Environment and Climate Change Canada
Environnement et Changement climatique Canada

MEASURING ENVIRONMENT CANADA'S RESEARCH AND DEVELOPMENT PERFORMANCE (2014)

Canada

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TABLE OF CONTENTS

KEY FINDINGS

Relevance

- Environment Canada is a science-based department, with all respondents to a 2014 survey of Program Alignment Architecture (PAA) programs, sub-programs and sub-sub-programs indicating they either use or produce science.
- Internal users of Environment Canada's R&D are satisfied with how the Department's science meets their needs, with the majority (83%) assigning it a positive or neutral ranking.
- Environment Canada's science delivers on all components of the Department's mandate, Science Strategy priorities and Strategic Outcomes.
- Environment Canada's science is focused on environmental issues of current significance to the Government of Canada, with the majority of publications (85%) supporting at least one Science Strategy priority area.

Transparency

- Environment Canada contributes to the Open Access movement, with nearly half of its scientific peer-reviewed publications available free and online.
- Environment Canada's scientific datasets are increasingly being made available to employees and the public under Open Data initiatives.
- Environment Canada's science is accessible to non-specialists through mechanisms such as EC Science Alert, traditional and social media.

Responsiveness

- Environment Canada's science is produced in a timely manner, with the majority of R&D-using survey respondents (74%) assigning it a positive or neutral ranking.
- Environment Canada's science is adaptable, with the majority of survey respondents (78% R&D users, 84% R&D producers) assigning it a positive or neutral ranking.
- The proportion of Environment Canada's budget and total workforce devoted to S&T activities has remained relatively stable at around 60% over the past decade.
- Environment Canada publishes across a diversity of scientific fields.

Excellence

- Environment Canada is a highly productive institution, publishing around 700 scientific peer-reviewed papers per year.
- According to bibliometrics, the scientific impact of Environment Canada's publications is well above world average.
- Compared to other institutions, Environment Canada's science is world-leading in Contaminants & Stressors (PA1) and Weather (PA2), in terms of productivity, scientific impact and specialization.
- Environment Canada's science is most impactful in Climate Change (PA3) and least impactful when it does not fall under one of the Science Strategy priority areas.

Collaboration

- Environment Canada is highly collaborative, with nearly 90% of its publications co-authored with external partners.
- Collaboration greatly increases the scientific impact of Environment Canada's publications.
- Canadian universities remain top national collaborators and American governmental institutions remain top international collaborators.
- Environment Canada collaborates with Indigenous communities and provincial and territorial governments.

INTRODUCTION

Science is the foundation of Environment Canada's work. Research and development (R&D) supports many of the Department's science-based functions, including its legislative obligations, commitment to be a world class regulator, enforcement activities, weather services and policy development. R&D is an integral component of the Department's science; as such, regular assessment is important.

The objective of this report is to provide an updated assessment of Environment Canada's R&D performance. The report establishes baseline measures of R&D performance according to the principles of Environment Canada's Science Strategy 2014-2019: Relevance, Transparency, Responsiveness, Excellence and Collaboration. Where possible, the report compares current and past performance, as assessed in the 2009 report Measuring Environment Canada's Research and Development Performance.

In order to clearly distinguish R&D from other scientific work, this report draws on Statistics Canada definitions. Science and technology (S&T) includes two elements: R&D and related scientific activities (RSA). R&D activities focus on the production of new scientific knowledge. RSA, such as monitoring, focus on applying existing scientific knowledge.

SOURCES OF INFORMATION

Two main information sources used in this report are described below:

1. Bibliometric data on Environment Canada's peer-reviewed scientific publications from 2003-2013

Bibliometrics is the statistical study of publications classified by area of work, authors, institutions, etc. It provides insight on the quality and quantity of science produced, allowing analysis of EC's publication trends and status within the Canadian and international environmental research landscape. This report uses bibliometrics to analyze publication productivity, scientific impact, collaboration, accessibility, and relevance to Science Strategy priority areas. Bibliometric data used in this report was compiled from several internal sources and externally commissioned reports that examined departmental publications over the time period 2003-2013.

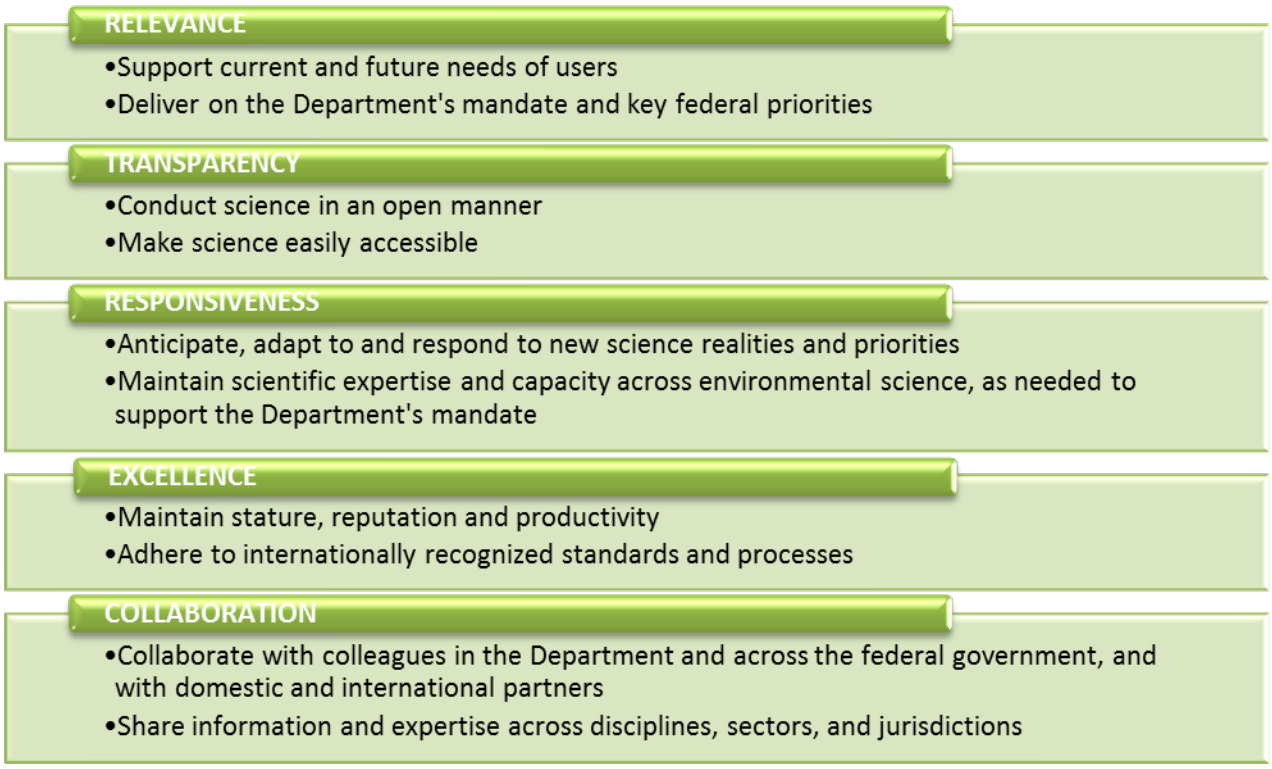
2. 2014 Survey of linkages between science users and producers within Environment Canada

Program Alignment Architecture (PAA) programs, sub-programs and sub-sub-programs in EC were asked about their science activities in the 2014 calendar year. The response rate was 92% (36 out of 39 lowest-level programs under Strategic Outcomes 1, 2 and 3). Internal Services such as finance and human resources were excluded from the survey, as they do not fall under a specific Strategic Outcome. This report presents survey responses from programs that use and/or produce R&D (on its own, or in addition to RSA). Programs that use or produce only RSA are excluded unless specifically indicated. A similar survey of R&D users, producers and funders was completed in 2009. However, the organizational structure of the Department has since changed, meaning that current and past programs may not be directly comparable.

PERFORMANCE MEASUREMENT FRAMEWORK

The Science Strategy 2014-19 guides all of EC's science, ensuring a Department-wide focus on federal environmental priorities and commitment to core principles. In this report, R&D performance is assessed using the following Performance Measurement Framework based on the Science Strategy. The Framework breaks down each Science Strategy principle into the components of its definition. International best practices for performance measurement were used to guide the selection of indicators for each component.[1]

Figure 1: Performance Measurement Framework



The Science Strategy identifies four priority areas for EC's science. These are areas of national and global importance that the Department has selected to drive much of its scientific work between 2014-2019. Where possible within a principle, performance is assessed using priority areas (PA).

- **Contaminants & Stressors (PA1)**: Reducing the impacts of contaminants and other environmental stressors on the natural environment
- **Weather (PA2)**: Providing early warnings about changing weather, climate and other environmental conditions

[1] Best practices included the Organization for Economic Co-operation and Development (OECD) report, *Environmental indicators: Development, measurement and use* and the Regions for Sustainable Change resource, Guidelines for indicators: Indicators toolkit.

- **Climate Change (PA3)**: Climate change mitigation and adaptation
- **Conservation & Protection (PA4)**: Strengthening environmental conservation and protection to support responsible resource development

RELEVANCE

- **Support current and future needs of users**
- Deliver on the Department's mandate and key federal priorities

Why we measure

The linkages between science users and science producers, both within EC and beyond, must be robust in order for EC's science to effectively and efficiently deliver on the Department's mandate and key federal priorities. It is for this reason that the Science Strategy identifies the enhancement of such linkages as one of the key mechanisms to put the Strategy's mission, vision and principles into practice.

How we measure

To measure the relevance of EC's R&D in supporting the current and future needs of users, PAA program survey respondents were asked to identify themselves as users and/or producers of EC's science, rank their most significant linkages to other users/producers, and assess their degree of satisfaction with Departmental science.

Note that the survey is meant to gauge opinions across science-related EC programs. Its limitations should be considered when interpreting results; for example, each program's response is counted equally (meaning that differences in program size and resources are not accounted for).

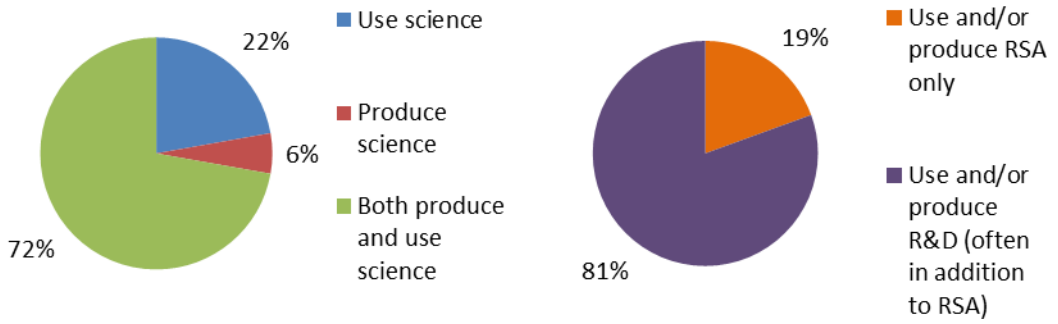
Results

Environment Canada is a science-based department, with all survey respondents (36 lowest-level PAA programs) using or producing science.

Out of 36 lowest-level PAA programs under Strategic Outcomes 1, 2 and 3 who responded to the survey, all either use or produce science. The majority (72%) both use and produce science. Out of the programs that use science, nearly all of them (97%) use RSA and about two thirds (68%) use R&D. Out of the programs that produce science, nearly all of them (93%) produce RSA and about two thirds (68%) produce R&D. Overall, 81% of program respondents are involved in using and/or producing R&D, on its own or in conjunction with RSA.

The 2009 and 2014 surveys reveal the same general finding: R&D is performed and used throughout the Department. In 2009, EC's organizational structure was different and Outcome Project leads (not PAA program leads) were surveyed. 80% of past survey respondents indicated a connection to R&D as a user, producer or funder, and almost 30% of respondents played all three roles.

Figure 2: Proportion of PAA programs surveyed that use or produce science (RSA/R&D breakdown), 2014



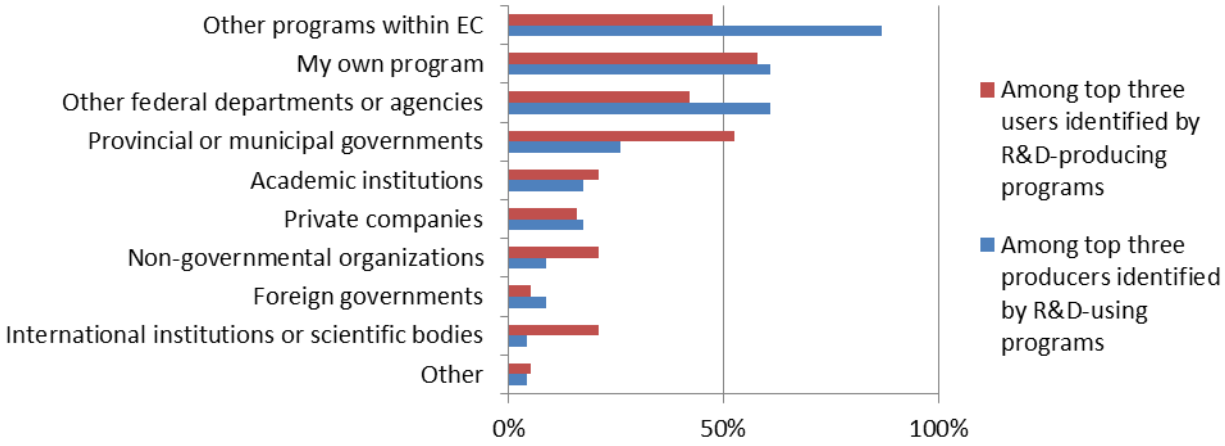
Source: Internal survey of lowest-level PAA leads (2015)

For the rest of this report, survey findings are restricted to the 23 R&D-using programs and the 19 R&D-producing programs. Programs that use or produce only RSA are excluded.

Environment Canada's science is regarded by Departmental science users/producers as highly relevant to Department and government-wide priorities while also supporting the needs of key public- and private-sector clients.

The figure below lists the most common users and producers of EC's science, as identified by R&D-producing and using PAA programs within EC. Each bar shows the percentage of PAA programs that identify that partner as one of their program's top three science users or producers.

Figure 3: Most common producers and users of EC's science, 2014



Source: Internal survey of lowest-level PAA leads (2015)

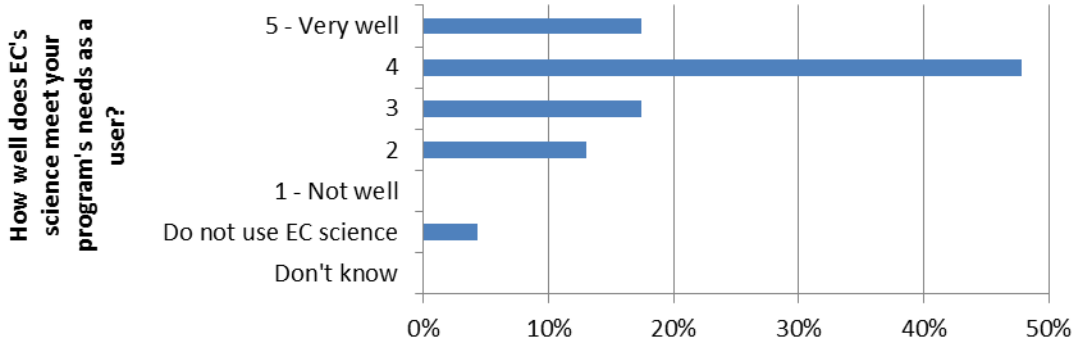
Note that 21% of R&D-producing programs ranked international institutions or scientific bodies among their top three users. This is consistent with EC's role as a prominent contributor to international fora; for example, four EC scientists were lead authors or review editors for a recent Intergovernmental Panel on Climate Change (IPCC) report, *Climate Change 2014: Impacts, Adaptation and Vulnerability*.

The 2009 and 2014 surveys reveal the same general finding: EC's science remains highly relevant to Departmental and governmental priorities. In 2009, "Other EC Outcome Projects" were identified as top science users and producers, and "Other federal departments and agencies" were top science users.[2] Present results are similar, with other EC programs and federal departments and agencies among the top users and producers.

Internal users of Environment Canada's R&D are satisfied with how Departmental science meets their needs, with the majority (83%) assigning it a positive or neutral ranking (3 or higher out of 5).

As part of the survey, R&D-using PAA programs rated how well EC's science meets their needs. As shown in the figure below, the majority (65%) feel EC's science meets their needs well or very well, and 17% are neutral. Results cannot be compared over time, as user satisfaction was not assessed in the 2009 survey.

Figure 4: Satisfaction of EC's R&D users, 2014



Source: Internal survey of lowest-level PAA leads (2015)

Environment Canada undertakes various initiatives to enhance science user/producer linkages. An inter-branch ADM forum established by the Assistant Deputy Ministers of S&T Branch and the Environmental Stewardship Branch is one example of these initiatives in which we strive to improve the alignment and communication of the Department's science in relation to our regulatory efforts.

RELEVANCE

- Support current and future needs of users
- **Deliver on the Department's mandate and key federal priorities**

Why we measure

In addition to robust linkages between science users and producers, the Department's R&D activities stay relevant by focusing on the priority areas identified in the Science Strategy. This focus helps EC's science play a meaningful role in delivering on the Department's mandate and on key federal priorities.

[2] Note that Outcome Projects were past organizational units similar to current PAA programs.

How we measure

To measure the alignment of EC's R&D with its stated priorities, the Department's journal publications were sorted by priority area. Additionally, the PAA survey asked respondents to rate the level of support their program provides to each component of EC's mandate, the Science Strategy priorities and the Department's Strategic Outcomes.

Results

Environment Canada's science delivers on all components of the Department's mandate, is aligned with Science Strategy priority areas and helps provide a clean, safe and sustainable environment for Canadians.

R&D-producing programs (19 in total) support each of the six components of EC's mandate:

- Preserve and enhance the quality of the natural environment, including water, air, soil, flora and fauna (79% of R&D producers agree their science supports this component)
- Conserve and protect Canada's water resources (63%)
- Coordinate environmental policies and programs for the federal government (53%)
- Conserve Canada's renewable resources (26%)
- Enforce rules relating to boundary waters (21%)
- Forecast daily weather conditions and warnings, and provide detailed meteorological information to all of Canada (11%)

R&D-producing programs also indicate that EC's science is relevant to all Strategic Outcomes (SO):

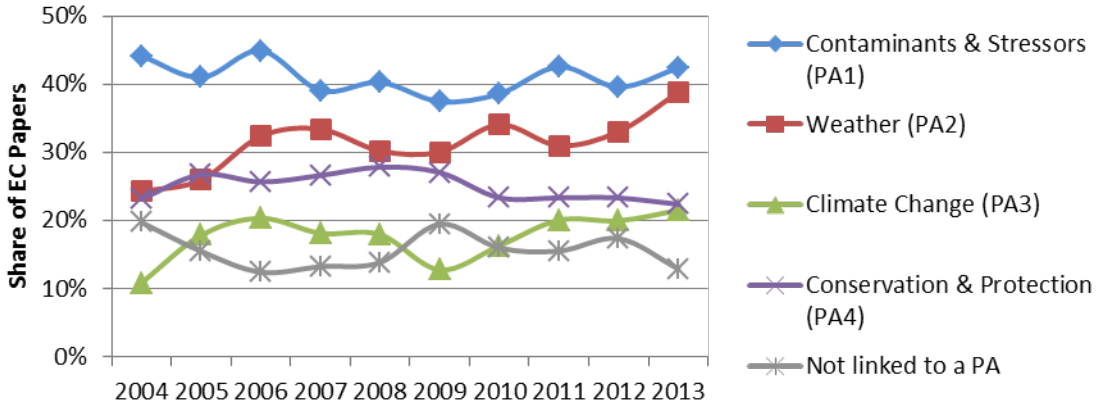
- Clean: Threats to Canadians and our environment from pollution are minimized (79% of R&D producers agree their science supports this SO)
- Safe: Canadians are equipped to make informed decisions on changing weather, water and climate conditions (42%)
- Sustainable: Canada's natural environment is conserved and restored for present and future generations (84%)

In the survey, R&D-producing respondents were asked to indicate the degree to which their program's science supports each Science Strategy priority area. A large share of respondents (84%) indicated support for Contaminants & Stressors (PA1), while Conservation & Protection (PA4) and Climate Change (PA3) had the most overall support (95% and 89% respectively). A lower percentage of respondents (58%) indicated support for Weather (PA2), which is consistent with the percentage of programs supporting the weather-focused Strategic Outcome 2 in the 2014-15 PAA.

Environment Canada's science is focused on environmental issues of current significance to the Government of Canada, with the large majority of publications (85%) supporting at least one Science Strategy priority area.

Figure 5 shows that, between 2004 and 2013, the majority of EC's publications supported one or more of the four Science Strategy priority areas (based on a study sample size of 5,711 EC papers). Of those papers, 48% were associated with Contaminants & Stressors (PA1); 37% with Weather (PA2); 21% with Climate Change (PA3); and 29% with Conservation & Protection (PA4). Note that the total equates to a sum larger than 100% as some publications were associated with more than one priority area.

Figure 5: Share of EC's publications linked to Science Strategy priority areas, 2004-2013



Source: Observatoire des sciences et des technologies, Web of Science (2014)

Overall, EC's productivity in each priority area has been sustained over the past decade. For example, EC produced between 204 and 272 publications per year related to PA1 Contaminants and Stressors. Note that scientific peer-reviewed publications are only one of many science outputs at EC.

TRANSPARENCY

- **Conduct science in an open manner**
- Make science easily accessible

Why we measure

The commitment to transparency in science fosters greater collaboration and engagement with the scientific community, the private sector, and the general public. As part of a broader Government of Canada-wide move towards Open Government, it is a priority at EC to conduct science in an open manner and facilitate access to our science, including R&D publications and data. With EC and Industry Canada as co-leads, science-based departments and agencies have committed to developing a government-wide Open Science implementation Plan.

The Open Science commitment includes the following streams of activity:

- **Open Access**: Maximize open access to publications resulting from federally-funded S&T activities.
- **Open Data**: Maximize open access to data resulting from federally-funded S&T activities, such as data supporting publications and data derived from operational activities.
- **Public Engagement**: Make information available on federally-funded S&T activities, and identify opportunities for collaboration and citizen participation.

How we measure

To measure the degree to which EC science is conducted in an open manner, the Department's publications, and the journals in which they appear, were sorted according to their approach to achieving Open Access. Additionally, analyses were carried out on the availability of datasets through Open Data initiatives.

Results

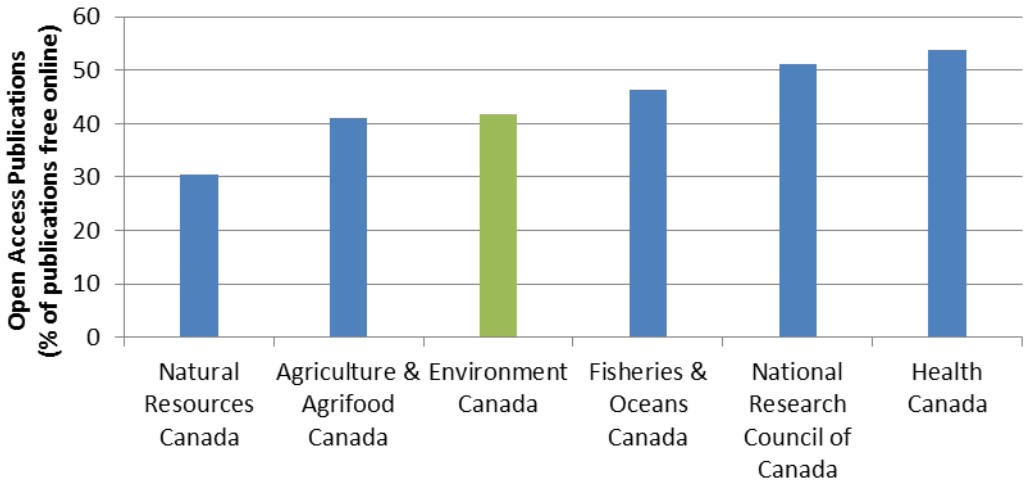
Environment Canada contributes to the Open Access movement, with nearly half of its 2010-2012 scientific peer-reviewed publications available free and online.

In this report, the definition of an "Open Access" (OA) publication is limited to any scientific peer-reviewed publication with the full text available online and free of charge, for everyone to read. No copyright licence analysis was done to determine the extent of reuse allowed. Open Access makes methodologies and results more widely available, enabling a larger community to view the scientific research. This openness to critical discussion is central to the scientific process, and every effort to facilitate such discussion ultimately contributes to the increased quality of research.

According to a 2013 pilot study by the Observatoire des sciences et des technologies (OST), about 42% of EC publications are OA. That sits in the middle of the range of the six most productive (in terms of number of publications) science-based departments and agencies.

For context, based on a study by Science-Metrix completed in 2013, about 43% of peer-reviewed papers published world-wide between 2008 and 2011 are OA. The study also notes that OA levels tend to differ by scientific field; OA papers are most common in general S&T (64%), biomedical research (61%) and biology (57%). In comparison, about 45% of papers in earth and environmental sciences worldwide are OA. So, overall, EC and other federal departments are in step with the international science community in terms of OA.

Figure 6: Proportion of Open Access federal publications, 2011-2012



Source: Observatoire des sciences et des technologies, Web of Science (2013)

A follow-up OST study focused specifically on EC, examining all of the Department's publications from 2010-2012. Through this more comprehensive assessment, it was determined that nearly half (49%) of EC's publications from those years are OA.

The assessment also examined the journals in which EC work was published, cataloguing how those journals offered Open Access to the articles they published, and sorting journals into four categories:

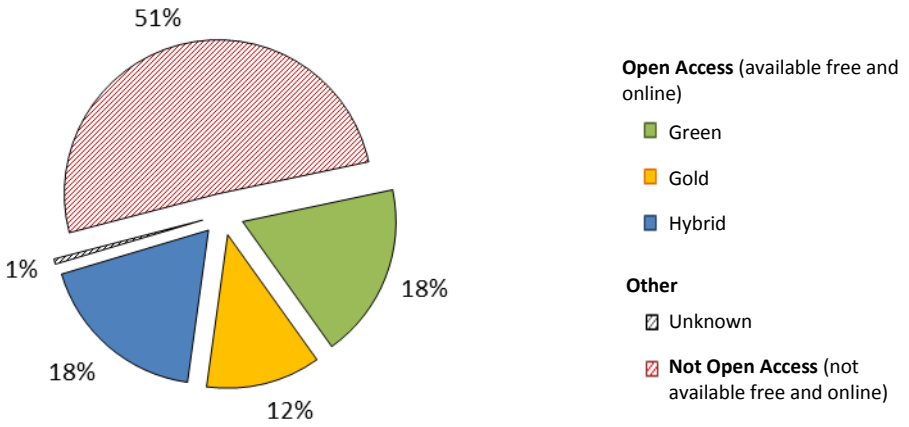
- Gold[3] journals make all their articles OA through their own repositories, either free of charge or through a publication fee paid by the authors, called an "article processing charge" (APC);
- Green journals achieve OA by allowing authors to self-archive their articles, usually through a disciplinary, institutional or personal repository;
- Hybrid journals give authors the option to either pay an APC in exchange for immediate OA to their article through journal repositories, or distribute the article for free through journal repositories after a predetermined embargo period;
- Red journals offer none of the above.

As shown in figure 7, about 12% of EC's publications are in Gold journals. Although 37% of EC's publications are published in Green journals, only about half of those articles (18%) are available online free of charge through an external archive. Articles in Hybrid journals make up the largest portion of EC's publications (49%) and about one third of EC papers published in that category (18%) are freely available (either because the author paid the fee, or because the embargo period had elapsed).

[3] Note that "Gold" characterizes a level of accessibility, not necessarily a level of quality. The first priority for EC authors is to publish in an appropriate journal; OA may not be an option. For information on the scientific impact of EC's research, see the Excellence section in this report.

Data is not available for previous levels of Open Access as this was not included in the assessment of EC R&D conducted in 2009. In future reports, these findings can provide an important baseline against which to gauge ongoing efforts to promote transparency at EC.

Figure 7: Breakdown of EC publications by online availability and OA category, 2010-2012



Source: Observatoire des sciences et des technologies, Web of Science (2013)

Environment Canada's scientific datasets are increasingly being made available to employees and the public under Open Data initiatives.

With Canada's Action Plan on Open Government 2014-16, the Government of Canada is shifting towards an environment where data and information are released openly to the public by default, while respecting privacy, security and confidentiality restrictions. The Government of Canada Open Data Portal was launched in 2011, and as of February 12, 2015, it provides online access to 244 EC datasets on topics such as greenhouse gas emissions, water quality, biodiversity, chemicals and pollution. Where possible, this content is provided in non-proprietary, machine-readable formats, to facilitate re-purposing the data for novel applications.

The Canada-Alberta Oil Sands Environmental Monitoring Information Portal is a key example of Open Data.

The Government of Canada and the Alberta Environmental Monitoring, Evaluation and Reporting Agency are collaborating to provide the public with data about the impacts of oil sands activity over an area covering some 140 000 km^2, including maps of monitoring regions, details of monitoring sites and raw datasets, as well as scientific analysis and interpretation of that data. The portal was launched April 22, 2013. Its content is organized according to the themes of air, biodiversity and land disturbance, water, and wildlife.

In addition to making EC datasets available to the public through the Government of Canada's Open Data Portal, EC employees have access to 611 datasets and 1343 monitoring sites through the EC Data Catalogue as of August 20, 2015. The EC Data Catalogue had 1979 unique visitors and 7456 total visitors from October 2014 to July 2015. Datasets can include numerous resources, such as methodological information and summary materials. While EC is moving towards a

consolidated approach to Open Data, it is important to note that the EC Data Catalogue does not capture all data produced by the Department. For example, MSC produces extensive monitoring and model output data which is not included in the EC Data catalogue.

TRANSPARENCY

- Conduct science in an open manner
- **Make science easily accessible**

Why we measure

Increasing the availability of EC science, by providing free online access to publications is an important element of transparency; but availability alone does not guarantee that the science will be fully accessible to those who need to use it. For example, comprehension barriers sometimes stand in the way of non-specialists. EC scientists take a number of steps to overcome these kinds of obstacles, contributing to the transparency of Departmental science to users.

How we measure

The degree of accessibility of EC science was assessed based on the provision of plain-language summaries, scientific expert profiles, and traditional and social media activity.

Results

Environment Canada's science is accessible to non-specialists through initiatives such as EC Science Alert, traditional and social media.

- **Authors of technical articles write a plain-language summary and discussion of policy implications.**

These materials are included with the record of publication in EC Science Alert's science summary database, and thereby made accessible to policy- and decision-makers, analysts, and the rest of EC staff. In 2014, 724 publication records were added to the database, each of which included a plain-language summary.

- **EC science is accessible to the public through Departmental websites, ec.gc.ca and weather.gc.ca.**

This includes Environmental Science Experts, a collection of over 300 profiles of the Department's scientists and technical experts (including contact information and a description of current research) which is available on EC's website. It allows colleagues within government, academia, industry and the public to connect with experts in specific scientific fields. In 2014, Expert profiles received 62 086 views—about one third of total views in the S&T Branch section of EC's website.

- **EC science is accessible to the public through traditional news and social media.**

In 2014, EC received close to 5,800 requests for information from media. In response to these requests, more than 4,100 interviews were granted by subject matter experts. Of these, more

than 3,800 were handled by Warning Preparedness Meteorologists, and 369 interviews were granted by other subject matter experts, including scientists, climatologists and ice forecasters.

EC engages the public via social media, in particular Facebook and Twitter. The Department also runs special activities for the public, such as lab tours and youth engagement. For example, in early 2015, a group of high school students and media toured the Atlantic Laboratory for Environmental Testing and met the facility's leading researchers and technicians.

RESPONSIVENESS

- **Anticipate, adapt to and respond to new science realities and priorities**
- Maintain scientific expertise and capacity across environmental science, as needed to support the Department's mandate

Why we measure

To remain relevant in a rapidly changing global context, the Department's R&D must be responsive to new science realities and priorities. Such responsiveness helps EC produce scientific knowledge in a timely manner in order to deliver on its mandate and address complex environmental problems of national importance.

How we measure

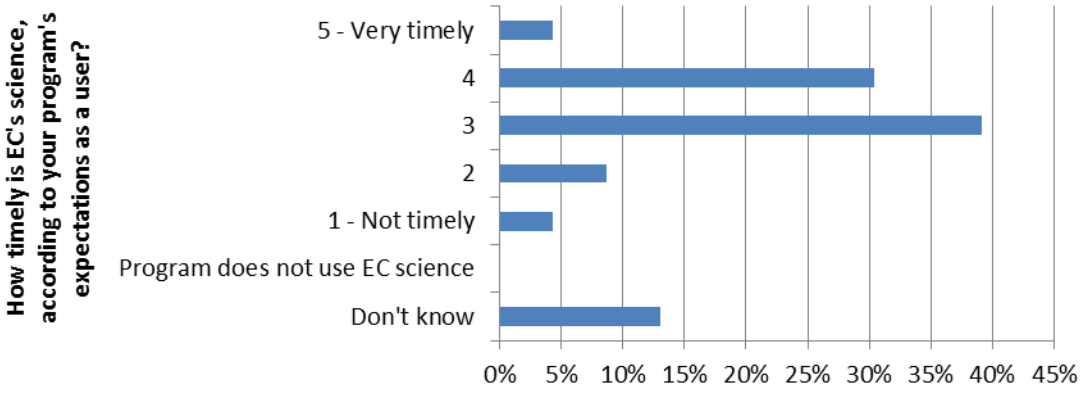
To measure the Department's responsiveness to changing realities and priorities, the PAA survey asked respondents to rate the timeliness and adaptability of EC's science.

Results

Environment Canada's science is produced in a timely manner, with the majority of R&D-using survey respondents (74%) assigning it a positive or neutral ranking (3 or higher out of 5).

As part of the survey, R&D-using PAA programs (23 in total) rated the timeliness of EC's science. As shown in Figure 8, 4% of users feel EC's science is not timely. About one third (35%) of users feel EC's science is timely or very timely, and 39% are neutral.

Figure 8: Timeliness of EC's science, according to R&D users, 2014



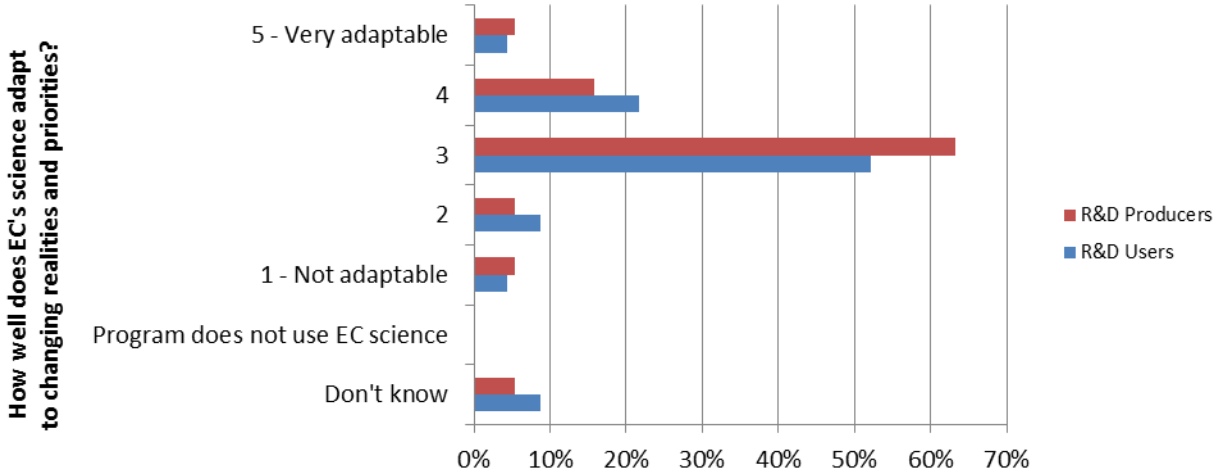
Source: Internal survey of lowest-level PAA leads (2015)

This data represents a decrease from the findings from the 2009 report, where 86% of Outcome Projects that funded or relied on EC's R&D ranked timeliness as 3 or higher out of 5: 70% reported that EC's R&D was timely or very timely, and 16% were neutral.

Environment Canada's science is adaptable, with the majority of survey respondents (78% R&D users, 84% R&D producers) assigning it a positive or neutral ranking (3 or higher out of 5).

As part of the survey, R&D-using programs (23 in total) and producing programs (19 in total) rated the adaptability of EC's science. These results are shown in the figure below. Both users and producers felt similarly about the adaptability of EC's science.

Figure 9: Adaptability of EC's science, according to R&D users and producers, 2014



Source: Internal survey of lowest-level PAA leads (2015)

About one quarter (26% users, 21% producers) feel that EC's science is adaptable or very adaptable, and the majority are neutral (52% users, 63% producers). Only 4-5% of R&D users and producers feel EC's science is not adaptable.

This data represents a decrease from the findings in the 2009 report, where 84% of Outcome Projects that funded or relied on EC's R&D ranked adaptability as 3 or higher out of 5: 68% reported that EC's R&D was responsive or very responsive to their priorities, and 16% were neutral.

The apparent decreases in timeliness and adaptability compared to 2009 levels cannot be explained with the information currently available. To obtain further information, future work such as interviews with science users and producers (i.e., PAA program leads, individual scientists and users of science within the department) would have to be conducted.

Through the Science Strategy, EC is focused on improving all aspects of linkages between users and producers, including user satisfaction, timeliness and adaptability. Open Science is another mechanism for improving the timeliness of EC's science; for example, EC is working to publish scientific data and peer-reviewed publications online in a timely manner.

EC's science contributes to responsiveness through World Class Tanker Safety initiatives.

EC's contributions to the World Class Tanker Safety initiatives are a clear demonstration of responsiveness to increasing shipments of Canadian oil products. Funding was approved for a state-of-the-art Next Generation Environmental Simulator that will be unique of its kind in North America. This simulator will enable EC's emergencies S&T scientists to undertake large-scale experiments on oil fate and behavior in marine environments. This builds on the strong research EC and other federal departments have produced in this area in recent years, such as a 2013 report on the marine spill behaviour and other properties of diluted bitumen products from the Canadian Oil Sands.

RESPONSIVENESS

- Anticipate, adapt to and respond to new science realities and priorities
- **Maintain scientific expertise and capacity across environmental science, as needed to support the Department's mandate**

Why we measure

A strong enabling environment, including financial resources, world-class infrastructure and highly skilled people, plays an important role in ensuring the Department's activities can anticipate and adapt to evolving realities.

How we measure

To measure the health of this environment, Statistics Canada and Finance Branch data was analyzed, cataloguing EC's personnel as well as gross and capital expenditures dedicated to R&D. Additionally, the distribution of Departmental publications across scientific fields was examined.

Results

The proportion of EC's budget devoted to science and technology has remained relatively stable over the past decade.

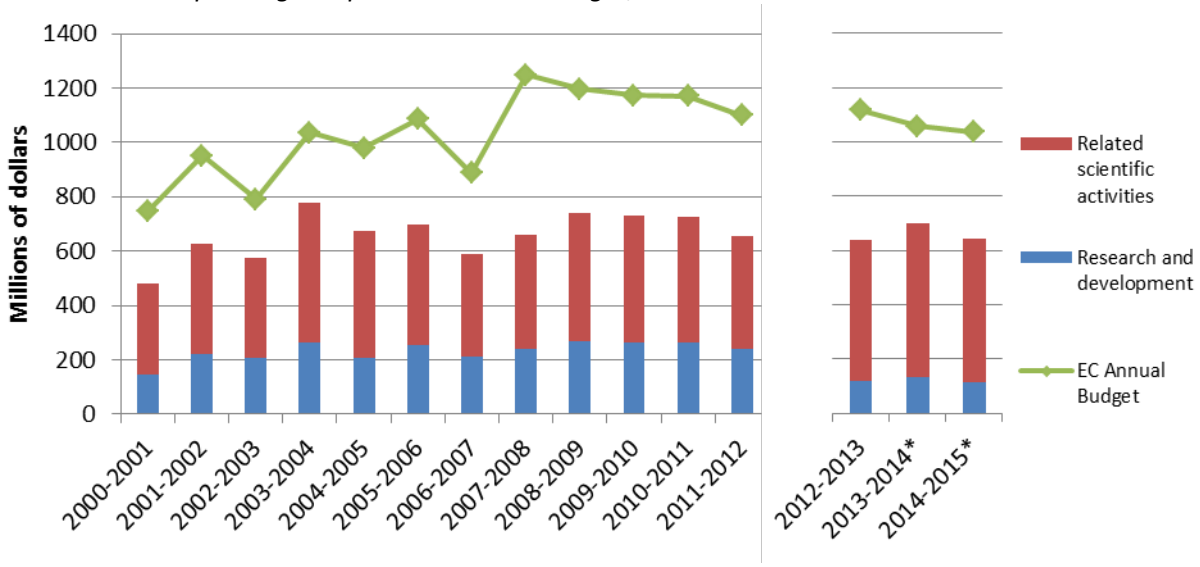
Figure 10 shows EC's S&T spending (separated into R&D and RSA) compared to EC's annual budget for the periods of 2000-2012 and 2012-2015. A methodological change in the allocation of RSA vs. R&D expenditures and personnel makes it impossible to compare R&D spending between the two periods.[4]

However, it is possible to compare EC's total S&T spending with the Department's annual budget over the two time periods. Increases and decreases in EC's S&T spending are closely associated

[4] Due to a change in reporting methodology, personnel and spending are shown in two different time periods: 2000-01 to 2011-12, and 2012-13 to 2014-15. During the first time period, data from 2001 was used to develop fixed ratios to divide S&T spending at the Departmental level into R&D and RSA components. This fixed ratio was kept until 2011-12. For the 2012-13 data, that ratio was updated, using an internal survey of cost centres and analysis of contracts, grants and contributions, and capital spending data. Moving forward, this ratio will be updated annually, allowing data to be collected at a finer level of detail and more accurate analyses to be conducted.

with increases and decreases in the annual budget. S&T spending in 2012-13 remained consistent with previous years. Overall, the proportion of Departmental spending devoted to S&T has remained relatively stable (around 60%) for the past decade.

Figure 10: EC S&T spending compared to annual budget, 2000-2015

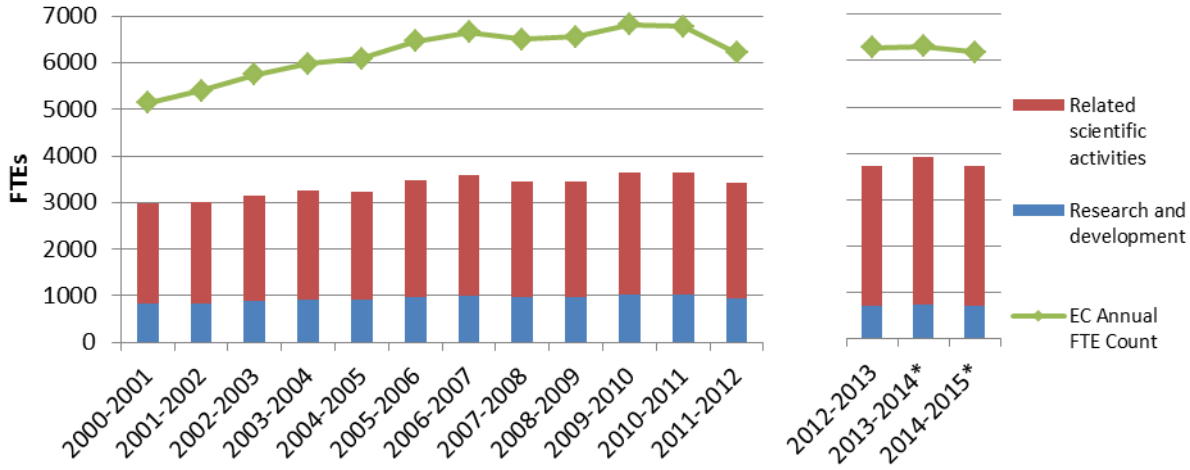


Source: Statistics Canada, CANSIM Table 358-0163 "Federal expenditures on science and technology, by major departments and agencies, annual (dollar)" (2014)
**Data for 2013-2014 and 2014-2015 are projections.*

The majority of EC's staff (around 60%) were engaged in EC's S&T activities in 2012-13, either directly or in a supporting role. This proportion has remained relatively stable over the past decade.

Figure 11 shows EC's S&T personnel (separated into R&D and RSA) in both time periods, before and after the reporting methodology change. As with expenditures, increases and decreases in EC's S&T personnel are closely associated with increases and decreases in EC's total FTE count. Note that the apparent drop in R&D personnel between both time periods can be attributed to the methodological change that affected how EC defines and measures its R&D and RSA activities. Overall, the proportion of Departmental FTEs devoted to S&T has remained relatively stable (around 60%) for the past decade.

Figure 11: EC S&T personnel compared to total personnel, 2000-2015

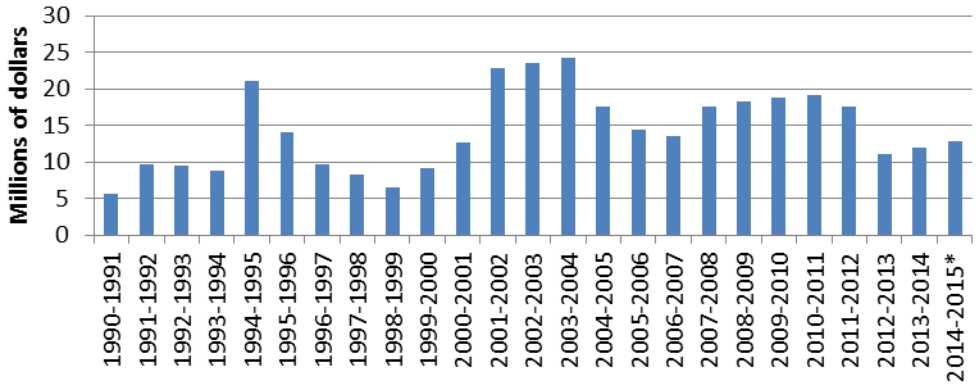


Source: Statistics Canada, CANSIM Table 358-0166 "Federal personnel engaged in science and technological activities, by major departments and agencies, annual (number)" (2014)
**Data for 2013-2014 and 2014-2015 are projections.*

Since 2012-13, EC's S&T capital expenditures on R&D are about $12 million per year.

The figure below shows that EC's S&T capital expenditures on R&D (facilities, laboratory equipment, etc.) have seen a large degree of variation since 1990. It should be noted that weather-related R&D relies extensively on MSC's capital expenditures, such as radar system upgrades. International projects and investments, such as research stations, are also leveraged whenever possible. Overall, EC's infrastructure is currently in good shape: laboratory facilities are relatively young compared to those of other federal science-based departments and agencies, capital planning processes are well-managed, and projects are planned with a holistic approach.

Figure 12: EC's S&T capital expenditures on R&D, 1990-2013

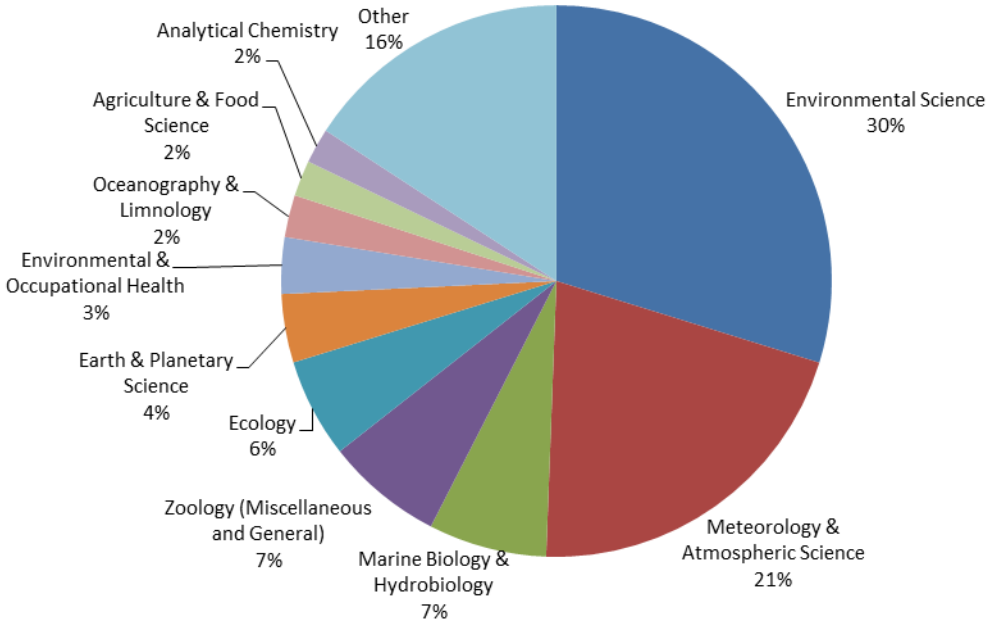


Source: EC Finance Branch data (2014)
**Data for 2014-2015 is a projection.*

Environment Canada publishes across a diversity of scientific fields.

Publication in a diversity of scientific fields shows that EC has the broad base of scientific expertise necessary to respond to emerging issues. The figure below uses a study sample size of 5,711 EC papers from 2004-2013 to demonstrate this diversity.

Figure 13: EC's R&D diversity, 2004-2013



Source: Observatoire des sciences et des technologies, Web of Science (2014)
Note: Categories are based on Thomson-Reuters journal categories.

EC's R&D has a strong focus on the categories of Environmental Science and Meteorology & Atmospheric Science. These two categories together make up more than half of EC's publications.

Although direct comparisons to the 2009 data is difficult due to different database classification systems (Scopus versus Thomson-Reuters) and timescales (2003-2007 versus 2004-2013), it is interesting to note that, in the 2009 report, the largest category was Climate, Meteorology and Atmospheric Sciences (24%). This finding is similar to the data shown above, with 21% of journals in Meteorology & Atmospheric Science.

EXCELLENCE

- **Maintain stature, reputation and productivity**
- Adhere to internationally recognized standards and processes

Why we measure

EC is regarded as a world leader in environmental science. That reputation for excellence is built on the Department's R&D, which is conducted by highly skilled researchers and scientists working with integrity, rigour, and creativity.

How we measure

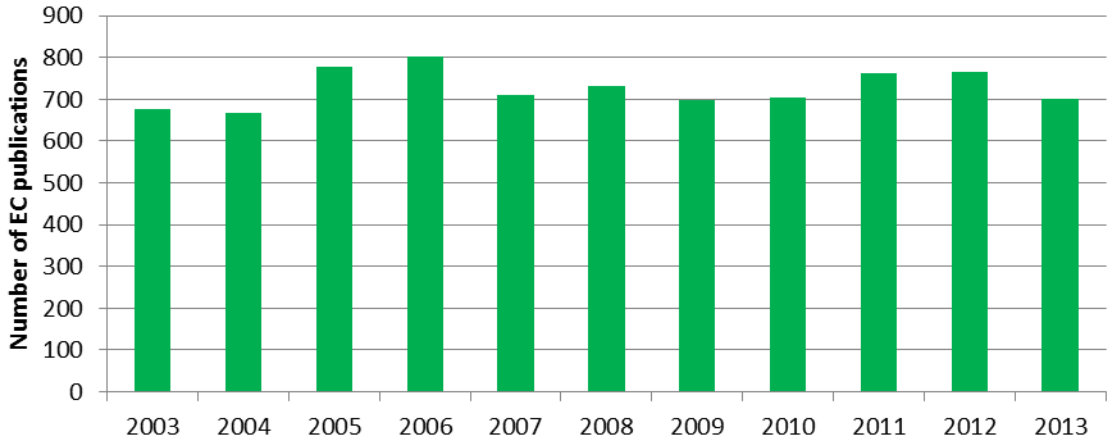
The excellence of EC's R&D is measured by the number and scientific impact of EC's publications in peer-reviewed journals.

Results

Environment Canada is a highly productive institution, publishing around 700 scientific peer-reviewed papers per year.

Based on 2012 Science-Metrix data, EC ranks second in Canada (behind the University of British Columbia) and twentieth in the world in terms of number of environmental science publications. In a previous study, EC had ranked first in Canada and seventh in the world (Science-Metrix 2007). This decline in rank is primarily due to the fact that some other institutions have seen significant growth in the number of environmental science publications, while EC's scientific publication output has remained relatively stable, as shown in the figure below. EC has produced around 700 scientific peer-reviewed papers per year over the past decade.

Figure 14: Number of EC's publications, 2003–2013



Source: Scopus data compiled by Science-Metrix for years 2003-2009 (2012) and by EC for years 2010-2013 (2014)

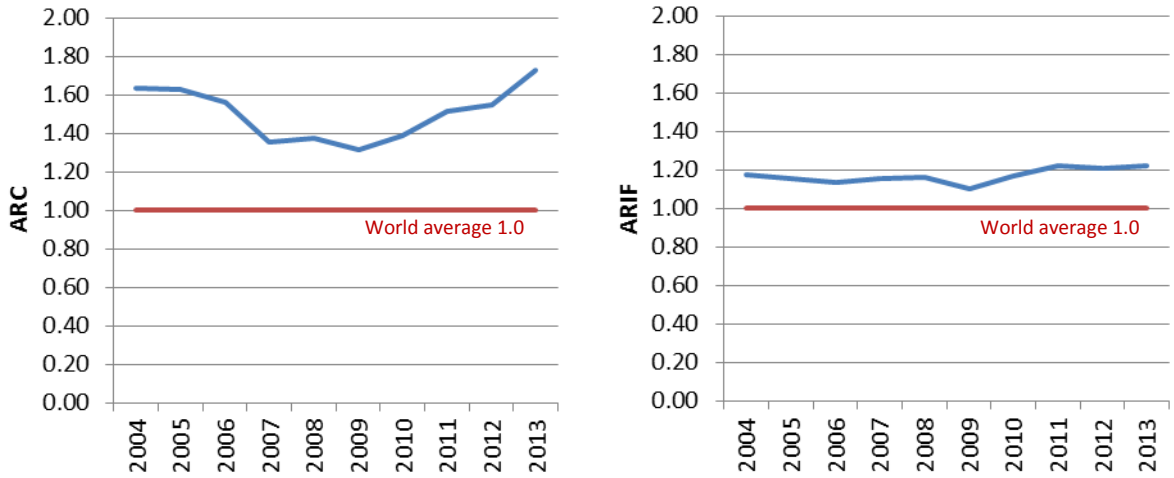
The scientific impact of Environment Canada's publications is well above world average as measured by Average Relative Citation (ARC) and Average Relative Impact Factor (ARIF).

EC excels in quality as well as quantity of publications. Based on an OST study of 5,711 EC papers from 2004-2013, EC's papers are cited 50 per cent more than world average (ARC 1.5)[5] and are published in more impactful journals than world average (ARIF 1.17).[6] This data represents an increase from the ARC of 1.4 presented in the 2009 report for papers from 2003-2007.

Based on the figure below, the ARC of EC's publications decreased from 2004 to 2009, but has increased since then. This apparent fluctuation in scientific impact cannot be explained with the data currently available. ARIF has remained relatively stable since 2004.

Even at their lowest point, EC's ARC and ARIF are well above world average. This sustained high quality of EC's peer-reviewed scientific publications contributes to the institution's credibility and reputation.

Figure 15: Scientific impact of EC's publications, 2004-2013



Source: Observatoire des sciences et des technologies, Web of Science (2014)

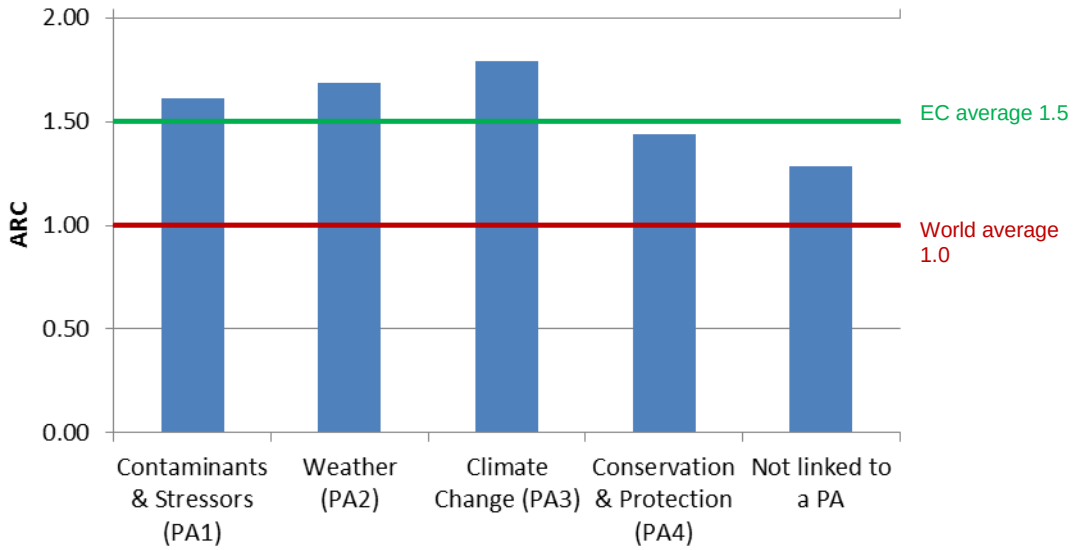
[5] Average of relative citations (ARC): This indicator provides the number of citations received by each paper, normalized by the average number of citations received by all papers of the same year of publication and the same subfield (as defined by US National Science Foundation classification of journals), hence taking into account the fact that citations practices are different for each subfield.

[6] Average relative impact factor (ARIF): This indicator provides a measure of the scientific impact of the journals in which an entity (i.e., country or institution) publishes. Each journal has an impact factor (IF), which is calculated annually by counting the number of citations the journal receives relative to the number of papers it publishes. For calculating the ARIF, the value of a journal's IF is first assigned to each paper it publishes. In order to account for different citation patterns across disciplines and specialities, each paper's IF is then divided by the average IF of the papers in its particular subfield in order to obtain a Relative Impact Factor (RIF). The ARIF of a given entity is computed using the average RIF of all papers it published.

Within Environment Canada, the Department's science is most impactful in Climate Change (PA3) and least impactful when it does not fall under a priority area (as measured by ARC).

Papers published in Contaminants & Stressors (PA1) and Weather (PA2) are highly impactful, with ARCs above both world and EC average. The ARC of papers published in Conservation & Protection (PA4) is above world average, but below EC average.

Figure 16: Scientific impact of EC's publications by priority area (ARC), 2004-2013



Source: Observatoire des sciences et des technologies, Web of Science (2014)

Compared to other institutions, Environment Canada's science is world-leading in Contaminants & Stressors (PA1) and Weather (PA2). Productivity in Climate Change (PA3) and Conservation & Protection (PA4) are potential areas for improvement.

EC's productivity, scientific impact and specialization in each priority area were compared with top national and international institutions. Productivity was measured by number of publications. Scientific impact was measured by ARC. Specialization was measured by a specialization index, based on the intensity of institutions' publications in a particular field (i.e., priority area).

Figure 17: EC's productivity, scientific impact and specialization by priority area, 2004-2013

Priority area	Productivity		Scientific impact		Specialization	
	Rank in Canada	Rank in world	Rank in Canada	Rank in world	Rank in Canada	Rank in world
Contaminants & Stressors (PA1)	1st	4th	6th	10th	1st	2nd
Weather (PA2)	1st	16th	5th	16th	2nd	3rd
Climate Change (PA3)	3rd	n/a	8th	n/a	2nd	n/a
Conservation & Protection (PA4)	4th	n/a	8th	n/a	4th	n/a

Source: Observatoire des sciences et des technologies, Web of Science (2014)
Note: Top Canadian and international institutions were identified by their productivity in each priority area. A rank of "n/a" means that EC was not in the top 25 most productive institutions. No further comparison was done.

EXCELLENCE

- Maintain stature, reputation and productivity
- **Adhere to internationally recognized standards and processes**

Why we measure

In addition to its strong publication record, Environment Canada maintains excellence by adhering to internationally recognized standards and processes, which assure the integrity of EC science within the scientific community worldwide.

How we measure

EC's adherence to these standards was measured by reference to the accreditation of Departmental labs and systems under the Canadian Association for Laboratory Accreditation Inc. (CALA) and International Organization for Standardization (ISO), and by EC's contribution to the establishment of a new ISO standard.

Results

Environment Canada upholds the importance of international standards by securing accreditation of its laboratories through the Canadian Association for Laboratory Accreditation Inc.

The accreditation and governance of an institution's facilities are important components when examining the excellence of its science. EC currently has 15 laboratories accredited through CALA, including 11 "wet" labs and 4 "dry" labs.[7] The Department's consolidation of the S&T Branch in 2005 contributed to more effective capital planning, investment, and overall enterprise management of the Department's laboratory assets.

[7] "Wet" labs are facilities equipped with the appropriate plumbing, ventilation, and instrumentation for hands-on scientific research and experimentation. These facilities enable EC's scientific personnel to conduct analysis in disciplines such as biology, chemistry, ecotoxicology, microbiology and genomics. "Dry" labs are computer-based facilities where applied mathematical analyses and computer-generated models are used for science, such as climate and weather modeling and simulation.

One way in which EC adheres to internationally recognized standards and processes in its laboratories is by securing accreditation by CALA where possible. CALA is recognized internationally as a not-for-profit accreditation body. It serves public and private sector testing laboratories in Canada and abroad, with laboratory accreditation programs in the fields of environmental, food, mineral, and petroleum testing. CALA accreditation provides assurance that EC laboratories are competent to carry out the environmental testing that supports environmental monitoring programs and regulations.

According to the CALA Directory, there are currently twelve EC facilities accredited by CALA (including mobile laboratories and external laboratory space). This represents an increase from the 2009 report, which listed nine EC facilities certified under CALA.

Environment Canada contributes to international scientific standards and processes through a variety of fora.

MSC's weather warning system is certified to the International Organization for Standardization (ISO) 9001:2008 Standard through a Quality Management System. This standard provides a framework that helps MSC identify and understand customers' needs, and put in place processes to meet those needs. A key component of the certification is a commitment to continuously improving the quality of the information provided to Canadians.

EC not only adheres to international standards, it contributes to them in a variety of ways:

- **EC leads the development of an ISO standard on Environmental Technological Verification.**

Through the S&T Branch, EC manages Canada's Environmental Technology Verification (ETV) Program. The Program offers independent validation of environmental performance claims for innovative technologies, processes, and products. The ETV process is based on sound science, high-quality data, and recognized protocols.

In an effort to harmonize similar such initiatives globally, there was international interest in developing a common protocol for ETV. As a result, Canada is currently leading the development of an ISO standard on ETV. This standard, expected to be published in 2016, will facilitate recognition of environmental technologies and their capabilities across jurisdictions. International recognition of a common ETV protocol will foster faster and more widespread adoption of technologies to help solve environmental challenges.

- **EC develops standardized biological testing methods and contributes to international inter-laboratory validation activities.**

Standardized biological testing methods for monitoring and controlling toxins and contaminants are essential for protection of the Canadian environment. Since 1990, EC has published 24 standardized test methods and 7 supporting national guidance documents for performing biological testing in water, sediment and soil. Each method was primarily developed to help fulfill an existing or future regulatory need in Canada (i.e., CEPA, Fisheries Act, provincial regulations).

A high degree of national and international consistency has been achieved due to the collaboration of laboratories during the development of each test method. Each method undergoes a rigorous process of development and validation, including two rounds of peer review and numerous rounds of inter-laboratory validation. The research and standardization process can take up to several years to complete.

COLLABORATION

- **Collaborate with colleagues in the Department and across federal government, and with domestic and international partners**
- Share information and expertise across disciplines, sectors, and jurisdictions

Why we measure

Science is a collaborative enterprise, and EC's science is strengthened by the Department's collaborations with domestic and international partners. Examining the Department's partnerships allows EC to better position itself within the broader environmental research landscape.

How we measure

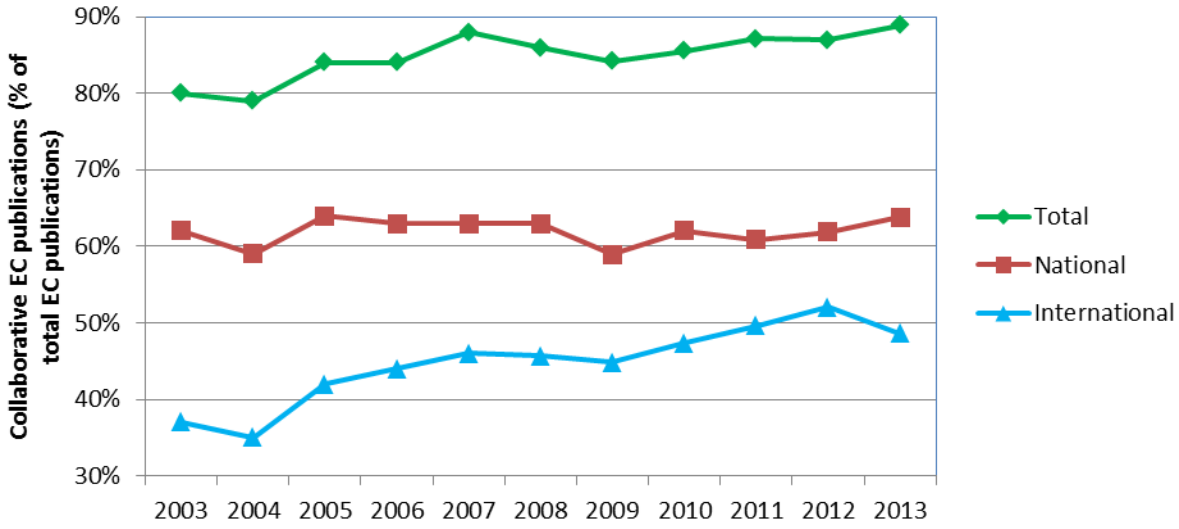
The extent of EC's scientific collaborations was measured by analysing information on rates of publication co-authorship and home institutions of those co-authors. The effect of collaborations was measured by comparing the scientific impact of collaborative and non-collaborative publications.

Results

Environment Canada is highly collaborative, co-authoring nearly 90% of its publications in 2013.

Figure 18 shows the share of EC publications that are co-authored with external partners, both national and international. The overall trend is an increase in collaboration over time. National collaboration has remained relatively steady, while international collaboration has increased more sharply. This sustained high level of collaboration with top national and international institutions helps EC stay at the leading edge of scientific inquiry.

Figure 18: Collaboration with national and international partners, 2003-2013



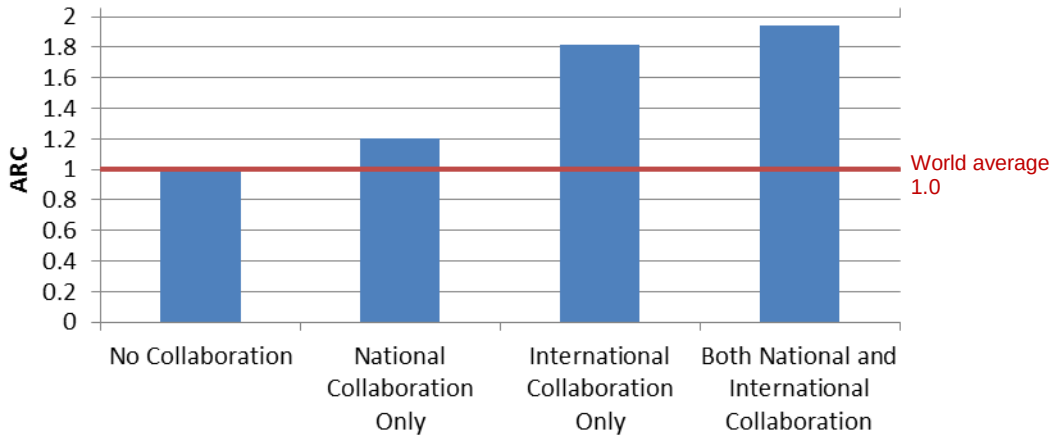
Source: Scopus data compiled by Science-Metrix for 2003-2007 (2009), and EC for 2008-2013 (2014)
Note: Some papers are published with both national and international partners making the sum of international and national collaborations greater than the total number of collaborations.

Collaboration greatly increases the scientific impact of Environment Canada's R&D (as measured by ARC).

Compared to EC publications produced without any external collaboration, papers with national co-authors are cited 20% more often, those with international co-authors 80% more often, and those with both national and international co-authors almost twice as often. Similar trends were observed in the 2009 report.

The high scientific impact of papers with international co-authors is well-aligned with the trend of increasing international collaboration (see Figure 18, above).

Figure 19: Scientific impact of collaborative versus non-collaborative papers (ARC), 2008-2013



Source: Observatoire des sciences et des technologies, Web of Science (2014)

Environment Canada's top national collaborators have changed slightly over time, but Canadian universities remain the Department's strongest partners. At the same time, top international collaborators have stayed relatively unchanged, with American governmental institutions remaining the Department's strongest partners.

As shown in the figure below, collaboration with the University of Alberta has increased significantly in recent years; it is now one of EC's top five national collaborators. The other four top national collaborators have remained relatively stable. Fisheries and Oceans Canada remains the top collaborating federal department. Environmental Chemistry and Ecology, Evolution, Behavior and Systematics are the main scientific fields for national collaboration.

Figure 20: EC's top national collaborators, 2003-2013

Institution	Rank in 2008-2013	Change in rank since 2003-2007	Main scientific field 2008-2013
University of Toronto	1	0	Atmospheric Science
University of Saskatchewan	2	+1	Ecology, Evolution, Behavior and Systematics
Fisheries and Oceans Canada	3	+1	Environmental Chemistry
University of Alberta	4	+9	Ecology, Evolution, Behavior and Systematics
University of Waterloo	5	0	Environmental Chemistry

Source: Scopus data compiled by Science-Metrix for 2003-2007 (2009), and EC for 2008-2013 (2014)

The number of collaborations per year with EC's top national collaborators is generally higher now than in the past. For example, the University of Toronto remains EC's top national collaborator, but its present rate of collaboration (measured by number of co-authored publications) has increased by about 15 papers per year compared to its past rate.

Internationally, EC's scientists collaborate most with partners in the United States. Five years ago, EC's top collaborating institutions were based in the United States (NOAA, NASA, USGS), France (CNRS) and Denmark (NERI). Today, two different American institutions (UCAR/NCAR and University of Colorado) have entered the top five. Atmospheric Science is the main field for international collaboration.

Figure 21: EC's top international collaborators, 2003-2013

Institution	Rank in 2008-2013	Change in rank since 2003-2007	Main scientific field 2008-2013
NOAA - National Oceanic and Atmospheric Administration (USA)	1	0	Atmospheric Science
CNRS - Centre national de la recherche scientifique (France)	2	+1	Atmospheric Science
UCAR/NCAR - University Corporation for Atmospheric Research and National Center for Atmospheric Research (USA) [8]	3	+5	Atmospheric Science
NASA - National Aeronautics and Space Administration (USA)	4	-2	Atmospheric Science
University of Colorado (USA)	5	+1	Atmospheric Science

Source: Scopus data compiled by Science-Metrix for 2003-2007 (2009), and EC for 2008-2013 (2014)

As above, EC's rate of collaboration with these top institutions has increased over time. For example, NOAA remains EC's top international collaborator, but its rate of collaboration (measured by number of co-authored publications) has increased by about 10 papers per year.

COLLABORATION

- Collaborate with colleagues in the Department and across federal government, and with domestic and international partners
- **Share information and expertise across disciplines, sectors, and jurisdictions**

Why we measure

By sharing resources such as facilities, funding, information and expertise, EC is a highly active member of the scientific community, greatly improving the quality of its science.

How we measure

In addition to its institutional partnerships, the Department's collaboration can be measured through partnerships with different sectors, different jurisdictions, and Indigenous communities.

[8] UCAR and NCAR are essentially the same institution and have been combined in this table. UCAR was the more popular affiliation in 2003-2007, NCAR in 2008-2013.

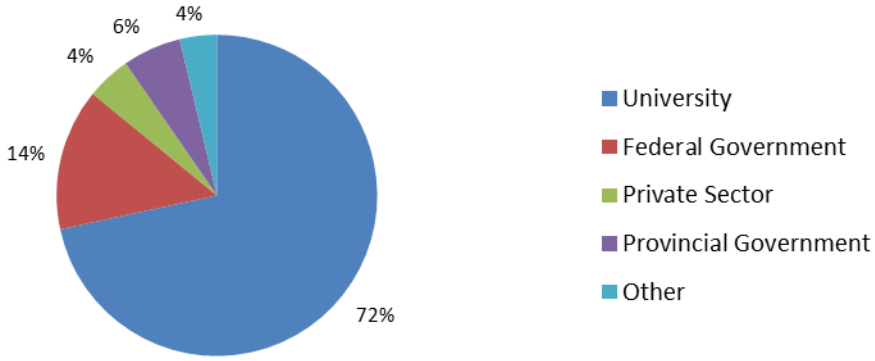
Results

While Environment Canada collaborates with a diversity of sectors, the academic sector remains the Department's strongest national partner.

The figure below shows national collaboration by sector for 2008-2013. The 2008-2013 proportions are similar to the 2003-2007 proportions presented in the 2009 report: co-authorship with universities and the federal government has increased, co-authorship with provincial governments has remained stable, and co-authorship with the private sector, health sector and other sectors has decreased.

This strong collaboration with the national academic sector is consistent with Figure 20 above, showing the top five national collaborators (past and present).

Figure 22: National collaboration by sector, 2008-2013



Source: Scopus data compiled by EC (2014)

Environment Canada collaborates with provincial and territorial governments to perform R&D.

Figure 23 shows the number of co-authors associated with a provincial or territorial government who collaborated on at least one publication with EC between 2008 and 2013. As the environment is a cross-jurisdictional responsibility, it is important for all levels of government to be involved in R&D. In the time period examined, EC collaborated with every Canadian province and territory. EC collaborated most frequently with Ontario, followed by Quebec, Alberta and British Columbia.

Figure 23: Collaboration with provincial and territorial governments, 2008-2013

Source: Scopus data compiled by EC (2014)

Environment Canada collaborates with Indigenous communities.

Collaboration between EC scientists and Indigenous communities is important for R&D in environmental science. As EC conducts environmental research in many areas of the country, including on Indigenous lands, the Department has an important responsibility to work closely with Indigenous governments, organizations and communities, considering community viewpoints and Aboriginal Traditional Knowledge alongside its scientific research.

One example is the 2012 Recovery Strategy for the Woodland Caribou in Canada. Recognizing the important traditional, cultural, and spiritual role of boreal caribou in the lives of Indigenous people, EC sought considerable involvement from Indigenous communities in the development of the recovery strategy for boreal caribou. Two rounds of engagement were undertaken, with a focus on seeking input and sharing information with Indigenous communities. In addition, EC supported processes to gather Aboriginal Traditional Knowledge. These two components were essential in the development of the Recovery Strategy.

Nationally, EC contacted over 260 Indigenous communities located within and adjacent to the current distribution of boreal caribou during both rounds of engagement, inviting them to participate in the development of the recovery strategy for boreal caribou.

CONCLUSION

This report compares EC's present R&D performance with the Department's performance in 2009, as measured in the previous report, *Measuring Environment Canada's Research & Development Performance*. Several metrics indicate improvement: for example, EC's collaboration rate and scientific impact have increased. Other metrics indicate opportunities for growth: for example, timeliness and adaptability have decreased relative to past rankings. However, most metrics indicate sustained strength in R&D: for example, the Department continues to have a strong record in overall productivity, relevance to federal priorities, support to users and producers, top national and international partners, and S&T funding and personnel. EC's sustained high-quality R&D performance is a key factor in its reliability and credibility as a scientific institution.

This report establishes baselines for EC's R&D performance in each Science Strategy principle. Overall, EC's R&D is relevant, transparent, responsive, excellent and collaborative. These five principles guide the work of all EC staff and help the Department achieve its mandate.

Excellence and Collaboration are well-established areas of strength for EC. The scientific impact of EC's science is well above world average, and the Department adheres and contributes to international standards. EC's science is increasingly collaborative, with Canadian universities remaining the Department's strongest partners. EC's R&D Excellence and Collaboration underpin the Department's role as a leader within the environmental science community.

EC's performance in Relevance and Responsiveness is strong, but reveals several strategic areas for improvement. EC is clearly a science-based department, with the majority of PAA programs using and producing science that is highly relevant to the Department's mandate, Strategic Outcomes and federal priorities. EC's enabling environment is stable in terms of funding, infrastructure and personnel. There are opportunities to improve user satisfaction, timeliness and adaptability through continued focus on user/producer linkages, one of the key mechanisms in the Science Strategy.

Transparency is an emerging area of focus for EC. A substantial amount of scientific data and nearly half EC's publications are already freely available online. Beyond availability, EC is taking steps to improve accessibility of its science. As one of the leads for the Government of Canada's Open Science commitment, EC's efforts in the area of scientific transparency will increase in the coming years.

This report also establishes baselines for EC's R&D performance in each Science Strategy priority area. Contaminants & Stressors (PA1) is a clear area of strength for EC, based on publication productivity and comparison with other Canadian and international institutions. EC also performs well in Weather (PA2), based on its share of publications in this area and its productivity, scientific impact and specialization compared to other institutions. Publications in Climate Change (PA3) have the highest ARC; however, EC's productivity in this priority area is lower relative to other areas within EC, and relative to other institutions. Conservation & Protection (PA4) is a priority

area with potential for improvement in terms of productivity and scientific impact compared to other priority areas.

Overall, EC's R&D performance is strong in each Science Strategy principle and priority area. EC's sustained R&D strength underlies the ability of the Department's policies, programs and services to help provide Canadians with a clean, safe and sustainable environment.

ANNEX 1: ACRONYMS AND ABBREVIATIONS

ARC	Average of relative citations
ARIF	Average relative impact factor
CALA	Canadian Association for Laboratory Accreditation Inc.
CNRS	Centre national de la recherche scientifique
EC	Environment Canada
ETV	Environmental Technology Verification
FTE	Full-time equivalents
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
MSC	Meteorological Service of Canada
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NERI	National Environmental Research Institute
NOAA	National Oceanic and Atmospheric Administration
OST	Observatoire des sciences et des technologies, Université du Québec à Montréal
OA	Open Access
OECD	Organization for Economic Co-operation and Development
PA1-4	Priority areas 1 through 4 of Environment Canada's Science Strategy 2014-2019
PAA	Program alignment architecture
RSA	Related scientific activities
R&D	Research and development
S&T	Science and technology
USGS	United States Geological Survey
UCAR	University Corporation for Atmospheric Research