of Atlantic salmon in Newfoundland and Labrador: assessment of genetic differences between wild and aquaculture strains and analyses of genetic structuring for the identification of important within-species biodiversity
- Discriminating capelin populations in the northwest Atlantic
- Redfish (*Sebastes sp.*) species identification and stock structure based on genetic analysis of archived otoliths
- Dolly Varden char population structure and genetic diversity in the western Arctic
- Investments in the Aquatic Biotechnology Service Lab at the Bedford Institute of Oceanography

***Increase understanding of the behavioural, physiological and immunological responses to the environment***

- Microbial characterization of produced water and its influence on the microbial community in the marine environment around the Hibernia production platform
- Application of genetic markers to resolve species identification and population structure of aquatic invasive species

***Management of aquatic animal diseases, important for both the wild fisheries and the aquaculture industry***

- Immune function of salmon and disease resistance against infectious salmon anemia virus (ISAV) - phase 2
- The effects of wild and captive rearing environments, and associated parasite and pathogen regimes, on the diversity and nature of genetic variation in Atlantic salmon
- Host parasite interactions: a functional genomics approach to characterising salmonid responses to the salmon louse

# Appendix A

## Supplemental Performance Details

Annex 2 – Highly Qualified Personnel (HQP) by Department, expressed in terms of number of persons involved in the GRDI

### National Research Council Canada

179 research and technical personnel were supported under the initiative:

- 49 research officers
- 72 technical officers
- 33 research associates
- 21 students
- 4 administrative officers

### Agriculture and Agri-Food Canada

188 research and technical personnel were supported under the initiative:

- 64 research scientists
- 86 technical positions
- 24 postdoctoral fellows
- 14 university students (graduates)

### Health Canada

42 research and technical personnel were supported under the initiative:

- 13 principal investigators
- 16 research professionals
- 1 technical position
- 6 postdoctoral fellows
- 6 university students (3 PhD, 3 MSc)

### Public Health Agency of Canada

100 research and technical personnel were supported under the initiative:

- 30 principal investigators
- 17 research professionals
- 28 technical positions
- 4 postdoctoral fellows
- 21 university students

### Natural Resources Canada

107 research and technical personnel were supported under the initiative:

- 19 research scientists
- 40 biologists/technicians
- 23 postdoctoral fellows
- 1 visiting scientist
- 24 university students (16 MSc and PhD, 8 undergraduates)

### Environment Canada

156 research and technical personnel were supported under the initiative:

- 30 research scientists
- 21 research professionals
- 29 research technicians
- 9 chemists
- 4 postdoctoral fellows
- 63 students (13 PhD, 26 MSc, 24 undergraduates)

### Fisheries and Oceans Canada

47 research and technical personnel were supported under the initiative:

- 18 research scientists
- 20 technical staff
- 5 postdoctoral fellows
- 4 students

# Appendix A

## Supplemental Performance Details

### Annex 3 – Planned Results versus Achieved Results (2010-11)

#### Planned Result 1

*Develop commercially relevant advances in areas of genomics R&D related to human health (e.g. genetic testing, diagnostics, microbial genomic applications, treating and preventing human diseases such as cancer and cardiovascular disease, and pathogen detection)*

#### Achieved Result 1

A targeted cancer therapy based on tumour-specific antibodies developed in the NRC Cancer project has received US-FDA approval to enter Phase I clinical trials in patients with advanced lung cancer in the US. The antibody developed by NRC will be coupled to a drug developed by NRC's industrial partner, Helix Biopharma that uses the body's natural processes to create an alkaline environment toxic to the cancer cells. The NRC antibody will deliver this drug payload to specific, targeted cancer cells to alter the tumour environment and kill the cancer cells. It is anticipated that this approach will result in greater effectiveness and in fewer side effects compared to the currently used broad-spectrum cancer chemotherapies. Helix Biopharma anticipates that approval will soon be granted for a larger European clinical trial that will further assess the safety and efficacy of the drug both by itself and in combination with other chemotherapies.

A fundamental principle of medicine is: "first do no harm." Yet for doctors who treat breast cancer, this is easier said than done. Every year, almost 22,000 Canadian women are diagnosed with breast cancer — their treatment usually involves surgery to remove a tumour and then chemotherapy to reduce the risk of cancer returning. But studies show that for most patients with early stage breast cancer, chemotherapy following surgery is totally unnecessary and therefore does more harm than good. Currently, most doctors assess a patient's prognosis using their age and "tumour grade," but this approach doesn't work very well. Now, NRC researchers have developed a tool to determine which breast cancer patients have little risk

of their disease recurring. The tool — an algorithm that identifies "gene expression signatures" or biomarkers that can predict low risk tumours with 87–100 percent accuracy in different groups of patients — has the potential to virtually eliminate unnecessary chemotherapy.

A bench-top prototype incorporating biochip technology has been developed and built by NRC that dramatically shortens the time required for detecting and distinguishing between closely related bacterial strains related to human health. This tool will be further refined into a compact, storable unit that will shorten and simplify the protocol for pathogen detection in food products. As part of this effort the NRC team has successfully demonstrated the detection and identification of pathogenic *E. coli* bacteria using a photonic waveguide sensor platform. The sensor chips were prepared by attaching strain specific antibodies to the sensor waveguide surface. When exposed to liquids containing *E. coli* O157 target bacteria, the sensor produced a strong binding response caused by the capture of the target bacteria at the activated surface. The pathogen signal was then amplified and confirmed using a secondary antibody step, in which the sensor is exposed to a liquid containing free floating strain specific antibodies. The amplification step confirmed the identity of the *E. coli* O157 strain, since the secondary antibodies only bind to the trapped target bacteria. Using this system, the team was able to successfully distinguish between two closely related *E. coli* strains, O157 and O111, when these were both present in a complex solution.

#### Planned Result 2

*Realize crop value improvements in cereals, legumes and canola through improvements in areas related to adaptation to biotic and abiotic stresses (e.g. resistance to disease, tolerance to cold), as well as seed development and metabolism (e.g. industrial applications, health and nutrition benefits and enhanced end-use quality)*

## Achieved Result 2

Several genes of interest were identified in 2010-11: 1) A gene that regulates the isoflavonoid producing pathway in soybean was identified. This knowledge will enable the production of soybean varieties with enhanced isoflavonoid levels. Isoflavonoids are known to provide human health benefits; 2) Genes involved in the establishment of beneficial root symbiosis in legumes were identified and characterized. This research will assist in harnessing biological nitrogen fixation which is essential for sustainable crop production systems; 3) A gene that confers resistance to white rust in canola was discovered and characterized, thus enabling genetic screening for enhanced durable resistance to white rust; and 4) Specific genes responsible for susceptibility or resistance to Fusarium toxins were identified in yeast. This will enable the understanding of similar genes in wheat and corn to enhance their resistance to Fusarium diseases. Wheat lines with increased genetic disease resistance were produced. These lines will be tested in the field in 2011 to observe their resistance to Fusarium Head Blight, a major disease of wheat.

A specific protein was identified in Soybean Mosaic Virus as being responsible for virulence. This soybean protein is a candidate for designing new strategies against Soybean Mosaic Virus infection.

The first complete database of proteins expressed by the haustorium (the specific tissue of the wheat leaf rust fungus responsible for crop losses) was produced. This database will be critical in identifying proteins responsible for infection and disease in wheat and developing new resistance strategies.

Significant progress was made to understand how some viruses infect insect pests (such as the canola pest Bertha Army Worm), an important step to explore the use of natural viruses as biopesticides.

New gene expression mechanisms related to seed maturation were discovered. Seed maturation is important for the development of higher yielding crop varieties with improved quality characteristics.

Diagnostic markers were produced for the identification of soybean genotypes that have a reduced ability to accumulate cadmium in the seed. High cadmium is a potential health risk and also a barrier to export markets where strict limits on cadmium content are in

place. Diagnostic markers were also produced for a pathogen of lentil. These markers can be used to screen seed samples to prove the absence of the pathogen prior to export, thus reducing export trade barriers. These markers also distinguish between isolates of the pathogen of different aggressiveness. A Grade 8 student, Rui Song, participated in this work and was selected as part of Team Canada to represent the country at the Intel International Science and Engineering Fair, the world's largest science fair, in Los Angeles, May 2011.

Canola (*Brassica napus*) and the related *B. carinata* are potential candidates as biofuel crops. The Canadian agricultural biotechnology company Agrisoma has formed a strategic partnership with NRC and will test in *B. carinata* five specific genes identified by NRC researchers and shown to increase seed oil content and crop yield, to develop a value added crop for bio-diesel production. The genes were sent to Agrisoma by NRC scientists under Material Transfer Agreements for further industrial development.

Another Material Transfer Agreement has also been concluded between NRC and Alberta Innovates, allowing the transfer of Brassica gene expression data and genes related to pod shattering resistance. Researchers at Alberta Innovates are utilizing the NRC research to develop Brassica varieties with better shattering resistance and higher yield.

## Planned Result 3

*Implement the sustainable management of aquatic resources through the use of genomics tools to: manage fishery openings; generate increased understanding of population genetics and structure; further understanding of behavioural, physiological and immunological responses to the environment; and through the management of aquatic animal diseases*

## Achieved Result 3

2010-11 saw the continuation of twelve projects initiated at DFO in fiscal year 2008-09 following a competition to select the projects that respond most to the department's priorities and strategic outcomes, as described below.



**1- Through the GRDI, DFO has initiated activities that seek to use genome based monitoring to help in the management of two important fisheries.**

***Genome based monitoring of beluga whales (*Delphinapterus leucas*) in and connected to proposed marine protected areas within the Beaufort Sea***

The beluga whales of the Beaufort Sea constitute an important subsistence fishery for the local Inuvialuit populations, with an average Canadian landed catch of 111 per year (1990-1999). This study was undertaken to determine the genetic population structure of these beluga such that the sustainability of the population can be maximized through harvesting plans based on sound scientific data and understanding how industrial development in the area may affect migrating animals. The overall goal is to ensure that this important fishery is open and productive into the future. Data collection on this project is almost complete and analyses and interpretation of the results are ongoing. Initial results suggest that different groups of whales are using different areas in the Beaufort Sea. Patterns of kinship and evidence of summer site fidelity within these groups will be examined once the dataset is fully complete.

***Genomics of migratory fitness in wild Salmon***

In January 2011, DFO published a paper in Science that documented the discovery of a mortality-related genomic signature in Fraser River sockeye salmon returning to spawn from a study that combined biotelemetry, non-destructive biopsy sampling and functional genomics. Additional genomic experiments have revealed that this same signature is present in multiple tissues (brain, liver, gill, heart, kidney, blood) and throughout the salmon life-cycle (parr to spawning adults). Sockeye salmon smolts leaving the river carry the highest prevalence of this signature, with prevalence decreasing during the first few months in the ocean through to their returning to the river as adults. Importantly, the highest prevalence observed thus far for this signature was in the 2005 brood-year salmon, a year-class that showed an unprecedented low productivity not anticipated by escapement models that resulted in a Judicial Inquiry being called. In comparison with the 2006 brood-year, which returned to the Fraser River a year later in unprecedented large numbers, DFO also showed through genomics that 2005 brood-year smolts were stressed, immuno-suppressed, and carried profiles in the ocean consistent with low-growth and poor feeding.

**2- DFO has initiated several projects to generate increased understanding of population genetics and structure of important economic fisheries. These include:**

***Genetic identification of Atlantic salmon from Newfoundland and Labrador in relation to nearby aquaculture and escapes into the wild***

Five hundred and four individuals collected in 2009 were analyzed at the 15 loci optimized in year 1. The 15 loci were then optimized for multiplexed analysis using the Qiagen Type-it microsatellite kit, reducing the number of PCR reactions from 15 to 3 per sample. These loci are in the process of being applied to 2832 samples collected from various locations around Newfoundland in 2009 and 2010. DNA has been extracted from all collected samples and sent for analysis, with duplicate samples preserved and archived for future research.

***Discriminating capelin populations in the northwest Atlantic***

Capelin, a key forage fish species in the northwest Atlantic, has recently been experiencing significant changes in biology, spawning, behaviour, and migration patterns. Since previous population structure had been based on those patterns, it was necessary to develop new information for capelin in the northwest Atlantic. Capelin collected at 15 spawning locations from 2002-2008 were genetically characterized. The results support 8 genetically-distinct populations. Capelin spawning at the most northerly sampling site in Unity Bay, Labrador is likely related to capelin further north in Hudson Strait. These groupings based on genetic data are somewhat different than determined previously and may require changes in current fisheries management practices.

***Redfish species (*Sebastes* sp.) identification and stock structure based on genetic analysis of archived otoliths***

Redfish is characterised by extensive variability in recruitment with stronger tractable pulses generally occurring at intervals of several years. Genetic analyses were carried out using the material adhering to the otoliths collected since 1974 to determine if the species composition of a given year-class was a key factor in the recruitment failure or success in Units 1 and 2 (geographical areas identified for fisheries management) of the Northwest Atlantic Fisheries Organization. The results led to the conclusions that

the last strong *S. mentella* year-class that greatly contributed to the fishery was produced 30 years ago. All other strong year-classes (1974, 1985, 1988, and 2003) in Units 1 and 2 were *S. fasciatus*. These *S. fasciatus* year-classes disappeared well before recruiting to the Unit 1 fishery and contributed marginally to Unit 2 fisheries (with the exception of the 2003 year-class which is still largely pre-recruit). More research is needed to elucidate the fate of these strong *S. fasciatus* cohorts.

#### ***Genetic variability in wild populations of charrs in the Arctic***

Preliminary results using nuclear microsatellites, mtDNA markers and nuclear genes indicate that Northern Dolly Varden constitutes a different taxon from other sub-specific forms, with well structured genetic groups corresponding to geographic units. These results suggest that such markers are useful to establish unit-stock baselines and may be valuable to estimate contribution rates of stock-of-origin fish to the coastal mixed fisheries in Canada and Alaska.

#### ***Alongside the projects undertaken, DFO has made investments into its Aquatic Biotechnology Service Lab at the Bedford Institute of Oceanography***

The Aquatic Biotechnology Lab participated in 5 projects, bringing in an extra \$47K of O&M funding. Under this project, an optimized extraction procedure and PCR conditions were applied to samples collected by GRDI scientists to evaluate collection/storage methods.

#### ***3- Several new projects serve to increase our understanding of the behavioural, physiological and immunological responses to the environment. These projects include:***

##### ***Microbial characterization of produced water and its influence on the microbial community in the marine environment around the Hibernia production platform***

Results from the analysis of the produced water and sea water samples collected from around the Hibernia production platform were published this year. The same techniques were applied to produced water and sea water collected from around the Terra Nova platform. This included a comparison of the Denaturing Gradient Gel Electrophoresis (DGGE) and clone library results from the same samples.

##### ***Application of genetic markers to resolve species identification and population structure of aquatic invasive species***

Collections of *Didemnum vexillum*, a high risk colonial tunicate species with a global invasion history, were made at different spatial scales from several populations in British Columbia including the West Coast of Vancouver Island, Strait of Georgia, and the Sunshine Coast, and recently identified (2010) populations in Oregon State. Scientists at DFO applied the microsatellite markers to characterize population structures and are in the process of relating the genetic signals to invasion vectors, thereby providing insights to invasion dynamics. Scientists at DFO are perhaps the first to attempt to understand invasions at different spatial scales linked to invasion vectors. Results will be useful in providing advice for the management of aquatic invasive species.

#### ***4- The management of aquatic animal diseases is important for both the wild fisheries as well as the aquaculture industry. Research under the GRDI at DFO continues to focus on issues such as:***

##### ***Immune function of salmon and disease resistance against infectious salmon anemia virus***

Just as people who contract chicken pox as children are immune to the virus later in life, DFO hypothesized that fish surviving an infection by the Infectious Salmon Anemia Virus (ISAV) would become immune to all strains of this virus. As hypothesized, DFO observed that fish having survived a primary exposure to a low-virulence ISAV isolate were immune to the high-virulence isolate a full 18 months later. Interestingly, viral loads in the kidney, which seems to be a primary target organ for ISAV, were much higher and peak viral loads were reached more quickly in naïve fish relative to the immune fish. As viral loads in the kidney of immune fish remained low, DFO hypothesized that certain organs must be affected early in the infection process, and these organs mount a strong defence in the immune fish, thus impeding viral replication and minimizing the viremia towards other target organs. To better understand this process on a molecular level, DFO used DNA microarrays to identify genes related to both the innate immune system, which was most active in the naïve fish, and the acquired immune system, which was most active in the immune fish. This information will be very useful for the production of efficacious vaccines against the ISAV.

***The effects of wild and captive rearing environments, and associated parasite and pathogen regimes, on the diversity and nature of genetic variation in Atlantic salmon***

In response to precipitous declines in populations of Inner Bay of Fundy Atlantic salmon, DFO initiated a Live Gene Banking program to prevent the imminent local extinction of within species genetic diversity. Salmon representatives were captured, reared in captivity, genotyped, placed in population-specific pedigrees, and spawned using modern genetic principles intended to minimize loss of genetic variation due to random genetic drift. The resulting offspring were both reared in captivity under standard hatchery conditions, and released into native river habitat for exposure to wild conditions and natural selection. Juveniles from both environments were then collected, tissue sampled, genotyped, and placed into population-specific pedigrees for production of the next generation of endangered Atlantic Salmon. Scientists at DFO have nearly completed analyses of a Big Salmon River population of nearly 400 individuals, using both DGGE and diploid sequencing. Parent and offspring genotypes for a specific locus were confirmed using extensive pedigree information existing for this group. The results obtained were very different from those based on DGGE only for the Stewiack River population, revealing very high levels of genetic variation, and many different alleles not seen previously.

***Host parasite interactions: a functional genomics approach to characterising salmonid responses to the salmon louse***

This project has allowed DFO to understand the mechanisms behind the transition from louse-susceptible pink salmon to louse-resistant pink salmon during the growth of very young fish. In a paper published in Comparative Biochemistry and Physiology Part D, DFO has shown that pathways associated with inflammation, cell proliferation, tissue remodelling and immunity were associated with this transition. In addition, development of a novel salmon louse-specific, 38K oligo-array has shown how these important parasites respond to important environmental cues such as salinity, temperature and a drug commonly used for treatment (emamectin benzoate). Scientists have also discovered that sea lice were infected with their own parasites. These parasites, called microsporidia, were found to have a significant effect on the sea

lice response to environmental cues. The possibility that microsporidia may serve as a biological control agents for sea lice is being explored.

**Planned Result 4**

*Position the Canadian regulatory system for health to enable innovation while minimizing the risks to Canadians through a focused genomics R&D program aimed at strengthening research in priority areas such as genetic information, biotechnology products, human genomics and microbial genomics, related to human, animal and environmental health. Improve knowledge and understanding of human infectious and chronic diseases for public health-related applications including the development of improved or new diagnostic tools*

**Achieved Result 4**

Work under the health portfolio was undertaken to generate, synthesize, and translate new knowledge in pathogen and human genomics to: strengthen infectious disease surveillance, prevention and control through applications such as diagnostics, molecular risk assessment, vaccines, intervention strategies, mitigation of antimicrobial resistance; and, develop applications to diagnose and prevent diseases and promote health through predictive genetic screening and/or modulation of gene-environment interactions.

***Molecular genomics applied to radiation risk assessment***

Biological and molecular effects of acoustic noise, radiations emitted by natural sources (radon, UV rays) and radiofrequency fields (as emitted by devices such as cell phones) were investigated in animal and cell models using controlled radiation sources. Unique dose-responsive genes were identified for UV and alpha-particle exposures, expanding the current knowledge base of molecular pathways affected by such exposures. Analysis of numerous discreet rodent brain functional regions has identified potential brain region-specific responses to noise-stress and radiofrequency field exposures. These responding elements are being validated by additional studies using conventional techniques to assess their biological plausibility and physiological significance in relation to short- and long-term health effects. This work will provide molecular insight into the significance of

potential subtle biological effects, allowing the development of refined safety standards for radiation emitting devices commonly used in our living/working environments.

### ***Environmental health applications of toxicogenomics and proteomics***

Environmental and occupational exposures are primarily to complex mixtures of chemicals and particles (e.g., urban dust, tobacco smoke and diesel exhaust). Whole genome DNA microarrays, tandem mass spectrometry-proteomics, and rigorous bioinformatics were employed to study the effects of exposure to diesel exhaust particulate and extracts of coal tar using an *in vitro* murine transgenic cell culture model. Adverse outcome pathways and a subset of genes/proteins that are predictive of plausible hazards of exposure to complex mixtures were identified. These proteins are being validated to delineate their role in coal tar induced effects for their use as candidate markers of exposure that could be used for regulatory decision-making.

### ***Development and validation of toxicogenomic tools and integrated systems biology approaches in regulatory toxicology***

Recent policy changes require the development of suitable alternatives to traditional toxicology approaches for the evaluation of thousands of chemicals found in the Canadian marketplace. Scientists at HC are generating novel biomarkers of adverse health effects (hepatotoxicity, genotoxicity, inflammatory response, disruption of thyroid hormone signalling) based on mRNA, microRNA and protein analyses. The project has culminated in the formation of the HC Genomics Working Group, comprised of approximately 40 scientists, regulators and managers to develop a framework for the implementation of toxicogenomics into regulatory risk assessment.

### ***Colon epithelial cell genetic responses to dietary fibre***

Research at HC has used differences in colon epithelial gene expression as a means of determining the relationship between a material's fermentability and the quality and safety of the source of fermentable material. This information is needed by Health Canada regulators decide whether fermentability values can be used as a defining characteristic of dietary fibre, and to update HC's definition of dietary fibre. Gene expression patterns were shown to depend on the

type and amount of fermentable materials, and slow and incomplete fermentable materials were shown to be the most protective against tumour incidence. Health Canada continues to study other biomarkers to help elucidate gene response mechanisms and to investigate any potential effect on colon and/or host health. This will lead to refined food labelling policies addressing health claims of foods.

Scientists at PHAC have developed a new comparative genomic fingerprinting method for the characterization of food-borne pathogens. The method allows for high-throughput/high-resolution analysis of bacterial genomes and provides a solution to the identified need for rapid, high-specificity sub-typing in surveillance and outbreak investigations. The method was applied to the high priority pathogens *E. coli*, *Campylobacter jejuni* and *Listeria monocytogenes*. In addition, a bioinformatics pipeline to perform comparative genomic analysis of multiple genomes and to automate the development of fingerprinting assays from any species of interest was developed. Collaborations with Canadian pathogen surveillance networks and provincial health laboratories were widely established to increase the visibility of the technique and facilitate its wide deployment.

Scientists at PHAC have developed bioinformatic tools for pangenomic DNA sequence analysis and are using these tools for the comparative analysis of genome sequence data from *C. jejuni*, *L. monocytogenes* and *Salmonella enteritidis*. These web-based tools, such as PanSeq, have been made freely available to the scientific community, and will lead to a better understanding of virulence and pathogenicity factors, and to the development of enhanced molecular diagnostics for the pathogens.

Shiga toxin-producing *E. coli* (STEC) can cause massive outbreaks and the potentially fatal hemolytic uremic syndrome. Although O157:H7 is the most common STEC serotype, more than 200 virulent non-O157 isolates have emerged globally that are associated with human disease. While some non-O157 STEC strains may also be fatal, others are associated with only mild diarrhoea or with no human disease at all. GRDI support has allowed PHAC researchers to sequence and characterise the genomes of 19 non-O157 STEC strains. This work has determined the entire catalogue of virulence determinants, which will enable the development of a molecular risk assessment strategy using specific



nucleic acid-based diagnostic tests to rapidly identify and respond to emerging non-O157 STEC that pose a serious public health risk to humans.

Researchers at PHAC conducted comparative studies of pathogenic and non-pathogenic *E. coli* in order to understand the mechanisms that contribute to virulence and to develop novel therapeutic approaches. Approximately 600 strains of *E. coli* were isolated from human urinary tract infections and fecal samples from human and livestock, and were assessed using several approaches, including enterobacterial repetitive intergenic consensus PCR, multilocus sequence typing and multiple-locus variable number tandem repeat analysis. The ability of bacterial strains to form biofilms is recognised as an important virulence factor. Hence, the researchers determined the ability of collected strains to form biofilms. Biofilm-forming strains were further characterized by serotyping and used as hosts for the isolation of novel, potentially therapeutic bacteriophages. This study has improved our understanding of the genetic diversity among *E. coli* strains causing urinary tract infections and has identified new potential therapeutic bacteriophage that are active on the most virulent biofilm-forming pathogenic strains of *E. coli*.

GRDI support has enabled PHAC researchers to develop HIV drug-resistance testing methodology that detects and characterises drug resistance mutations associated with HIV infection. The results of the assay can be used to guide therapy and track the emergence of drug resistant strains to inform public health responses to HIV.

Cystic fibrosis is a multi-organ disease, with the majority of mortalities resulting from pulmonary failure due to repeated pulmonary exacerbations. Recently, members of the *Streptococcus milleri* group have been implicated as important etiological pathogens contributing to pulmonary exacerbations in cystic fibrosis patients. Using whole genome comparative analysis, genetic factors contributing to virulence and pathogenicity were identified, yielding potential targets for future studies of therapeutic strategies for this unique group of bacteria. In addition, a diagnostic PCR was developed for detection and identification of the bacteria within clinical specimens, and novel monoclonal antibodies were developed to support further studies of the pathogenesis of these bacteria.

To investigate the role of vitamin D on the outcome of influenza infection, PHAC researchers collaborated with other research institutes to establish the largest study cohort of influenza patients in Canada. Genetic polymorphisms within genes important to vitamin D metabolism were determined among the study participants. When analysing the distribution of these polymorphisms, scientists discovered significant enrichment of two genotypes among severe influenza cases. This work suggests a role for vitamin D in the pathogenesis of influenza and supports the need for further studies to evaluate the potential of vitamin D in the mitigation of influenza infection outcomes.

Genomic approaches were used to investigate a class of gene expression regulators called microRNAs. Researchers developed new experimental approaches to study the global expression of different microRNAs, to identify their gene targets and determine their effects on the products of gene targets. Specifically, the role of microRNAs during viral infection was studied to determine their involvement in controlling the expression of both viral and host genes in prion, influenza, poliovirus, JC virus (a type of human polyomavirus) and herpes simplex virus infected cells. These studies have identified new pathways suspected to play a role in viral tropism and pathogenesis, and have identified new potential therapeutic targets for the control of virus infections.

Scientists at PHAC developed a new methodology and bioinformatic analysis tools to study the high mutation rates in RNA viruses, including HIV, Hepatitis B virus, and Hepatitis C virus that result in the generation of variant genomes, called *viral quasispecies*. It is important to understand the diversity, recombination, and evolution of these viral quasispecies genome populations from infected individuals to develop control strategies, diagnostics, vaccines, and antiviral therapies.

A new method for detecting interactions between viral proteins and the host proteome was developed. The method was used to identify several new host proteins that interact with virally encoded proteins from Hepatitis C and human papilloma viruses implicated in causing cancer. These protein interactions will be studied further to determine their possible role in cancer.



## Planned Result 5

*Increase knowledge for forest generation and protection methods, and for addressing environmental impact considerations, through a focused genomics R&D effort on species and traits that are of economic importance to Canada*

## Achieved Result 5

### ***Increased knowledge of genomics-based pest control and diagnostics***

The genomics program of NRCan provides knowledge of forest pests and their pathogens, including pathogen modes of action, host defence mechanisms, and host-pathogen interactions. Three economically important invasive coleopteran species: emerald ash borer, mountain pine beetle, and brown spruce longhorn beetle were tested for the presence of insect killing pathogens (entomopathogens), which include various virus families, microsporidia and fungi. Entomopathogen loads differed between species and populations. Molecular characterization and virulence assays of fungal pathogens are well underway. Expressed sequence tags generated from emerald ash borer revealed the presence of compounds homologous to known chemosensory proteins, odorant-binding proteins and gustatory receptors – compounds involved in the chemical communication of insects. Understanding the genomic basis of chemical communication is the first step in the development of potential sensory based control options for this alien invasive insect. Mutant viruses were assayed to determine what key domains are involved in the process of infection of pest larvae, an information required for the identification of candidates for potential release to control established pest populations.

Scientists at NRCan aim at furthering the understanding of relationship between forest pathogens and their hosts. They worked towards the identification and characterization of genes responsible for resistance in Douglas fir to the fungal pathogen responsible for root rot. Expression profiles for nine plant defense-related genes were established, showing that fungal infection resulted in up-regulation of the genes to varying degrees. On the pathogen side, numerous putative genes involved in pathogenicity have been identified and work continues towards their characterization. These genes may become potential markers to be used in Douglas fir breeding and screening programs.

In 2010-2011, the molecular characterization of key signalling processes of poplar-rust interactions continued. Genes associated with rust resistance were identified by transcriptome analyses. Next steps include elucidating the potential role of these genes in poplar rust resistance. Western white pine breeding programs will benefit from work performed on resistance related genes. One of the identified genes directs the production of an anti-microbial peptide that can be used as a biomarker to distinguish different mechanisms of partial host resistance.

Research on genomics-based pest control products for species that are of economic importance involves searching for active ingredients, target sites, and new or improved strains for the development of environmentally benign pest control methods. Scientists at NRCan continued the development of molecular markers for the identification, monitoring and potential control of two economically important defoliating species (white-marked tussock moth and hemlock looper). Microarray analyses were performed to identify genes involved in reduced susceptibility to the insecticide tebufenozide in white-marked tussock moth and Single Nucleotide Polymorphisms (SNPs) were tested to differentiate hemlock looper populations. The assembly and annotation of the spruce budworm, another important defoliating species, have been initiated.

### ***Identification of genes controlling desirable attributes in economically important tree species***

The genomics program at NRCan-CFS directs research towards the development of methods, tools and databases for the discovery of genes in forest trees coding for attributes favouring fibre quality and forest sustainability: growth; wood quality characteristics; resistance to biotic and abiotic factors; and adaptation to environmental change. Work in 2010-2011 continued to explore and identify specific regions of the spruce genome coding for features such as adaptation to climate change and resistance to insect and diseases. For example, defence response and gene regulation in spruce trees were investigated by the production of transgenic white spruce trees with knockout genes.

Working towards the development of molecular markers as screening and selection tools for breeders, scientists at NRCan investigated candidate genes for growth and adaptation in spruce. A complete

population of 949 trees was genotyped for the 13,661 gene SNPs suspected to be involved in growth related traits. Analyses of phenotyping data for bud flush, growth and bud set continued towards the establishment of robust quantitative trait loci. 2010-2011 saw the genotyping of 2000 siblings from a genetic mapping population for 14,145 gene SNPs which will enrich the existing white spruce genetic linkage map, expecting to near 10,000 positioned genes. An association study of wood traits using a discovery population of 480 black spruce trees led to the identification of a first list of markers. These markers were applied to a Newfoundland and Labrador breeding population to select trees for the next breeding generation. Working with trees from the New Brunswick white spruce breeding program, molecular markers associated with wood traits were validated.

### **Planned Result 6**

*Develop genome-science applications to support regulatory and enforcement activities in key areas such as environmental risk assessment and management; enforcement and compliance; pollution detection, monitoring and prevention; conservation biology and wildlife genetics; technology forecasting and assessment; and the responsible and sustainable development and use of bio-based products and industrial processes*

### **Achieved Result 6**

In 2010-11 EC made significant advances in the application of the genomic tools and data that have been generated over the life span of the GRDI. Using GRDI funding, EC has developed and applied genomics tools related to the areas of risk assessment/management and wildlife conservation/management.

#### ***Risk Assessment/Management:***

- A collaborative partnership was established with the University of Prince Edwards Island's Lobster Research Center, to use the same microarrays designs and similar methodology to align research goals for the Atlantic region as closely as possible while preventing duplication of resources.
- Scientists at EC established consistent protocols across laboratories using the amphipod array. An inter-laboratory comparison study is being planned for 2011-12, to enhance and validate the technique and to develop consistent approaches in both Canada and the USA.
- The results of extensive DGGE analyses suggest that soybean plants genetically modified to express herbicide and insect tolerance genes had no effect on soil microbial communities when compared to their unmodified relatives. This was in agreement with previous studies showing no effect of genetically modified maize lines on the abundance in the soil of a gene involved in microbial nitrogen cycling.
- Q-PCR analyses of the *Bacillus* species confirm long term survival of these bacteria in aquatic habitats and a positive impact of low temperatures on survival. Therefore any product, inoculum or consortium containing *Bacillus* spp. must be assessed for their potential longer term effects.
- Research in the Athabasca River region has shown that microbial communities, in response to oilsands development, shifted to more specialized populations able to use specific substrates or tolerate particular stresses.
- Novel effects of several of the newer perfluoroalkyl compounds (PFCs) were observed at low doses in chicken embryo cardiomyocytes and neuronal cells. These findings are unique and will facilitate risk assessments of the newer PFCs under the Chemicals Management Plan.
- A qPCR array with 15 selected genes was used to better understand the toxic impacts of municipal effluents from 12 cities across Canada.
- A DNA microarray was developed using a set of 250 stress-related genes in rainbow trout to investigate the effects of products of nanotechnology.
- A new DNA extraction method using microwaves was developed with model bacteria and fungi. New cell buffers, reagents and protocols were also established to optimize the method.
- Scientists at EC have developed genomics tools for the Randle Reef Remediation Team to assess genetic damage and sub-lethal health effects in fish that are diagnostic of both exposure to and the effects of polycyclic aromatic hydrocarbon contaminated sediments.

- Scientists at EC have developed and tested methodologies to better understand the sources of fecal pollution to guide beach clean up efforts in highly populated areas such as Toronto.
- Gene expression data were related to *in situ* field observations in orchard ponds to measure amphibian survivorship, growth, time-to-metamorphosis, sexual development, deformity rates, and occurrence of albinism in *Rana luteiventris*.

#### **Wildlife Conservation/Management:**

- Scientists at EC have developed new PCR screening tools to identify *Pasteurella multocida* in avian and environmental samples, providing more rapid, less expensive, and more reliable results compared to traditional bacteriological methods. The methods will enable users to identify the sources of the recent emergence of *P. multocida* strains causing outbreaks in Canada's eastern Arctic and east coast, distinguish strains isolated from different avian species, assess short-term genetic drift within outbreaks, compare strains in different geographical areas, and compare strains from outbreaks in the same location from year to year.
- Gulls in Newfoundland were shown to carry avian influenza virus that contains both Eurasian and North American lineages. This result indicates that intercontinental mixing across the Atlantic occurs in wild birds, as seen in the Pacific. Overall, the prevalence of avian influenza virus is relatively low among seabirds, with a different seasonality from that of waterfowl and thus surveillance efforts will need to be adapted. Furthermore, the avian influenza virus could be isolated and sequenced from fecal samples from the environment, which provides another sampling technique that is less expensive and time-consuming, and thus potentially more strategic, than live bird sampling.
- New species of parasites have been included in the Canadian and International Barcode of Life database.
- The Great Lakes/St. Lawrence – Canadian Shield population of the western chorus frog (*Pseudacris triseriata*) was listed as threatened species by Committee on the Status of Endangered Wildlife in Canada in 2008. Scientists at EC characterized this species genetically for accurate identification, an important step for conservation management decisions.

In 2010-11 investments continued in environmental genomics foresight, knowledge development, instrumentation, infrastructure, and outreach (e.g. periodic comparative analysis of international environmental genomics activities via bilateral exchanges with the US Environmental Protection Agency). Environment Canada is also working closely with the Organization for Economic Co-operation and Development and the International Programme on Chemical Safety of the World Health Organization in developing strategies and work plans to lead and coordinate international efforts for the application of toxicogenomic methods and approaches within a regulatory context.

# Appendix A Supplemental Performance Details

## Annex 4 – R&D Outputs by Department

### National Research Council Canada

- 38 publications in refereed journals
- 58 publications in refereed conference proceedings
- 47 invited presentations
- 6 technical reports
- 10 other publications (e.g. books and book chapters)
- 4 participations in national/international conferences, workshops, committees and networks
- 14 disclosures filed
- 10 patent applications
- 7 patents issued
- 4 licenses issued
- 6 material transfer agreements
- 4 peer-reviewed grants leveraged
- 80 collaborative agreements, including with OGDs, of which 16 are formal

### Agriculture and Agri-Food Canada

- 32 publications in refereed journals
- 19 invited presentations (of which 16 international)
- 48 posters
- 7 book chapters
- 1 patent
- 20 agreements with external organizations

### Health Canada

- 27 publications in refereed journals
- 22 presentations, of which 2 were invited
- 2 technical reports
- 1 invited book chapter

### Public Health Agency of Canada

- 13 publications in refereed journals
- 1 publication in refereed conference proceedings
- 6 invited presentations
- 1 technical reports
- 3 other publications (e.g. books and book chapters)

- 30 participations in national/international conferences, workshops, committees and networks
- 4 material transfer agreements
- 4 collaborative agreements
- 5 genomics-related databases developed and launched
- 16 bioinformatics programs or tools developed
- 144 genomic database deposits

### Natural Resources Canada

- 33 publications in referred journals
- 3 publications in conference proceedings
- 32 invited presentations
- 3 book chapters
- 45 national/international conference presentations and posters
- 3 formal collaborative agreements
- 1 material transfer agreement
- Genomics related databases and libraries: numerous GenBank deposits (various insects and their pathogens)

### Environment Canada

- 49 publications in refereed journals
- 17 publications in refereed conference proceedings
- 18 invited presentations
- 1 other presentation
- 25 participations in national conferences/workshops
- 22 participations in international conferences/workshops
- 1 participant in a national network
- 3 participants in international committees
- 2 book chapters
- 4 technical reports
- 3 formal collaborative agreements

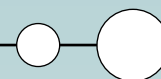
### Fisheries and Oceans Canada

- 6 publications in refereed journals

# Appendix A

## Supplemental Performance Details

### Annex 5 – Outreach by Department



#### **National Research Council Canada**

- Active external website and project wikis
- 6 media interviews/stories
- 3 press releases
- 6 external website stories published
- 1 public lecture
- Brochures distributed to promote the initiative

#### **Agriculture and Agri-Food Canada**

- Presentations to agricultural producers and agriculture industry groups
- Participation in science fairs

#### **Health Canada**

- Contribution to policy: updated Health Canada definition on Dietary Fibre
- Annual Health Canada Science Forum, with departmental and external invitees
- Research exchanges with other government departments, including student training (2 MSc and 3 PhD)
- 5 lectures in graduate seminar courses at local Universities
- Creation of the Health Canada Genomics Working Group, which includes regulators and scientists from across HC as well as Environment Canada
- Invited to participate in WHO expert panel on radiation related carcinogenesis

#### **Public Health Agency of Canada**

- 2 external websites developed
- 6 media interviews
- 2 community presentations
- 1 citizen engagement event

#### **Natural Resources Canada**

- 3 media interviews
- 4 press releases
- 2 community presentations
- 4 web pages
- 9 factsheets

#### **Environment Canada**

- 1 Environmental Genomics Workshop, with departmental scientists and external researchers and potential end-users
- 5 genomics-related databases
- 5 First Nations community/Hunter-Trapper Organization consultations
- 2 community outreach events

#### **Fisheries and Oceans Canada**

- 3 demonstration tours



## Appendix B

# Genomics R&D Initiative: RMAF Overview

### Overview

In fulfillment of the requirements and guidelines of the Treasury Board Secretariat, a Results-based Management and Accountability Framework (RMAF) has been developed for the interdepartmental GRDI. The RMAF formalizes the commitment of the six departments involved in the Initiative regarding common measurement and accountability requirements.

A logic model has been developed (Figure 1) that reflects the overall objectives of the Initiative, recognizing that there are significant differences in particular needs and priorities of each department. The key objective of the GRDI is to sustain federal genomics research in support of departmental mandates and key federal public policy objectives in areas of national interest (human health, agriculture and food safety, environment and natural resources management), to strengthen innovation, promote global competitiveness, and ensure sustainability for the benefit of all Canadians. Key results are related to four important program areas:

**Management** – While good management is an important aspect of any government programming, it is particularly important to recognize for this initiative because of the number of players: there are six departments and agencies involved and it is important that the practices in place support effective departmental and interdepartmental coordination. It is also critical that departmental and initiative priorities be well defined so that the projects are selected to ensure that government-wide priorities for genomics research information are addressed and to ensure that genomics research adequately supports policy, regulatory, and other types of decisions.

**Capacity Building** – Capacity building was the focus of the earlier phases of this initiative and it is critical that this continue. The hiring of highly qualified personnel (HQP), training of existing personnel, and provision of effective and efficient tools to enable research are essential components to successfully undertake research projects as well as be credible participants in genomics research and applications.

**Research and Development** – Research and development is the central component of this initiative. All activities surrounding the actual conduct of R&D, the transfer and adoption of the technologies developed, and the dissemination of the research results and scientific knowledge, are critical to ensuring progress towards all outcomes and ensuing impacts.

**Outreach (communications)** – While the previous three components are important to ensuring that the right research is done at the right time and that the research results are disseminated to the scientific community, it is also important for genomics to be well understood and accepted by Canadians. Direct and indirect public communications are therefore an important aspect of this initiative.

### Performance Measurement Plan

**Table 5** outlines the performance indicators, sources and responsibility for the outcomes outlined in the logic model presented in **Figure 1**. Information outlined in this table will be collected and reported annually.

**Table 6** outlines the performance indicators, sources and responsibility for the outcomes outlined in the logic model which should be examined at the time of a future impact evaluation. While information in this table may be collected annually, it will be analyzed and reported upon at the time of the impact evaluation.

Individual departments may also report on their individual progress in their Departmental Performance Report and use the information to adapt their programming and priorities.

**Tables 5 and 6** therefore outline specific data that needs to be collected by all departments, where appropriate. While some of the data will only be collected and analyzed at the time of the impact evaluation, the tables outline the following ongoing departmental requirements:

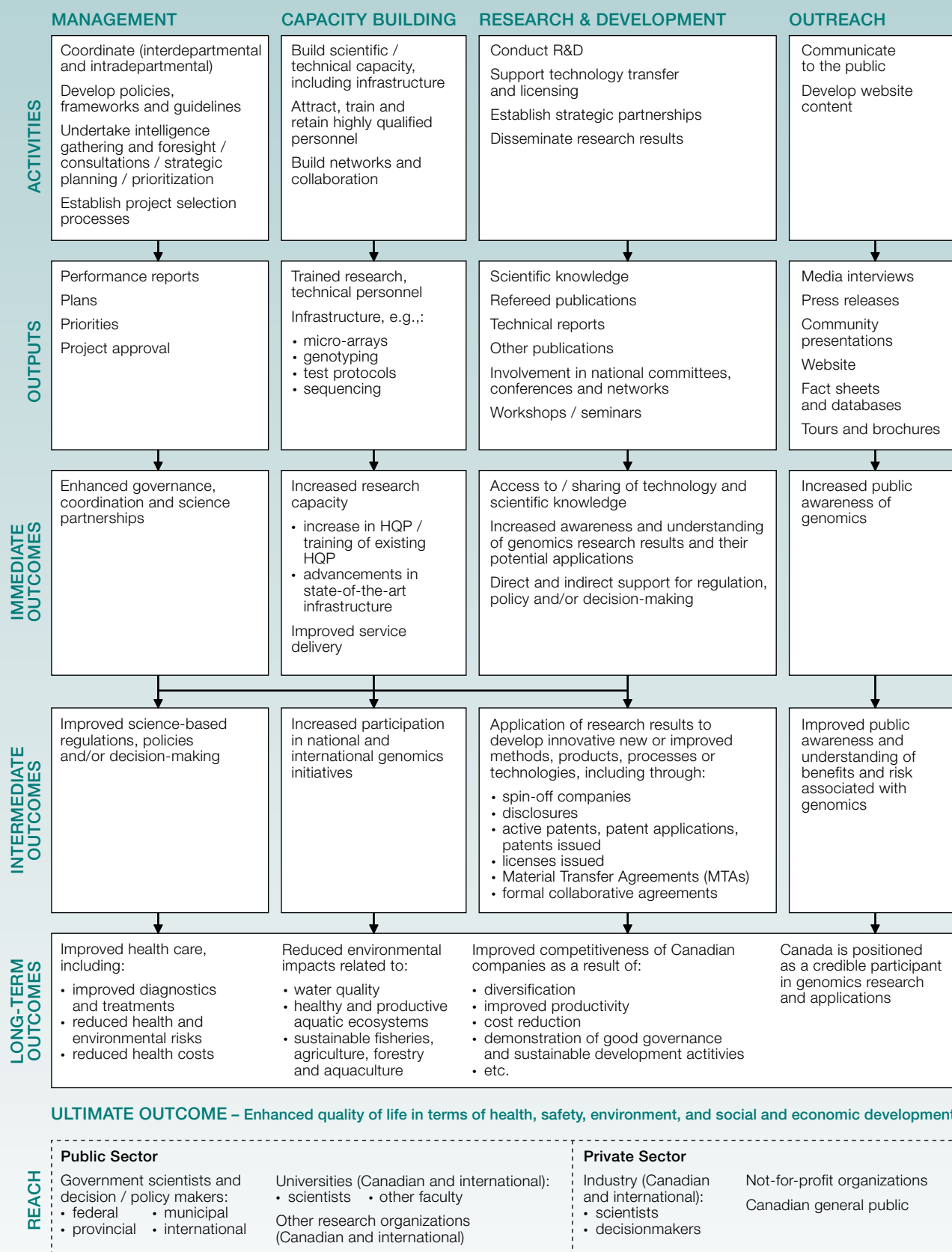
**Interdepartmental information:** Departments must maintain a record of all minutes of meetings, decision records, planning documents, etc. of an interdepartmental nature that has affected the way in which the initiative has been implemented in their own departments.

**Departmental information:** Departments also need to maintain a record of internal information that has affected the way in which the initiative has been implemented in their department. This includes program-level funding information (A-base and B-base funding), human resource information (hiring, training), non-project specific participation in national and international committees, conferences and networks, and website statistics.

**Project-specific information:** This includes the following information on projects:

- project applications (proposals, peer review assessments, etc.);
- projects approved (title, scope, funding level, description, objectives, lead scientist, team members);
- interdepartmental projects (title, scope, funding level, number of departments, description, objectives, lead scientist, team members);
- partners, collaborators on projects (names, type, financial contribution, in-kind contribution, role);
- regulators, policy makers, others accessing research results (names, titles, contact information);
- use of project funds (budgets including overhead charges or corporate taxes);
- infrastructure projects (types, funding level, % of total);
- # of papers in refereed journals (names of journals);
- # of papers in refereed conference proceedings;
- # of invited presentations;
- # of technical reports;
- # of book chapters;
- # of other publications;
- # and type of participation in national and international committees, conferences and networks related to projects;
- # and type of genomics related databases, libraries, etc. resulting from projects;
- application of research results and technology transferred;
- new products, tools, processes developed;
- spin-off companies (#, types, names, contact information);
- # of disclosures;
- # of active patents, patent applications, patents issued;
- # of licenses issued;
- # of material transfer agreements (MTAs);
- # of formal collaborative agreements; and
- # of standard operating protocols.

**Figure 1 – Logic Model for the Interdepartmental Genomics R&D Initiative**



**Table 5: Annual Performance Measurement Strategy**

AREA	ONGOING INDICATORS	SOURCES	RESPONSIBILITY
<b>IMMEDIATE OUTCOMES</b>			
Enhanced governance, coordination and science partnerships	# of interdepartmental research initiatives (table summarizing initiative, scope, funding level, # of departments involved, description)	Project information	Departments
	# of partnerships / collaborations on projects by type, e.g.: <ul style="list-style-type: none"> <li>• OGDs</li> <li>• universities</li> <li>• international organizations</li> <li>• private sector</li> <li>• Genome Canada</li> <li>• etc.</li> </ul>	Project information	Departments
	Internal funds leveraged: A-base and B-base funding	Departmental records	Departments
	Other funding and in-kind contributions by type (complementary to previous information on collaborations), e.g.: <ul style="list-style-type: none"> <li>• OGDs</li> <li>• universities</li> <li>• international organizations</li> <li>• private sector</li> <li>• Genome Canada</li> <li>• etc.</li> </ul>	Project information	Departments
Increased research capacity: <ul style="list-style-type: none"> <li>• Increase in HQP / training of existing HQP</li> </ul>	# and type of new research personnel: <ul style="list-style-type: none"> <li>• permanent and temporary (PDFs, students)</li> <li>• scientific and technical support</li> </ul>	Departmental records	Departments
	\$ and % of allocation to training and related HQP activity	Departmental records	Departments
	# of existing staff trained (genomics related)	Departmental records	Departments
	# of existing departmental staff working on GRDI funded projects (increasing expertise by doing research)	Departmental records	Departments
• advancements in state-of-the-art infrastructure	Type of infrastructure: <ul style="list-style-type: none"> <li>• acquired</li> <li>• adapted</li> <li>• upgraded</li> <li>• maintained</li> </ul>	Project reports	Departments
	\$ and % of allocation to infrastructure	Departmental records	Departments

AREA	ONGOING INDICATORS	SOURCES	RESPONSIBILITY
Access to and sharing of technology and scientific knowledge	<ul style="list-style-type: none"> <li># of papers in refereed journals (hard copy / electronic)</li> <li>information about journals available on request</li> </ul>	Project reports	Departments
	# of papers in refereed conference proceedings	Project reports	Departments
	# of invited presentations	Project reports	Departments
	# of technical reports	Project reports	Departments
	# of book chapters	Project reports	Departments
	# of other publications	Project reports	Departments
	# and type of participation in national and international committees, conferences and networks	Project reports Departmental records	Departments
	# and type of genomics related databases, libraries, etc.	Project reports	Departments
Public awareness of genomics	Web presence / # website hits / other website statistics	Analysis of website statistics	Departments
<b>INTERMEDIATE OUTCOMES</b>			
Increased participation in national and international genomics initiatives	Extent to which scientists in departments participate in other projects <ul style="list-style-type: none"> <li>national vs international</li> <li>role on projects</li> <li>leveraging</li> <li># of partners</li> <li>OGDs vs universities vs private sector vs Genome Canada vs others</li> <li>etc.</li> </ul>	Project information	Departments
	Other types of participation in national and international genomics initiatives <ul style="list-style-type: none"> <li>number of initiatives</li> <li>types of initiatives</li> <li>role of departments / scientists</li> </ul>	Departmental records	Departments
Application of research results to develop innovative new or improved methods, products, processes or technologies, including through: <ul style="list-style-type: none"> <li>spin-off companies</li> <li>disclosures</li> <li>active patents, patent applications, patents issues</li> <li>licenses issued</li> <li>material transfer agreements (MTAs)</li> <li>formal collaborative agreements</li> </ul>	Description of application of research results (internal and external) and technology transferred	Departmental records	Departments
	# and types of spin-off companies	Project reports	Departments
	# of disclosures	Project reports	Departments
	# of active patents, patent applications, patents issued	Project reports	Departments
	# of licenses issued	Project reports	Departments
	# of MTAs	Project reports	Departments
	# of formal collaborative agreements / # of standard operating protocols	Project reports	Departments



**Table 6: Impact Evaluation Performance Measurement Strategy Requirements**

AREA	ONGOING INDICATORS	SOURCES	RESPONSIBILITY
<b>IMMEDIATE OUTCOMES</b>			
Enhanced governance, coordination and science partnerships	Evidence of coordinated planning (interdepartmental and intra-departmental), priority setting and management approaches (e.g., GRDI ADM Coordinating Committee, GRDI Working Group, linkages to the Canadian Regulatory System for Biotechnology)	Minutes of meetings, decision records, planning documents, etc.	Departments GRDI ADM Coordinating Committee GRDI Working Group
	# of interdepartmental research initiatives (initiative, scope, funding, # of departments involved, description)	Project information	Evaluators based on departmental information
	# of partnerships / collaborations on projects by type, e.g.: <ul style="list-style-type: none"><li>• OGDs</li><li>• universities</li><li>• international organizations</li><li>• private sector</li><li>• Genome Canada</li></ul>	Project information	Evaluators based on departmental information
	Internal funds leveraged: A-base and B-base funding	Departmental records	Evaluators based on departmental information
	Utilization of funds for intended purposes	Project information	Evaluators based on departmental information
	Other funding and in-kind contributions by type (complementary to previous information on collaborations), e.g.,: <ul style="list-style-type: none"><li>• OGDs</li><li>• universities</li><li>• international organizations</li><li>• private sector</li><li>• Genome Canada</li></ul>	Project information	Evaluators based on departmental information
Increased awareness and understanding of genomics research results and their potential applications	Extent to which projects have addressed key genomics information needs within the departments	Comparison of project objectives to departmental priorities; interviews with departmental managers	Evaluators based on departmental information
	Extent to which regulators, policy makers, decision-makers are aware of projects, their results <ul style="list-style-type: none"><li>• within departments</li><li>• in other departments</li><li>• in other levels of government</li><li>• in other organizations</li></ul>	Interviews with regulators, policy makers, other managers and others	Evaluators based on departmental information
Direct and indirect support for regulation, policy and / or decision-making	Extent to which scientific evidence related to genomics is available and used in the development of regulations and policies as well as in other types of decisions <ul style="list-style-type: none"><li>• within departments</li><li>• in other departments</li><li>• in other levels of government</li></ul>	Interviews with regulators, policy makers and other managers, review of decision records, discussion documents, White Papers	Evaluators based on departmental information
Public awareness of genomics	Level of public awareness of genomics	Survey of general public	Evaluators
	Web presence / # website hits / other website statistics	Analysis of website statistics	Evaluators based on departmental information

AREA	ONGOING INDICATORS	SOURCES	RESPONSIBILITY
<b>INTERMEDIATE OUTCOMES</b>			
Improved science-based regulations, policies and / or decision-making	Evidence of contribution of scientific evidence to regulatory, enforcement, environmental assessment, public health and policy discussions and decisions <ul style="list-style-type: none"> <li>• within departments</li> <li>• in other departments</li> <li>• in other levels of government</li> </ul>	Interviews with regulators, policy makers and other managers, review of discussion documents, White Papers	Evaluators based on departmental information
Increased participation in national and international genomics initiatives	Extent to which scientists in departments participate in other projects <ul style="list-style-type: none"> <li>• national vs international</li> <li>• role on projects</li> <li>• leveraging</li> <li>• # of partners</li> <li>• OGDs vs universities vs private sector vs GC vs others.</li> </ul>	Project information, interviews with scientists and partners	Evaluators based on departmental information
	Other types of participation in national and international genomics initiatives <ul style="list-style-type: none"> <li>• number and types of initiatives</li> <li>• role of departments / scientists</li> </ul>	Departmental records, interviews with dept reps / reps of other initiatives	Evaluators based on departmental information
Application of research results to develop innovative new or improved methods, products, processes and technologies through: <ul style="list-style-type: none"> <li>• spin-off companies</li> <li>• disclosures</li> <li>• active patents, patent applications,</li> <li>• licenses issued</li> <li>• Material Transfer Agreements</li> <li>• formal collaborative agreements</li> </ul>	Description of application of research results (internal and external) and / or technology transferred	Departmental records	Evaluators based on departmental information
	# and type of products, tools and processes developed due to application of research results; description of use	Departmental records, interviews with recipient organizations	Evaluators based on departmental information
	# and types of citations	Citation analysis	Evaluators based on departmental information
Public understanding of genomics as an important contributor to their quality of life	Change in the level of public understanding	Survey of general public	Evaluators
	Change in media reporting	Content analysis of newspapers, other publications	Evaluators
<b>LONG-TERM OUTCOMES</b>			
Improved health care, including: <ul style="list-style-type: none"> <li>• improved diagnostics and treatments</li> <li>• reduced health and environmental risks</li> <li>• reduced health costs</li> </ul>	Extent to which research results are used for diagnostics, treatments, prevention, etc.	Case studies, interviews	Evaluators based on departmental information
	Specific health care impacts (refer to Departmental RMAFs for specific indicators)	Case studies, analysis of secondary data on health care	Evaluators
Reduced environmental impacts related to: <ul style="list-style-type: none"> <li>• water quality</li> <li>• healthy and productive aquatic ecosystems</li> <li>• sustainable fisheries, agriculture, forestry and aquaculture</li> </ul>	Extent to which research results are used to refine environmental regulations and improve pollution detection, monitoring, and enforcement activities	Case studies, interviews	Evaluators based on departmental information
	Specific environmental impacts (refer to Departmental RMAFs for specific indicators)	Case studies, analysis of secondary data on environment	Evaluators

AREA	ONGOING INDICATORS	SOURCES	RESPONSIBILITY
Improved competitiveness of Canadian companies as a result of: <ul style="list-style-type: none"> <li>• diversification</li> <li>• improved productivity</li> <li>• cost reduction</li> <li>• demonstration of good governance and sustainable development</li> </ul>	Extent to which research results are used by Canadian companies	Case studies, interviews	Evaluators based on departmental information
	Performance of companies using research results vs others in that sector (refer to Departmental RMAFs for specific indicators)	Case studies, analysis of secondary data	Evaluators
	Improved performance of specific sectors affected by research results	Case studies, analysis of secondary data	Evaluators
Canada is positioned as a credible participant in genomics research and applications	Level of participation in international initiatives	Departmental records, interviews with departmental reps and reps of other initiatives	Evaluators based on departmental information
	Opinions of experts regarding participation of Canada	Literature review, interviews with experts	Evaluators based on departmental information
	Level of public and private investment in genomics R&D	Case studies, analysis of secondary data	Evaluators
ULTIMATE OUTCOME			
Enhanced quality of life in terms of health, safety, environment, and social and economic development	Miscellaneous quality of life indicators (e.g., improved health services / treatments, employment opportunities, lifestyle improvement, environmental benefits, etc.)	Case studies, secondary data, special studies, etc.	Evaluators

