BIBLIOMETRIC PROFILE OF ENVIRONMENTAL SCIENCE IN CANADA ■ 1980-1998

Report submitted to Environment Canada
February 2002

BIBLIOMETRIC PROFILE OF ENVIRONMENTAL SCIENCE IN CANADA ▪ 1980-1998

www.ost.qc.ca

Supervision

Benoît GODIN

Analysis and Drafting

Frédéric TREMPE-BERTRAND

Jean-Pierre ROBITAILLE

Data Production

Grégoire CÔTÉ

Translation

Environment Canada

Observatoire des sciences et des technologies

3465, Durocher Street, Montreal, Quebec, H2X 2C6

Telephone: (514) 499-4074 Fax: (514) 499-4065

www.ost.qc.ca

Table of contents

Summary

This report paints a quantitative picture of the research output of Canadian environmental science from 1980 to 1998. It also provides a means for comparing the Canadian effort in this area with that of other countries. The report is based on bibliometric data taken from 317 specialized environmental science journals. These journals were classified into seven specialties, making it possible to produce relatively detailed statistics on the various research topics of the area.

The report begins with a general overview of environmental science in Canada and around the world. Next, it identifies the main Canadian institutions that are active in the area, as well as the collaborative networks to which they belong. The principal findings are as follows:

Canada and the World

- At the international level, environmental science experienced sustained growth over the period examined (1980-1998). There were 10,685 research articles in the field in 1980, by 1998 that number had grown to 23,917. This 124% increase is much higher than that for overall world scientific output (65%).
- With 21,503 articles between 1980 and 1998, Canada ranked third behind the United States (137,692) and the United Kingdom (25,781), and ahead of Germany (15,367), Australia (12,772), France (11,411) and Japan (9,921).
- In terms of relative effort, Canada also ranked third at the international level, with 4.6% of its scientific publications dedicated to environmental science (1980-1998).
- Between 1980 and 1998, Canadian articles focused primarily on the following specialties: *Ecology* (22.8%), *Water Resources* (16.1%), and *General Environment* (25.6%).
- A breakdown of Canadian output into the seven specialties in question shows that articles on *Ecology* and *Water Resources* gradually declined in number, while there was an increase in those on *Environmental Engineering* and *Meteorology and Atmospheric Science*.
- Between 1980 and 1998, Canada ranked third in the world in terms of scientific impact, behind the United States and Sweden. That impact grew considerably over the same period.
- International collaborative efforts among the top ten countries in environmental science also rose. The figure for Canada, which stood at 13.2% between 1980 and 1984, was 30.5% between 1995 and 1998.
- During the years under study, Canada's three largest collaborators were the United States (46.5% of all international collaborations), the United Kingdom (7.2%), and Germany (4.8%).

The Canadian Scene

- The university sector dominates environmental science, accounting for some 67% of Canadian articles between 1980 and 1998. It is also the sector that contributed most to the growth in output.

- The performance of the federal government (including Environment Canada) was also impressive, with 32% of all Canadian articles. Environment Canada was responsible for approximately 44% of federal government output in environmental science, and 14% of total Canadian output.

- Environment Canada was, by far, the institution that produced the most environmental science articles (2,985 between 1980 and 1998). With 58% of its articles dedicated to this field, the Department was also the institution with the highest percentage of its publications in environmental science.

- Environment Canada largely dominated the *General Environment*, *Meteorology and Atmospheric Sciences*, and *Health and Environmental Toxicology* specialties. It was also very active in *Environmental Engineering* and *Water Resources*, where it placed a close second.

- After Environment Canada, the other four most prolific Canadian institutions were Fisheries and Oceans Canada (1,661 publications), the University of British Columbia (1,524), the University of Toronto (1,293) and McGill University (1,142).

- Environment Canada was the main partner of the nine other most productive Canadian institutions in environmental science.

- In order, Environment Canada's main partners were Fisheries and Oceans Canada, the University of Waterloo, the University of Guelph, McGill University, and York University.

1 Introduction

1.1 Context

In March 2000, the *Observatoire des sciences et des technologies* (OST) submitted a bibliometric study[1] to Environment Canada on the Department's scientific research publications. The study made the following five observations:

- Between 1980 and 1997, Environment Canada produced a total of 4,800 scientific research articles. Its annual output, depending on the year in question, represented between 6% and 12% of all federal government publications.
- The vast majority of these articles were in the disciplines of Biology and of Earth and Space Sciences.
- Environment Canada's focus has changed over time, from Biology in the 1980s to the Earth and Space Sciences in the 1990s.
- As measured by the impact factor, the quality of Environment Canada's publications is comparable to that of other Canadian researchers.
- Environment Canada has developed an extensive network of collaborators, both national and international. The Department's national collaborators, however, are much more numerous.

The aim of the current study is to paint a quantitative picture of environmental science in Canada and around the world. After discussing the top ten countries in the field, it describes the research activities of the most active Canadian institutions, dealing with the distribution of their publications into seven environmental science specialties as well as developments in their inter-institutional collaborative practices.

[1] OST (2000), *Environment Canada's Scientific Research Publications, 1980 - 1997*, report submitted to Environment Canada, 19 p. (www.ost.qc.ca)

1.2 Method

The field of environmental science is difficult to define because of its multidisciplinary nature and considerable diversity of application. Indeed, to date, there is no consensus on the exact definition of specialties or of research in the area. For the purposes of this study, we have defined environmental science as all scientific and experimental studies aimed at analyzing the physical, biological and chemical processes forming the environment, as well as the relationship between human activities and these biotic and abiotic processes. In consultation with Environment Canada, we have divided the field into seven specialties: *Ecology*, *Environmental Engineering*, *Meteorology and Atmospheric Science*, *Water Resources*, *Health and Environmental Toxicology*, *Social Sciences*, and *General Environment*. The latter explores multidisciplinary environmental issues that are not well covered by any other single specialty. *General Environment* focuses on impact studies, pollution, the management and conservation of various environments and resources (urban, agricultural, arid, arctic, forest, soil, fresh- and salt-water), the study of global environmental phenomena (global warming, biogeochemical cycles, ecosystems), etc. (See Appendix 3)

The disciplines classified in most bibliometric data banks do not necessarily correspond with these seven specialties. To solve this problem, we established a set of 317 scientific journals (Appendix 3) taken from the *Science Citation Index* (SCI) and the *Social Science Citation Index* (SSCI), which in our view provided adequate coverage of environmental science publications (Table 1).

The process was conducted as follows: first, we selected all environmental science journals listed by the *Institute for Scientific Information* (ISI) and *CHI Research*. Second, we conducted a keyword search of all journal titles, which produced a few more titles that had not been classified in the area by ISI or CHI. We then selected those journals that were obviously dedicated to environmental science by analyzing their aims and scope. This analysis also made it possible to divide the journals into seven specialties (see Table 1 below).

Table 1. Number of Journals and Articles by Environmental Science Specialty, 1980 - 1998

	No. of Journals	No. of Articles
Ecology	68	65,333
General Environment	66	68,665
Environmental Engineering	28	21,948
Meteorology and Atmospheric Science	47	48,207
Water Resources	29	50,341
Health and Environmental Toxicology	44	44,576
Social Sciences	35	7,676
TOTAL	317	306,746

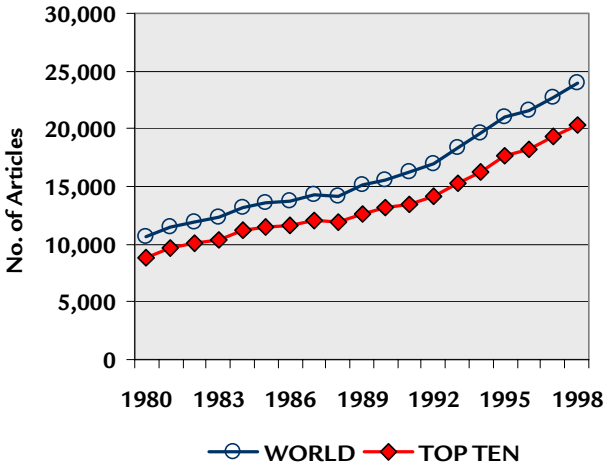
Source: Observatoire des sciences et des technologies (SCI/SSCI)

2 Environmental Science in Canada and in Other Countries

2.1 Number of Publications

Over the past 19 years, the annual international number of environmental science research articles has risen considerably, from 10,685 in 1980 to 23,917 in 1998, for a growth rate of 124% (Figure 1). This growth is much higher than that observed for worldwide scientific publications as a whole (65%) over the same period.

Figure 1. Annual Number of Environmental Science Articles, World and Top Ten Countries, 1980 - 1998

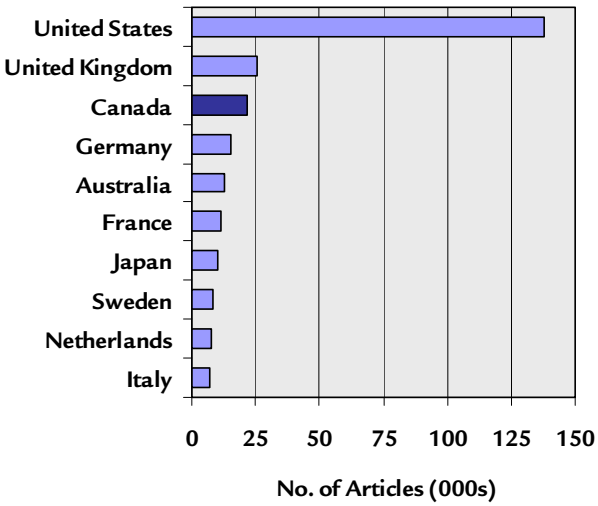


Source: Observatoire des sciences et des technologies (SCI/SSCI)

Between 1980 and 1998, the top ten countries in terms of volume were responsible for 79% of international output in the field (Figure 1). These countries were the United States (137,692 articles), the United Kingdom (25,781), Canada (21,503), Germany (15,367), Australia (12,772), France (11,411), Japan (9,921), Sweden (8,476), the Netherlands (7,959), and Italy (6,899) (Figure 2).

In third place, Canada made an excellent showing. Its ranking for all scientific articles (not only environmental science) in the same period was sixth in the world.

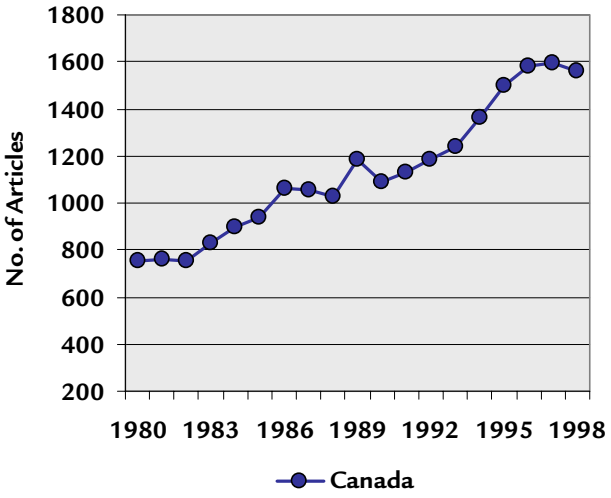
Figure 2. Environmental Science Articles by Top Ten Country, 1980 - 1998



Source: Observatoire des sciences et des technologies (SCI/SSCI)

Over the past 19 years, Canada's annual volume of environmental science articles has grown at a relatively constant rate (more than 42 publications per year, on average), from approximately 750 articles in the early 1980s to more than 1,500 as of 1995 (Figure 3, next page). Although output stagnated between 1986-1989 and 1996-1998, this phenomenon was not unique to the field; it held true for all scientific research publications in Canada, the United States and the United Kingdom.

Figure 3. Annual Number of Environmental Science Articles in Canada, 1980 - 1998



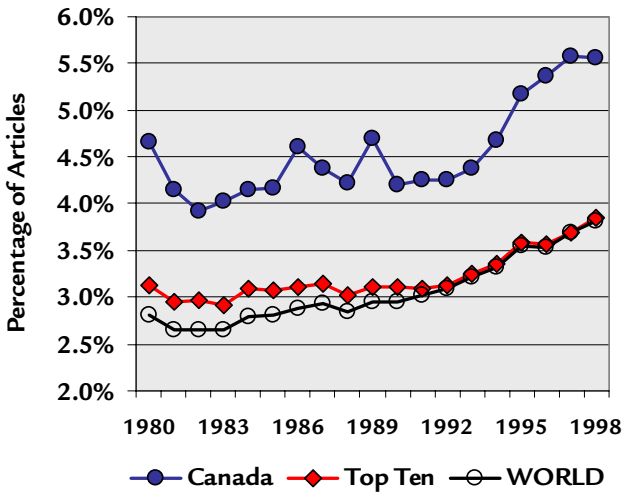
Source: Observatoire des sciences et des technologies (SCI/SSCI)

2.2 Relative Effort

Since 1980, the top ten countries in environmental science have been making an increasingly large relative effort. While in 1980 the ratio of environmental science publications to all scientific research articles (all fields included) stood at 3.1%, in 1998 the figure was 3.8% (Figure 4). This growth in relative effort became more pronounced with the onset of the 1990s. Since the beginning of the period under study, moreover, Canada's effort has surpassed that made by the rest of the world; during the 1990s, we see a pronounced increase in its relative effort, which reached 5.6% in 1998.

In terms of relative effort, Canada ranks third among the countries most specialized in environmental science (Table 2). Since the early 1980s, Australia has made the largest relative effort in the field; between 1985 and 1998, the percentage of its environmental science publications stood at 5.9%. Australia is followed by Sweden (5.4%), Canada (5.4%), the Netherlands (4.5%), and the United States (4.1%). Over the 1980-1998 period, France, the Netherlands and Japan saw the greatest increases in relative effort in the field.

Figure 4. Relative Effort of Canada, the Top Ten Countries, and the World, 1980 - 1998



Source: Observatoire des sciences et des technologies (SCI/SSCI)

2.3 Distribution of Articles By Specialty

Table 3 presents the number of environmental science articles of the top ten country producers by specialty. Countries are classified according to the total number of environmental science articles and ranked for each specialty.

Table 2. Relative Effort of Top Ten Countries, 1980 - 1998

Rank		1980-1984	1985-1989	1990-1994	1995-1998	TOTAL
1	Australia	4.8%	5.2%	5.4%	5.9%	5.4%
2	Sweden	3.4%	4.6%	4.9%	5.4%	4.7%
3	Canada	4.2%	4.4%	4.4%	5.4%	4.6%
4	United States	3.6%	3.6%	3.6%	4.1%	3.7%
5	Netherlands	2.7%	3.2%	3.9%	4.5%	3.7%
6	United Kingdom	2.7%	2.7%	2.9%	3.6%	3.0%
7	Italy	2.2%	2.1%	2.4%	2.6%	2.3%
8	France	1.5%	1.9%	2.2%	2.8%	2.2%
9	Germany	1.6%	1.8%	2.3%	2.6%	2.1%
10	Japan	1.0%	1.2%	1.3%	1.6%	1.3%
Top Ten	TOTAL	3.0%	3.1%	3.2%	3.7%	3.3%

Source: Observatoire des sciences et des technologies (SCI/SSCI)

Table 3. Top Ten Countries by Number of Articles in Each Specialty, 1980 - 1998

		Ecology		General Environment		Environmental Engineering		Meteorology & Atmospheric Science		Water Resources		Health & Environmental Toxicology		Social Sciences		Total Articles
Rank		Rk	#	Rk	#	Rk	#	Rk	#	Rk	#	Rk	#	Rk	#	TOTAL
1	United States	1	27,742	1	29,568	1	10,764	1	24,859	1	18,969	1	21,607	1	4,183	137,692
2	United Kingdom	2	6,529	2	6,284	2	1,270	2	4,021	2	4,170	3	2,680	2	827	25,781
3	Canada	4	4,901	3	5,508	3	1,078	4	2,787	3	3,456	2	3,346	3	427	21,503
4	Germany	6	2,663	4	3,199	6	616	3	3,501	4	2,891	4	2,366	6	131	15,367
5	Australia	3	5,841	7	2,128	9	471	6	1,709	7	1,890	10	481	4	252	12,772
6	France	5	3,229	10	1,400	4	1,073	5	2,050	5	2,464	9	1,092	8	103	11,411
7	Japan	8	1,754	9	1,499	5	858	7	1,664	6	2,007	5	2,089	9	50	9,921
8	Sweden	7	2,231	6	2,192	10	232	10	738	9	1,180	6	1,772	6	131	8,476
9	Netherlands	9	1,633	8	1,832	8	483	9	870	8	1,781	8	1,213	5	147	7,959
10	Italy	10	698	5	2,426	7	555	8	930	10	1,002	7	1,242	10	46	6,899
Top Ten	TOTAL (N) *		54,028		53,555		16,648		39,367		37,698		36,044		6,084	243,424

Source: Observatoire des sciences et des technologies (SCI/SSCI)

* The total number of articles is higher than the number for the top ten producers as a whole, because those that were co-authored at the international level have been multiplied accordingly.

Between 1980 and 1998, the United States ranked first in each of the seven environmental science specialties (Table 3). The United Kingdom placed second in all specialties except *Health and Environmental Toxicology*, which went to Canada.

Germany was ahead of Canada in *Meteorology and Atmospheric Science* by 714 publications. Australia posted a commendable performance in *Ecology*, taking third place behind the United Kingdom and ahead of Canada. In *Environmental Engineering*, France placed a respectable fourth (Table 3).

Despite ranking only seventh overall, Japan seems relatively strong in *Health and Environmental Toxicology*, standing fifth behind Germany. Similarly, in spite of its last place ranking overall, Italy stood fifth in *General Environment*, with 2,426 publications.

The relative effort of the top ten countries in each specialty (Table 4) can be summarized as follows. Australia took first place in *Ecology*, which represents 2.45% of all its scientific research publications. The top spot goes to Sweden (1.21%) for *General Environment*, to Australia for *Meteorology and Atmospheric Science* (0.72%), to the Netherlands for *Water Resources* (0.83%), to Sweden for *Health and Environmental Toxicology* (0.98%), and to the United States for *Environmental Engineering* (0.29%) and for *Social Sciences* (0.11%).

Canada, for its part, stood second or third in all specialties, except Social Science, in which it came in fourth.

The distribution of Canadian environmental science publications by specialty shows that *Ecology* and *Water Resources* have lost ground to *Environmental Engineering* (whose share rose from

Table 4. Top Ten Countries by Percentage of Articles in Each Specialty, 1980 – 1998

		Ecology		General Environment		Environmental Engineering		Meteorology & Atmospheric Science		Water Resources		Health & Environmental Toxicology		Social Sciences		Total Articles	% in Field
Rank		Rk	%	Rk	%	Rk	%	Rk	%	Rk	%	Rk	%	Rk	%	TOTAL	%
1	**Australia**	1	2.45%	3	0.89%	5	0.20%	1	0.72%	2	0.79%	10	0.20%	2	0.11%	**12,772**	**5.4%**
2	**Sweden**	2	1.23%	1	1.21%	8	0.13%	6	0.41%	4	0.65%	1	0.98%	5	0.07%	**8,476**	**4.7%**
3	**Canada**	3	1.05%	2	1.18%	2	0.23%	3	0.60%	3	0.74%	2	0.71%	4	0.09%	**21,503**	**4.6%**
4	**United States**	6	0.74%	6	0.79%	1	0.29%	2	0.67%	5	0.51%	3	0.58%	1	0.11%	**137,692**	**3.7%**
5	**Netherlands**	4	0.76%	4	0.85%	3	0.22%	7	0.40%	1	0.83%	4	0.56%	6	0.07%	**7,959**	**3.7%**
6	**United Kingdom**	5	0.76%	7	0.73%	7	0.15%	5	0.47%	6	0.48%	7	0.31%	3	0.10%	**25,781**	**3.0%**
7	**Italy**	9	0.24%	5	0.82%	6	0.19%	9	0.31%	9	0.34%	5	0.42%	9	0.02%	**6,899**	**2.3%**
8	**France**	7	0.61%	9	0.27%	4	0.20%	8	0.39%	7	0.47%	9	0.21%	7	0.02%	**11,411**	**2.2%**
9	**Germany**	8	0.36%	8	0.44%	10	0.08%	4	0.48%	8	0.40%	6	0.32%	8	0.02%	**15,367**	**2.1%**
10	**Japan**	10	0.23%	10	0.20%	9	0.11%	10	0.22%	10	0.26%	8	0.27%	10	0.01%	**9,921**	**1.3%**
Top Ten	**TOTAL (N)***		**0.72%**		**0.72%**		**0.22%**		**0.53%**		**0.50%**		**0.48%**		**0.08%**	**243,424**	**3.3%**

Source: Observatoire des sciences et des technologies (SCI/SSCI)

*** The total number of articles is higher than the number for the top ten producers as a whole, because those that were co-authored at the international level have been multiplied accordingly.**

Table 5. Distribution of Canadian Environmental Science Articles by Specialty and Period, 1980 - 1998

	1980-84	1985-89	1990-94	1995-98	TOTAL
Ecology	27.8%	24.7%	22.0%	18.8%	**22.8%**
General Environment	25.1%	27.2%	23.8%	26.4%	**25.6%**
Environmental Engineering	2.6%	4.3%	5.9%	6.3%	**5.0%**
Meteorology & Atmospheric Science	9.5%	10.5%	13.2%	17.0%	**13.0%**
Water Resources	18.7%	16.2%	16.6%	13.8%	**16.1%**
Health and Environmental Toxicology	14.7%	15.4%	16.9%	15.0%	**15.6%**
Social Sciences	1.6%	1.8%	1.7%	2.7%	**2.0%**
TOTAL (%)	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
TOTAL	**3,998**	**5,261**	**6,008**	**6,236**	**21,503**

Source: Observatoire des sciences et des technologies (SCI/SSCI)

2.6% to 6.3% over the period in question) and to *Meteorology and Atmospheric Science* (9.5% to 17.0%) (Table 5). Generally speaking, those specialties that were underrepresented in the early part of the period grew in importance, while those initially representing a large percentage of total output remained stable or declined.

The specialization index shown in Table 6 corresponds to the percentage of Canadian publications in each specialty divided by the percentage occupied by each specialty in international publications as a whole. An index of more than 1.0 means that Canada's relative effort is higher than the world average for the specialty in question.

Note that the growth of Canada's relative effort in environmental science has not translated into an increase in its specialization index (world baseline), as the effort made by other countries has resulted in similar growth (Table 6, next page).

Canada's overall specialization index was relatively stable between 1980 and 1998, remaining above the international average (between 1.5 and 1.7). In *Meteorology and Atmospheric Science*, however, it rose considerably, from 0.9 to 1.4 over the same period.

Table 6. Canadian Environmental Science Specialization Index by Specialty, 1980 - 1998 (baseline = 1.0)

	Ecology	General Environment	Environmental Engineering	Meteorology & Atmospheric Science	Water Resources	Health & Environmental Toxicology	Social Sciences	TOTAL
1980	2.0	2.1	0.6	0.9	1.9	1.6	0.8	**1.7**
1982	1.6	2.0	0.6	0.9	1.7	1.4	0.9	**1.5**
1984	2.0	1.6	0.5	0.9	1.7	1.3	1.0	**1.5**
1986	1.8	2.2	1.0	1.0	1.7	1.3	1.1	**1.6**
1988	1.5	1.7	1.4	1.0	1.5	1.7	1.4	**1.5**
1990	1.5	1.6	1.4	1.2	1.4	1.4	1.0	**1.4**
1992	1.5	1.4	1.2	1.2	1.3	1.6	0.7	**1.4**
1994	1.4	1.4	0.9	1.5	1.3	1.8	1.0	**1.4**
1996	1.5	1.6	1.2	1.5	1.3	1.8	1.4	**1.5**
1998	1.4	1.7	1.1	1.4	1.4	1.6	1.3	**1.5**
1980-98	**1.6**	**1.7**	**1.0**	**1.2**	**1.4**	**1.6**	**1.2**	**1.5**

Source: Observatoire des sciences et des technologies (SCI/SSCI)

2.4 Impact of Publications

The relative weighed impact factor (RWIF) measures the scientific impact of publications from a given group (country, region, institution, etc.) by comparing it to the impact of a reference set—in this case, the world (baseline = 1.0). Where a country's RWIF is higher than 1.0, its publications have an impact that is greater than that of the rest of the world (see the definition of the RWIF in Appendix 4).

As Table 7 shows, in environmental science (as in many other research fields), the United States ranked first in the world in terms of scientific impact for the period studied (1.11). It is followed by Sweden (1.07), Canada (1.04), the Netherlands (1.04), and the United Kingdom (1.02), whose RWIF remained comparable to or slightly higher than the figure for the world. Japan (0.96), France (0.95), and Germany (0.94) posted a RWIF that was somewhat lower than the world average, while Italy (0.91) and Australia (0.91) brought up the rear in terms of scientific impact.

Note that Germany's impact increased the most over the period in question, from 0.77 in 1980 to 1.02 in 1998. France also witnessed a major improvement, bringing its 1998 impact up to the level of that of the Netherlands (1.06). Since the middle of the 1980s, Canada's RWIF has been above the world average.

Table 7. Relative Weighed Impact Factor (RWIF) for Environmental Science Articles of Top Ten Countries, 1980 - 1998 (world baseline = 1.0)

	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998	AVERAGE
United States	1.12	1.06	1.11	1.09	1.11	1.13	1.13	1.12	1.14	1.12	**1.11**
Sweden	1.09	1.07	1.02	1.09	1.06	1.07	1.07	1.09	1.08	1.02	**1.07**
Canada	0.97	1.02	0.99	1.05	1.06	1.07	1.04	1.07	1.08	1.09	**1.04**
Pays-Bas	1.02	1.07	0.98	1.00	0.99	0.99	1.02	1.02	1.11	1.06	**1.04**
United Kingdom	1.03	1.10	1.04	1.04	1.01	1.05	1.03	1.00	1.00	1.04	**1.02**
Japan	1.07	1.05	1.07	0.99	0.94	0.98	0.94	0.86	0.91	0.95	**0.96**
France	0.92	0.83	0.78	0.82	0.83	0.92	0.98	1.04	1.04	1.06	**0.95**
Germany	0.77	0.88	0.80	1.00	0.96	0.95	1.00	0.97	0.98	1.02	**0.94**
Italy	0.78	0.92	0.87	0.96	0.91	0.87	0.84	1.00	0.93	0.94	**0.91**
Australia	0.94	0.91	0.94	0.90	0.88	0.88	0.91	0.88	0.84	0.88	**0.91**

Source: Observatoire des sciences et des technologies (SCI/SSCI)

Broken down by specialty (Table 8), Canada's RWIF is higher than the world average for the entire period (1980-1998) except in *Environmental Engineering* (0.91). In this specialty, Canada's score fell significantly, from 1.25 to 0.85. In *Ecology*, on the other hand, the RWIF for Canadian articles increased considerably, rising from 0.75 in 1980 to 1.15 in 1998. While several fluctuations in the country's RWIF occurred over the period in the other specialties, no lasting trend could be identified.

Table 8. Canada's Relative Weighed Impact Factor (RWIF) by Specialty, 1980 - 1998

	Ecology	General Environment	Environmental Engineering	Meteorology & Atmospheric Science	Water Resources	Health & Environmental Toxicology	TOTAL
1980	0.75	0.92	1.25	1.22	1.18	1.00	**0.97**
1982	0.87	1.00	1.60	1.36	1.02	1.05	**1.02**
1984	0.84	1.11	1.29	1.11	1.08	0.92	**0.99**
1986	1.05	1.06	0.88	1.06	1.03	1.10	**1.05**
1988	1.09	1.05	0.95	0.99	1.05	1.08	**1.06**
1990	1.13	1.09	0.86	1.09	1.09	1.01	**1.07**
1992	1.06	1.06	1.09	0.91	1.09	1.00	**1.04**
1994	1.09	1.02	0.89	1.00	1.16	1.13	**1.07**
1996	1.17	1.08	0.77	0.96	1.21	1.08	**1.08**
1998	1.15	1.11	0.85	1.04	1.07	1.14	**1.09**
TOTAL	**1.04**	**1.03**	**0.91**	**1.04**	**1.09**	**1.06**	**1.04**

Source: Observatoire des sciences et des technologies (SCI/SSCI)

2.5 International Collaboration

For the past two decades, the top ten country producers of environmental science articles have been enhancing their collaborative efforts with foreign partners. While in 1980 the percentage of publications written in international collaboration stood at 7%, in 1998 the figure was 27%.

A classification of countries by level of international collaboration puts Canada in sixth place for the period under study, with 21.7% (Table 9). First place belongs to France (30.3%), followed by Germany (25.9%) and Sweden (25.8%). Among the countries in question, France witnessed the greatest degree of increased international collaboration from 1980 to 1998. In 1998, it was also, together with Sweden and Germany, among those countries that most often worked with foreign partners (37% to 41%).

Table 10 presents a matrix of the environmental science collaborative efforts among the top ten country producers. For two decades (1981-1989 and 1990-1998), the United States was the leading environmental science partner of all countries in question, and Canada was the main partner of the United States. For the period overall, the second most important partner of all other countries was the United Kingdom, except for Italy, which co-authored more articles with France, and for Japan, which began working more with Canada in 1990.

Table 9. Rate of International Collaboration Among Top Ten Countries, 1980 - 1998

Rank		1980-1984	1985-1989	1990-1994	1995-1998	TOTAL
1	**France**	14.8%	21.6%	31.7%	39.9%	**30.3%**
2	**Germany**	11.9%	19.9%	26.2%	35.9%	**25.9%**
3	**Sweden**	15.3%	17.4%	26.3%	36.5%	**25.8%**
4	**Netherlands**	10.1%	16.7%	24.4%	32.5%	**24.0%**
5	**Italy**	10.2%	15.2%	25.2%	31.7%	**23.3%**
6	**Canada**	13.2%	16.6%	22.6%	30.5%	**21.7%**
7	**United Kingdom**	11.3%	15.2%	24.2%	30.0%	**21.6%**
8	**Australia**	9.9%	13.4%	18.8%	24.7%	**17.7%**
9	**Japon**	7.4%	13.0%	16.2%	23.1%	**16.8%**
10	**United States**	5.2%	8.4%	12.1%	16.8%	**11.0%**

Source : Observatoire des sciences et des technologies (SCI/SSCI)

Table 10. International Collaboration* Among Top Ten Countries, 1981 - 1989 and 1990 - 1998

Country 1		Australia		Canada		France		Germany		Italy		Japan		Netherlands		Sweden		United Kingdom		United States	
		%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
Australia	1981-1989			0.8%	(41)	0.3%	(14)	0.4%	(22)	0.1%	(7)	0.4%	(19)	0.2%	(10)	0.2%	(8)	1.5%	(74)	6.1%	(301)
	1990-1998			2.3%	(171)	1.6%	(117)	1.8%	(131)	0.4%	(33)	1.0%	(74)	0.4%	(31)	0.8%	(60)	3.5%	(261)	9.3%	(695)
Canada	1981-1989	0.5%	(41)			0.7%	(61)	0.4%	(38)	0.3%	(22)	0.6%	(47)	0.3%	(22)	0.3%	(24)	1.4%	(118)	9.1%	(778)
	1990-1998	1.4%	(171)			1.7%	(205)	1.9%	(234)	0.5%	(64)	1.1%	(136)	0.7%	(84)	0.8%	(101)	2.3%	(286)	15.1%	(1843)
France	1981-1989	0.4%	(14)	1.7%	(61)			1.5%	(55)	0.9%	(31)	0.3%	(12)	0.5%	(16)	0.3%	(10)	2.0%	(72)	4.9%	(174)
	1990-1998	1.5%	(117)	2.7%	(205)			4.0%	(301)	2.9%	(222)	0.8%	(64)	2.0%	(148)	1.1%	(81)	5.3%	(402)	10.5%	(796)
Germany	1981-1989	0.4%	(22)	0.7%	(38)	1.1%	(55)			0.3%	(17)	0.4%	(21)	1.1%	(55)	0.6%	(33)	1.8%	(91)	5.5%	(286)
	1990-1998	1.3%	(131)	2.4%	(234)	3.1%	(301)			1.7%	(162)	0.8%	(75)	2.4%	(233)	2.0%	(191)	4.3%	(419)	9.2%	(894)
Italy	1981-1989	0.3%	(7)	1.0%	(22)	1.4%	(31)	0.8%	(17)			0.2%	(4)	0.1%	(2)	0.7%	(16)	1.8%	(40)	4.6%	(102)
	1990-1998	0.7%	(33)	1.4%	(64)	4.9%	(222)	3.6%	(162)			0.5%	(22)	2.1%	(93)	1.9%	(88)	4.1%	(183)	8.7%	(395)
Japan	1981-1989	0.6%	(19)	1.5%	(47)	0.4%	(12)	0.7%	(21)	0.1%	(4)			0.0%	(1)	0.2%	(7)	0.4%	(12)	5.4%	(169)
	1990-1998	1.1%	(74)	2.1%	(136)	1.0%	(64)	1.2%	(75)	0.3%	(22)			0.7%	(45)	0.6%	(36)	1.4%	(93)	8.4%	(549)
Netherlands	1981-1989	0.4%	(10)	0.9%	(22)	0.7%	(16)	2.3%	(55)	0.1%	(2)	0.0%	(1)			0.8%	(19)	2.1%	(50)	3.8%	(91)
	1990-1998	0.6%	(31)	1.6%	(84)	2.7%	(148)	4.3%	(233)	1.7%	(93)	0.8%	(45)			2.2%	(120)	5.8%	(313)	6.6%	(358)
Sweden	1981-1989	0.3%	(8)	0.8%	(24)	0.3%	(10)	1.1%	(33)	0.5%	(16)	0.2%	(7)	0.6%	(19)			1.8%	(54)	5.9%	(180)
	1990-1998	1.2%	(60)	1.9%	(101)	1.6%	(81)	3.7%	(191)	1.7%	(88)	0.7%	(36)	2.3%	(120)			4.5%	(237)	8.4%	(438)
United Kingdom	1981-1989	0.8%	(74)	1.2%	(118)	0.7%	(72)	0.9%	(91)	0.4%	(40)	0.1%	(12)	0.5%	(50)	0.6%	(54)			4.5%	(439)
	1990-1998	1.7%	(261)	1.9%	(286)	2.7%	(402)	2.8%	(419)	1.2%	(183)	0.6%	(93)	2.1%	(313)	1.6%	(237)			7.7%	(1156)
United States	1981-1989	0.5%	(301)	1.3%	(778)	0.3%	(174)	0.5%	(286)	0.2%	(102)	0.3%	(169)	0.2%	(91)	0.3%	(180)	0.8%	(439)		
	1990-1998	0.9%	(695)	2.5%	(1843)	1.1%	(796)	1.2%	(894)	0.5%	(395)	0.7%	(549)	0.5%	(358)	0.6%	(438)	1.6%	(1156)		

Source: Observatoire des sciences et des technologies (SCI/SSCI)

*** Number of articles by Country 1 in collaboration with Country 2, divided by the number of articles by Country 1.**

During the second half of the period (1990 - 1998), we see a strengthening of collaborative networks among the European countries. After the United States and the United Kingdom, France and Germany ranked third or fourth as co-authors among European Union countries in the top ten producers. France's most important partners were Italy (4.9% of Italian publications), Germany (3.1%), the United Kingdom (2.7%), and the Netherlands (2.7%). Those countries that worked most with Germany are the Netherlands (4.3%), France (4.0%), Sweden (3.7%), Italy (3.6%) and the United Kingdom (2.8%).

Table 11. Canadian International Collaboration Rate by Specialty, 1980 - 1998

Rg		1980-1984	1985-1989	1990-1994	1995-1998	TOTAL
1	**Meteorology and Atmospheric Science**	19.5%	21.2%	28.1%	40.0%	**30.1%**
2	**Water Resources**	14.4%	20.0%	24.8%	31.9%	**23.1%**
3	**Ecology**	14.1%	17.5%	23.4%	32.7%	**22.0%**
4	**Environmental Engineering**	13.5%	18.4%	18.8%	27.4%	**21.3%**
5	**General Environment**	10.7%	14.1%	20.9%	25.9%	**18.8%**
6	**Health and Environmental Toxicology**	10.1%	12.5%	19.1%	27.5%	**18.3%**
7	**Social Sciences**	15.4%	18.1%	16.7%	16.9%	**16.9%**
	TOTAL	**13.2%**	**16.6%**	**22.6%**	**30.5%**	**21.7%**

Source: Observatoire des sciences et des technologies (SCI/SSCI)

Table 11 presents the changes in Canada's overall international collaboration rate between 1980 and 1998, as well as the rate for each of the seven environmental science specialties. For the period as a whole, the rate for *Meteorology and Atmospheric Science* stood at 30.1%, for *Water Resources*, at 23.1%, and for *Ecology*, at 22.0%. Researchers from *Meteorology and Atmospheric Science* and *Ecology* were the ones who increased their collaborative efforts with foreign colleagues the most, the corresponding figures rising from 19.5% and 14.1% between 1980 and 1984, respectively, to 40.0% and 32.7% from 1995 to 1998.

Table 12. Canadian International Collaboration, by Specialty and by Country, 1980 - 1998

		United States	United Kingdom	Germany	France	Australia	Japan	Sweden	Netherlands	New Zealand	China	Other (96 Countries)	TOTAL
Ecology	**1981-1989**	57.9%	9.4%	1.5%	3.8%	3.6%	1.5%	1.8%	0.8%	1.5%	0.5%	17.6%	100.0%
	1990-1998	41.2%	9.0%	3.7%	4.7%	5.4%	2.2%	2.6%	3.3%	3.9%	1.2%	22.9%	100.0%
	Total	**46.4%**	**9.1%**	**3.0%**	**4.4%**	**4.8%**	**2.0%**	**2.3%**	**2.5%**	**3.1%**	**1.0%**	**21.3%**	**100.0%**
General Environment	**1981-1989**	57.7%	4.8%	2.6%	2.9%	2.6%	3.5%	1.0%	1.6%	2.9%	1.3%	19.0%	100.0%
	1990-1998	43.9%	6.0%	7.0%	1.9%	3.4%	1.8%	3.2%	2.2%	1.3%	3.5%	25.8%	100.0%
	Total	**47.4%**	**5.7%**	**5.8%**	**2.1%**	**3.2%**	**2.2%**	**2.6%**	**2.1%**	**1.7%**	**3.0%**	**24.1%**	**100.0%**
Environmental Engineering	**1981-1989**	57.4%	1.9%	0.0%	3.7%	3.7%	1.9%	1.9%	3.7%	1.9%	1.9%	22.2%	100.0%
	1990-1998	43.3%	2.6%	1.5%	7.2%	2.1%	3.6%	0.0%	0.5%	1.0%	6.2%	32.0%	100.0%
	Total	**46.4%**	**2.4%**	**1.2%**	**6.5%**	**2.4%**	**3.2%**	**0.4%**	**1.2%**	**1.2%**	**5.2%**	**29.8%**	**100.0%**
Meteorology and	**1981-1989**	52.3%	10.0%	5.0%	5.5%	2.3%	3.6%	1.4%	1.8%	0.9%	0.9%	16.4%	100.0%
Atmospheric Science	**1990-1998**	46.7%	6.9%	7.7%	5.9%	6.1%	5.4%	1.6%	1.2%	1.3%	0.9%	16.4%	100.0%
	Total	**47.8%**	**7.5%**	**7.2%**	**5.8%**	**5.4%**	**5.0%**	**1.5%**	**1.3%**	**1.2%**	**0.9%**	**16.4%**	**100.0%**
Water Resources	**1981-1989**	40.9%	6.9%	3.3%	5.4%	2.2%	4.7%	2.5%	1.4%	3.3%	2.2%	27.2%	100.0%
	1990-1998	42.1%	6.2%	5.0%	6.0%	3.2%	2.8%	1.7%	1.3%	1.7%	1.7%	28.3%	100.0%
	Total	**41.8%**	**6.4%**	**4.5%**	**5.8%**	**2.9%**	**3.4%**	**1.9%**	**1.4%**	**2.2%**	**1.8%**	**27.9%**	**100.0%**
Health and Environmental	**1981-1989**	55.6%	11.7%	2.3%	4.7%	2.3%	4.7%	1.8%	2.3%	0.6%	1.2%	12.9%	100.0%
Toxicology	**1990-1998**	45.6%	6.8%	4.8%	6.7%	1.4%	4.1%	4.0%	2.5%	0.8%	1.6%	21.7%	100.0%
	Total	**47.7%**	**7.9%**	**4.2%**	**6.2%**	**1.6%**	**4.2%**	**3.5%**	**2.5%**	**0.7%**	**1.5%**	**19.9%**	**100.0%**
Social Sciences	**1981-1989**	66.7%	14.8%	0.0%	0.0%	7.4%	0.0%	0.0%	0.0%	0.0%	0.0%	11.1%	100.0%
	1990-1998	50.0%	7.7%	5.8%	0.0%	7.7%	0.0%	0.0%	0.0%	1.9%	3.8%	23.1%	100.0%
	Total	**55.7%**	**10.1%**	**3.8%**	**0.0%**	**7.6%**	**0.0%**	**0.0%**	**0.0%**	**1.3%**	**2.5%**	**19.0%**	**100.0%**
All Specialties	**1981-1989**	**53.7%**	**8.1%**	**2.6%**	**4.2%**	**2.8%**	**3.2%**	**1.7%**	**1.5%**	**1.9%**	**1.2%**	**19.0%**	**100.0%**
	1990-1998	**44.0%**	**6.8%**	**5.6%**	**4.9%**	**4.1%**	**3.2%**	**2.4%**	**2.0%**	**1.8%**	**2.0%**	**23.1%**	**100.0%**
	Total	**46.5%**	**7.2%**	**4.8%**	**4.7%**	**3.8%**	**3.2%**	**2.2%**	**1.9%**	**1.8%**	**1.8%**	**22.0%**	**100.0%**

Source: Observatoire des sciences et des technologies (SCI/SSCI)

Table 12 presents a breakdown of joint Canadian publications by main international partner. In all environmental science specialties, Canada-U.S. collaborations represent between 41% and 56% of all Canadian international co-authored work. Following the United States in order of importance are the United Kingdom (7.2%), Germany (4.8%), France (4.7%), Australia (3.8%), Japan (3.2%), and Sweden (2.2%).

Over time, however, such efforts began to diversify. While joint publications with such partners as the United States and the United Kingdom tended to decrease over the period under study, partnerships with other countries experienced noticeable growth, affecting international collaboration primarily in the areas of *Ecology*, *General Environment*, *Meteorology and Atmospheric Science*, and *Health and Environmental Toxicology*.

3 Canadian Publications

This section examines in greater detail Canadian output of environmental science articles. It analyzes that output by province and by institutional sector.

3.1 Provinces

The distribution on Canada's output in the environmental sciences is reflected in the capacity of its individual provinces. For the period studied, most Canadian publications came out of Ontario (10,217 articles, or 48%), Quebec (3,614, or 17%), British Columbia (3,209, or 15%) and Alberta (2,181, or 10%) (Table 13).

The ranking of provinces within each specialty reflects their ranking for environmental science as a whole. In other words, the provinces have developed expertise in all specialties and invest a comparable effort in those specialties (Table 13).

There are, however, certain areas of concentration. While most articles in each province are in *General Environment* and *Ecology* (Table 13), for example, this is not the case for Ontario and Quebec, where the five remaining specialties combined account for the greatest percentage of output. These two provinces are particularly active in *Meteorology and Atmospheric Science* and *Health and Environmental Toxicology*, publishing a higher percentage of documents in these two specialties than the Canadian average.

Table 13. Publication Number and Distribution by Specialty in Each Province, 1980 - 1998

		Ecology		General Environement		Environmental Engineering		Meteorology & Atmospheric Science		Water Resources		Environmental Health and Toxicology		Social Sciences		TOTAL	
Rg		%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
1	Ontario	15.3%	1,562	28.8%	2,945	4.9%	496	14.8%	1,514	16.0%	1,639	18.4%	1,882	1.8%	179	100.0%	10,217
2	Quebec	24.0%	869	21.5%	776	6.2%	225	15.9%	576	14.1%	511	17.0%	613	1.2%	44	100.0%	3,614
3	British Columbia	30.3%	973	20.4%	655	4.0%	127	12.2%	392	16.8%	540	12.1%	388	4.2%	134	100.0%	3,209
4	Alberta	29.2%	637	26.3%	574	7.4%	162	11.7%	256	14.8%	322	8.4%	184	2.1%	46	100.0%	2,181
5	Nova Scotia	38.2%	456	16.7%	200	2.3%	27	11.1%	133	22.3%	266	8.1%	97	1.3%	16	100.0%	1,195
6	Manitoba	19.0%	191	32.2%	324	6.4%	64	5.7%	57	15.7%	158	19.1%	192	1.9%	19	100.0%	1,005
7	Saskatchewan	26.4%	241	26.1%	239	3.8%	35	12.8%	117	15.4%	141	14.6%	133	0.9%	8	100.0%	914
8	Newfoundland	38.3%	201	16.0%	84	9.5%	50	5.3%	28	17.9%	94	12.8%	67	0.2%	1	100.0%	525
9	New Brunswick	29.5%	146	32.7%	162	3.8%	19	3.4%	17	14.5%	72	15.6%	77	0.4%	2	100.0%	495
10	Territories	25.0%	37	65.5%	97	1.4%	2	0.7%	1	4.7%	7	2.7%	4			100.0%	148
11	Prince Edward Island	13.9%	5	52.8%	19					11.1%	4	22.2%	8			100.0%	36

Source: Observatoire des sciences et des technologies (SCI/SSCI)

3.2 Institutional Sectors

The university sector dominates the field of environmental science, accounting for 67% of Canadian publications between 1980 and 1998 (Table 14). It is also the sector that most increased its number of publications, that figure rose from 61.2% to 71.5% between 1980-1984 and 1995-1998.

The federal government (including Environment Canada) maintained its share of the field, with 32% of all Canadian output, as did industry, which, ranking third in importance, represented 8% of all production between 1980 and 1998.

Provincial governments did not keep pace with development in other sectors. Their contribution to overall Canadian output fell from 7.6% in 1980-1984 to 5.9% in 1995-1998.

Between 1980 and 1998, Environment Canada was responsible for approximately 44% of all federal government articles in environmental science, and represented 14% of all Canadian output. During that period, the Department increased its share by some three percentage points (from 12.9% in 1980-1984 to 15.7% in 1995-1998). The growth in the number of Environment Canada environmental science publications was thus faster than that for the federal government as a whole.

Table 14. Environmental Science Articles by Institutional Sector* and Period, 1980 - 1998

		1980-1984		1985-1989		1990-1994		1995-1998		1980-1998	
Rg		%	#	%	#	%	#	%	#	%	#
1	**University**	61.2%	2,446	63.8%	3,359	68.0%	4,084	71.5%	4,456	**66.7%**	**14,345**
2	**Federal****	31.0%	1,241	31.9%	1,679	32.1%	1,930	32.0%	1,998	**31.8%**	**6,848**
	Environnement Canada	*12.9%*	*515*	*13.3%*	*698*	*13.2%*	*792*	*15.7%*	*980*	**13.9%**	**2,985**
3	**Industry**	8.0%	321	6.8%	358	7.6%	455	8.7%	543	**7.8%**	**1,677**
4	**Provincial**	7.6%	303	7.0%	368	6.0%	358	5.9%	365	**6.5%**	**1,394**
5	**Other**	2.7%	107	2.5%	132	2.8%	171	3.0%	190	**2.8%**	**600**
7	**Hospital**	0.5%	21	1.2%	61	1.2%	75	0.9%	57	**1.0%**	**214**
6	**Unknown**	1.8%	72	1.4%	76	1.3%	76	1.6%	98	**1.5%**	**322**
	Canada (N)	**100.0%**	**3,998**	**100.0%**	**5,261**	**100.0%**	**6,008**	**100.0%**	**6,236**	**100.0%**	**21,503**

Source : Observatoire des sciences et des technologies (SCI/SSCI)

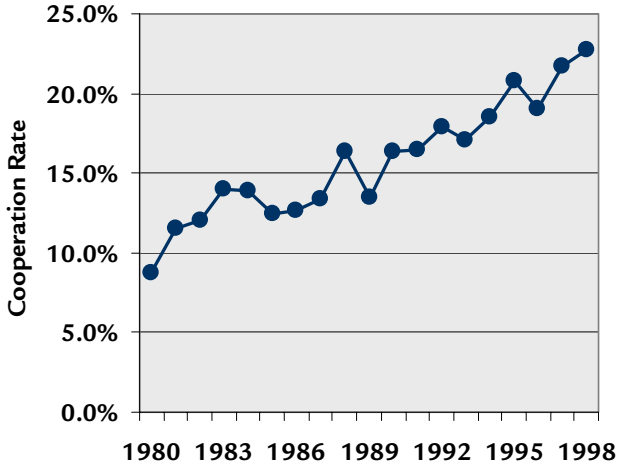
*** The number of publications for each sector is higher than that for Canada as a whole (N), because articles that are the result of inter-sectoral collaboration have been multiplied accordingly.**

**** Federal government publications include those of Environment Canada.**

3.3 Inter-Sectoral Collaboration

Canadian researchers active in environmental science have gradually been increasing their collaborative efforts with national partners (Figure 5). Between 1980 and 1998, the proportion of publications co-authored with partners from other sectors rose from 8.7% to 22.7%.

Figure 5. Canadian Environmental Science Inter-Sectoral Collaboration Rate, 1980 - 1998



Source: Observatoire des sciences et des technologies (SCI/SSCI)

The inter-sectoral collaboration matrix presented in Table 15 shows that the university sector represents the largest source of national partners for researchers in other sectors. Between 1990 and 1998, the latter co-authored from 31.7% to 59.1% of their environmental science publications with universities. Environment Canada and other federal departments represent the second largest source of partners for industry and provincial governments. Between 1990 and 1998, 6.7% of university environmental science publications were co-authored with Environment Canada, and 14.6% with federal government departments as a whole (including Environment Canada). Note that the federal and provincial government sectors almost doubled their rate of collaboration with universities between 1980-1989 and 1990-1998 (Table 15).

Reciprocally, universities also intensified their partnership efforts with other sectors, especially federal government departments. Between 1980-1989 and 1990-1998, there was an increase of more than six points in the collaboration rate between universities and the federal government (including Environment Canada), bringing that rate to 14.6% between 1990 and 1998.

Industry, too, worked more with all other sectors, especially with universities. This trend stemmed in part from efforts of Canadian funding agencies to promote industrial applications of sponsored research and university-industry partnerships. Previous work done by the OST also shows that the university sector had, over the past few years, increased the number of collaborative efforts with all other sectors, and that the opposite was also true[2].

Note that the collaborative practices of Canadian researchers active in environmental science are focused more at the international level rather than at the national. Since the mid-1980s, there has been a growing discrepancy between international and inter-sectoral collaboration. The substantial presence of the university sector in Canadian environmental science publications has had a considerable impact on this state of affairs. Indeed, for all disciplines taken as a whole, the university international collaboration rate between 1980 and 1998 was higher (about 30%) than the inter-sectoral collaboration rate (approximately 20%).

This does not hold true for the second largest sector, the federal government, whose national collaboration rate remains higher than its international rate. The proportion of federal government publications produced in collaboration with national partners rose from 18% to 42% between 1980 and 1997, whereas its international collaboration rate for the same period rose from 12% to 31%.[3] Another bibliometric study

Table 15. Inter-Sectoral Collaboration in Environmental Science in Canada by Period, 1980 - 1989 and 1990 - 1998*

Sector 1		Environment Canada		University		Provincial Government		Federal Government		Industry		Hospital		Other	
		%	#	%	#	%	#	%	#	%	#	%	#	%	#
Environment Canada	1980-1989			15.2%	(184)	3.8%	(46)	5.7%	(69)	5.4%	(66)	0.1%	(1)	0.3%	(4)
	1990-1998			32.3%	(572)	3.7%	(65)	9.2%	(163)	7.1%	(126)	0.2%	(4)	2.3%	(41)
University	1980-1989	3.2%	(184)			2.6%	(151)	8.4%	(488)	2.7%	(159)	0.9%	(54)	0.9%	(55)
	1990-1998	6.7%	(572)			3.5%	(295)	14.6%	(1246)	4.0%	(344)	0.9%	(78)	1.8%	(151)
Provincial Government	1980-1989	6.9%	(46)	22.5%	(151)			12.4%	(83)	4.2%	(28)	0.4%	(3)	1.5%	(10)
	1990-1998	9.0%	(65)	40.8%	(295)			18.0%	(130)	8.7%	(63)	2.4%	(17)	2.9%	(21)
Federal Government	1980-1989	2.4%	(69)	16.7%	(488)	2.8%	(83)			5.0%	(146)	0.3%	(8)	0.4%	(11)
	1990-1998	4.1%	(163)	31.7%	(1246)	3.3%	(130)			7.0%	(273)	0.4%	(14)	1.8%	(72)
Industry	1980-1989	9.7%	(66)	23.4%	(159)	4.1%	(28)	21.5%	(146)			0.3%	(2)	0.9%	(6)
	1990-1998	12.6%	(126)	34.5%	(344)	6.3%	(63)	27.4%	(273)			0.6%	(6)	2.4%	(24)
Hospital	1980-1989	1.2%	(1)	65.9%	(54)	3.7%	(3)	9.8%	(8)	2.4%	(2)			0.0%	
	1990-1998	3.0%	(4)	59.1%	(78)	12.9%	(17)	10.6%	(14)	4.5%	(6)			9.8%	(13)
Other	1980-1989	1.7%	(4)	23.0%	(55)	4.2%	(10)	4.6%	(11)	2.5%	(6)	0.0%			
	1990-1998	11.4%	(41)	41.8%	(151)	5.8%	(21)	19.9%	(72)	6.6%	(24)	3.6%	(13)		

Source: Observatoire des sciences et des technologies (SCI/SSCI)

*** Number of Sector 1 articles co-authored with Sector 2, divided by the number of articles by Sector 1.**

confirmed a similar trend for Environment Canada, whose national collaboration rate rose during the period in question from 22% to 51% and its international rate, from 14% to 32%.[4]

[2] B. Godin and Y. Gingras (1999), "The Place of Universities in the System of Knowledge Production," *Research Policy*, 29: 273-278.

[3] OST (2000), *The Canadian Government's Scientific Output: A Bibliometric Profile*, 21 p. (www.ost.qc.ca)

[4] OST (2000), *Environment Canada's Scientific Research Publications, 1980 – 1997*, report submitted to Environment Canada, 19 p. (www.ost.qc.ca)

4 Canadian Institutions

This section compares the research performance of Canadian institutions that are most active in environmental science. During the period under study, more than 990 institutions published 21,503 articles in the journals examined. We will discuss those that were the most prolific, describing their areas of specialization and collaborative networks.

4.1 Number of Publications

Table 16 lists the top 20 institutions in environmental science in 1980-1998.[5] The top performer in that period was Environment Canada, with 2,985 publications. Environment Canada accounted for approximately 14% of Canadian research articles and almost 1% of worldwide output. Fisheries and Oceans Canada ranked second, with 1,661 publications. In third place, and the most prolific institution of higher learning, was the University of British Columbia, with 1,524 articles. The breakdown also features 14 other universities, including five among the top ten performers: the University of Toronto (fourth), McGill University (fifth), the University of Alberta (sixth), the University of Waterloo (seventh), and the University of Guelph (eighth).

Three federal government departments are also included in the table: Agriculture and Agri-Food Canada (in ninth place, with 797 publications), Natural Resources Canada (tenth, with 603 publications), and Health Canada (13th, with 514 publications).

Among these departments, four made a relative effort (proportion of all publications in the field) that was clearly above the average of the first 20 institutions in the breakdown (8.7%). In addition to Environment Canada's output, that of Fisheries and Oceans Canada accounted for almost 27% of publications, that of Health Canada, 13%, and that of Natural Resources Canada, 9%. Other establishments also made a noteworthy effort: the University of Waterloo (7.5%), York University (6.4%), the University of Guelph (6.1%), Simon Fraser University (6.0%), and Agriculture and Agri-Food Canada (5.3%).

Table 16. The 20 Most Productive Canadian Institutions in Environmental Science (Rank and Number of Publications), 1980 - 1998

Rank		No. of Publications in the Field	No. of SCI/SSCI Publications	Relative Effort in the Field
		#	#	%
1	Environment Canada	2,985	5,139	58.1%
2	Fisheries and Oceans Canada	1,661	6,226	26.7%
3	University of British Columbia	1,524	35,994	4.2%
4	University of Toronto	1,293	60,500	2.1%
5	McGill University	1,142	37,254	3.1%
6	University of Alberta	1,046	28,555	3.7%
7	University of Waterloo	1,016	13,457	7.5%
8	University of Guelph	986	16,142	6.1%
9	Agriculture and Agri-Food Canada	797	15,163	5.3%
10	Natural Resources Canada	603	6,973	8.6%
11	Université Laval	541	14,607	3.7%
12	Dalhousie University	527	11,431	4.6%
13	Health Canada	514	3,840	13.4%
14	McMaster University	505	20,516	2.5%
15	University of Calgary	499	16,282	3.1%
16	University of Manitoba	463	16,103	2.9%
17	University of Saskatchewan	456	12,889	3.5%
18	Simon Fraser University	450	7,524	6.0%
19	York University	437	6,849	6.4%
20	Université de Montréal	425	24,287	1.7%

Source: Observatoire des sciences et des technologies (SCI/SSCI)

[5] Data for the 40 most prolific institutions may be found in Appendix 1.

4.2 Distribution of Articles by Specialty

Table 17 (next page) presents the top ten Canadian institutions by environmental science specialty between 1980 and 1998. Environment Canada largely dominated Canadian publications in *Meteorology and Atmospheric Science* (864), *Health and Environmental Toxicology* (378), and *General Environment* (945), and ranked a close second in *Water Resources* (465) and *Environmental Engineering* (95). With ninth place in *Ecology*, the Department's contribution was less significant than that of the universities and Fisheries and Oceans Canada, but nevertheless represented 4.7% of all Canadian publications in that specialty.

Fisheries and Oceans Canada did well in four out of the seven specialties, placing second in *Ecology* and *General Environment* and third in *Water Resources* and *Health and Environmental Toxicology*. This department also posted a noteworthy performance in *Ecology*, a specialty largely dominated by the university sector, with more than 9% of Canadian output.

Health Canada stood second in its own specialty (Health), after Environment Canada, demonstrating the department's interest in environmentally related research. It also ranked among the top ten performers in *General Environment*.

In all specialties, the institutions boasting the greatest relative effort (%) were federal government departments. This explains in part their higher ranking within each classification. Environment Canada dedicated 18.4% of all publications to *General Environment*, 16.8% to *Meteorology and Atmospheric Science*, 9.1% to *Water Resources*, 7.4% to *Health and Environmental Toxicology*, and 1.9% to *Environmental Engineering*. Fisheries and Oceans Canada expended the largest relative effort in *Ecology*, with 7.3% of all publications dedicated to that specialty.

The University of British Columbia and the University of Toronto ranked highest in all specialties in relation to other universities, which clearly demonstrates the significance and diversification of their investment in the field. The University of British Columbia's main strength was in *Ecology*, where it ranked first with 11% (528 publications) of Canadian output. The other universities included in the classification posted similar publication numbers in this specialty, or between 230 and 332 articles between 1980 and 1998. The University of Toronto ranked third in both *Meteorology and Atmospheric Science* and *General Environment*.

McGill University placed second over the period in *Meteorology and Atmospheric Science*, with a total of 291 publications.

The University of Alberta dominated *Environmental Engineering* (116 publications) and came in third in *Ecology* (332). The University of Waterloo dominated *Water Resources* (468), and ranked fourth in *Environmental Engineering* (69).

Table 17. Top Ten Canadian Institutions by Number of Articles and Relative Effort (%) in Each Environmental Science Specialty, 1980 - 1998

Rk	Ecology	#	%
1	University of British Columbia	528	2.5%
2	Fisheries and Oceans Canada	457	7.3%
3	University of Alberta	332	0.2%
4	University of Toronto	317	0.5%
5	University of Guelph	295	1.8%
6	McGill University	278	0.7%
7	Dalhousie University	255	2.2%
8	Université Laval	248	1.7%
9	Simon Fraser University	230	3.1%
9	Environment Canada	230	4.5%

Rk	General Environment	#	%
1	Environment Canada	945	18.4%
2	Fisheries and Oceans Canada	421	6.8%
3	University of Toronto	342	0.6%
4	Agriculture and Agri-Food Canada	288	1.9%
5	University of British Columbia	287	0.8%
6	University of Guelph	266	1.6%
7	University of Waterloo	240	1.8%
8	University of Alberta	231	0.8%
9	Natural Resources Canada	224	3.2%
10	Health Canada	188	4.9%

Rk	Environmental Engineering	#	%
1	University of Alberta	116	0.4%
2	Environment Canada	95	1.8%
3	University of British Columbia	74	0.2%
4	University of Waterloo	69	0.5%
5	National Research Council	63	0.4%
6	University of Manitoba	50	0.3%
7	University of Toronto	46	0.1%
8	Mem. Univ. of Newfoundland	42	0.6%
8	Natural Resources Canada	42	0.6%
10	McGill University	37	0.1%

Rk	Meteorology and Atm. Science	#	%
1	Environment Canada	864	16.8%
2	McGill University	291	0.8%
3	University of Toronto	219	0.4%
4	York University	180	2.6%
5	University of British Columbia	176	0.5%
6	Fisheries and Oceans Canada	137	2.2%
7	University of Alberta	105	0.4%
8	University of Victoria	97	1.6%
9	Agriculture and Agri-Food Canada	95	0.6%
10	National Research Council	92	0.6%

Rk	Health and Env. Toxicology	#	%
1	Environment Canada	378	7.4%
2	Health Canada	285	7.4%
3	Fisheries and Oceans Canada	227	3.6%
4	University of Guelph	218	1.4%
5	Agriculture and Agri-Food Canada	216	1.4%
6	McGill University	205	0.6%
7	University of Toronto	191	0.3%
8	University of British Columbia	164	0.5%
9	McMaster University	132	0.6%
10	Natural Resources Canada	120	1.7%

Rk	Water Resources	#	%
1	University of Waterloo	468	3.5%
2	Environment Canada	465	9.0%
3	Fisheries and Oceans Canada	386	6.2%
4	University of British Columbia	233	0.1%
5	University of Alberta	185	0.1%
6	University of Toronto	155	0.3%
7	McGill University	142	0.4%
8	Dalhousie University	116	1.0%
9	McMaster University	111	0.5%
10	INRS	100	3.7%

Source: Observatoire des sciences et des technologies (SCI/SSCI)

4.3 Inter-Institutional Collaboration

Table 18 presents data on collaborative efforts among the top ten Canadian institutions in environmental science. Appendix 2 contains information on the 40 main partners (national and international) of these establishments.

Environment Canada ranked first among the nine other top ten Canadian institutions (Table 18). Its most important collaborator over the period in question was Fisheries and Oceans Canada, followed by ten Canadian universities. Over the same period, Environment Canada also collaborated with three American federal departments: the U.S. Oceanic and Atmospheric Administration (NOAA) (2.0%*), NASA (1.4%*), and the U.S. National Center for Atmospheric Research (NCAR) (1.1%*).[6] We will examine Environment Canada's main Canadian partners more closely in Section 4.4.

Fisheries and Oceans Canada was the second most important partner of three institutions ranking among the top ten in Canada: the University of British Columbia, the University of Alberta, and the University of Waterloo. Fisheries and Oceans Canada's main partners were Dalhousie University (4.9%*), the University of Manitoba (3.8%*), and the University of British Columbia (2.5%).

In addition to its collaboration with Environment Canada (5.9%), Agriculture and Agri-Food Canada co-authored 5.1% of its publications with McGill University, 5.0%* with the National Research Council of Canada (NRC), and 4.0%* with the University of Guelph.

Natural Resources Canada collaborated primarily with the largest universities in the field and Agriculture and Agri-Food Canada (2.5%). It also co-authored 2.5%* of its publications with NASA.

Table 18. Inter-Institutional Collaboration Among Top Ten Canadian Institutions in Environmental Science, 1980 - 1998

Institution 1 \ Institution 2	Environment Canada		Fisheries and Oceans Canada		University of British Columbia		University of Toronto		McGill University		University of Alberta		University of Waterloo		Guelph University		Agriculture and Agri-Food Canada		Natural Resources Canada	
	Rk	%	Rk	%	Rk	%	Rk	%	Rk	%	Rk	%	Rk	%	Rk	%	Rk	%	Rk	%
Environment Canada			**1**	(3.8%)	**8**	(1.8%)	**6**	(2.1%)	**3**	(2.5%)	**13**	(1.4%)	**2**	(2.6%)	**4**	(2.5%)	**10**	(1.6%)	**15**	(1.0%)
Fisheries and Oceans Canada	**1**	(6.9%)			**4**	(2.5%)	**14**	(0.8%)	**10**	(1.6%)	**8**	(1.7%)	**7**	(2.1%)	**8**	(1.7%)				
University of British Columbia	**1**	(3.5%)	**2**	(2.7%)			**8**	(0.8%)			**4**	(1.5%)	**12**	(0.7%)					**7**	(1.0%)
University of Toronto	**1**	(4.8%)	**8**	(1.1%)	**9**	(0.9%)			**6**	(1.2%)	**15**	(0.7%)	**2**	(2.2%)	**14**	(0.8%)			**15**	(0.7%)
McGill University	**1**	(6.5%)	**5**	(2.3%)			**10**	(1.3%)									**3**	(3.6%)		
University of Alberta	**1**	(3.9%)	**2**	(2.7%)	**3**	(2.2%)	**10**	(0.9%)	**10**	(0.9%)			**8**	(1.1%)			**6**	(1.3%)	**4**	(2.1%)
University of Waterloo	**1**	(7.7%)	**2**	(3.4%)	**9**	(1.0%)	**3**	(2.8%)			**7**	(1.2%)			**4**	(2.5%)			**12**	(0.7%)
University of Guelph	**1**	(7.6%)	**3**	(2.8%)	**10**	(0.9%)	**9**	(1.0%)					**4**	(2.5%)			**2**	(3.2%)	**8**	(1.6%)
Agriculture and Agri-Food Canada	**1**	(5.9%)			**12**	(1.1%)			**2**	(5.1%)	**7**	(1.8%)			**4**	(4.0%)			**6**	(1.9%)
Natural Resources Canada	**1**	(5.0%)	**10**	(1.7%)	**3**	(2.7%)	**13**	(1.5%)	**10**	(1.7%)	**2**	(3.6%)			**3**	(2.7%)	**5**	(2.5%)		

Source : Observatoire des sciences et des technologies (SCI/SSCI)

* Number of Institution-1 articles co-autored with Institution-2, divided by the number of articles by Institution-1.

McGill University co-authored 6.5% of all its publications with Environment Canada, 4.7%* with the Université de Montréal, 3.6% with Agriculture and Agri-Food Canada, and 2.5%* with the National Research Council of Canada.

The University of British Columbia collaborated with Fisheries and Oceans Canada on 2.7% of its publications, with the University of Washington on 1.6%*, and with the University of Alberta on 1.5%*.

The University of Alberta co-authored 2.7% of its publications with Fisheries and Oceans Canada, 2.2% with the University of British Columbia, 2.1% with Natural Resources Canada, and 1.9%* with the Bamfield Marine Station, an inter-university marine biology research facility established by a consortium of five Canadian universities and funded by the National Research Council of Canada.

Aside from its work with Environment Canada (4.8%), the University of Toronto looked primarily to other Ontario universities: the University of Waterloo (2.2%), McMaster University (1.9%*), York University (1.7%*), and Trent University (1.6%*).

The University of Guelph collaborated primarily with Environment Canada (7.6%), but also jointly published with Agriculture and Agri-Food Canada (3.2%), Fisheries and Oceans Canada (2.8%), and the University of Waterloo (2.5%). It also collaborated with two Ontario government ministries: the Ministry of Natural Resources (2.1%*) and the Ministry of Agriculture (2.0%*).

The University of Waterloo ranked first among the top ten institutions in terms of the proportion of its publications with Environment Canada (7.7%). It also collaborated with Fisheries and Oceans Canada (3.4%), the University of Toronto (2.8%), the University of Guelph (2.5%), and the University of Manitoba (1.6%*).

In short, there is a diverse inter-institutional collaborative environmental science network in Canada. The most frequent collaboration occurs between Environment Canada on the one hand and the University of Waterloo, Fisheries and Oceans Canada, McGill University, Agriculture and Agri-Food Canada, Natural Resources Canada, and the University of Toronto on the other. Fairly frequent collaboration also occurs between Agriculture and Agri-Food Canada and McGill University, the University of Guelph, and the National Research Council of Canada. Collaborations between McGill University and the *Université de Montréal*, and between Fisheries and Oceans Canada and Dalhousie University, are also fairly frequent.

4.4 Environment Canada's Main Research Collaborators

Given that Environment Canada is the largest environmental science institution in Canada in terms of scientific research publications, and that it is the main partner of other Canadian institutions in the field, this last section will be devoted to a detailed analysis of the Department's collaborators.

The Department's primary partners in environmental science as a whole have already been identified (Table 18). Table 19 presents the proportion of Environment Canada articles written in collaboration with its main Canadian partners, for each specialty.

The number of the Department's collaborative efforts has increased over time, in most specialties. Over the second half of the period under study (1990-1998), there was frequent collaboration in *Ecology* with the University of Saskatchewan (11.0%) and the University of Alberta (11.0%). In the area of *General Environment*, publications with Fisheries and Oceans Canada represented 8.3% of the Department's total output, or double the rate recorded from 1980 to 1989. The same holds true for *Meteorology and Atmospheric Science*, where collaboration between the Department and York University rose from 1.5% to 7.0%, and with McGill University, from 2.6% to 6.4%. In *Water Resources*, cooperation with the University of Waterloo also almost doubled, from 4.2% to 10.1%. In *Health and*

Table 19. Environment Canada's Collaboration Rate by Canadian Institution, Environmental Science Specialty and Period, 1980 - 1989 and 1990 - 1998

		Fisheries and Oceans Canada	University of Waterloo	University of Guelph	McGill University	York University	University of Toronto	University of British Columbia	McMaster University	Agriculture & Agri-Food Canada	University of Saskatchewan	University of Alberta	Ressources naturelles Canada	UQAM	Ontario Min. Environment
Ecology	1980-1989	0.8%	0.0%	1.7%	2.5%	0.8%	0.8%	0.8%	0.0%	1.7%	1.7%	4.1%	2.5%	0.0%	0.0%
	1990-1998	0.9%	0.0%	2.8%	0.9%	0.0%	2.8%	4.6%	3.7%	0.0%	11.0%	11.0%	0.9%	0.0%	0.0%
General Environment	1980-1989	4.2%	0.9%	1.4%	0.0%	0.0%	1.9%	0.5%	1.6%	0.2%	0.2%	0.9%	0.9%	0.0%	1.4%
	1990-1998	8.3%	3.7%	2.3%	0.8%	1.0%	2.9%	1.0%	3.3%	2.5%	1.2%	1.5%	1.0%	0.2%	1.4%
Environmental Engineering	1980-1989	2.4%	9.5%	0.0%	0.0%	0.0%	2.4%	2.4%	0.0%	0.0%	0.0%	0.0%	2.4%	0.0%	0.0%
	1990-1998	1.9%	3.8%	3.8%	0.0%	3.8%	1.9%	5.7%	5.7%	0.0%	1.9%	0.0%	3.8%	1.9%	0.0%
Meteorology and Atmos.	1980-1989	1.5%	0.4%	0.8%	2.6%	1.5%	1.9%	0.4%	0.0%	0.4%	0.0%	0.0%	0.4%	0.0%	1.1%
Science	1990-1998	1.0%	0.5%	2.0%	6.4%	7.0%	2.5%	2.8%	0.8%	1.7%	0.7%	0.8%	1.2%	2.7%	0.5%
Water Resources	1980-1989	3.4%	4.2%	0.8%	0.4%	1.7%	1.3%	2.5%	2.9%	0.8%	0.4%	0.4%	0.8%	0.4%	0.8%
	1990-1998	3.1%	10.1%	0.9%	2.6%	1.8%	1.8%	1.3%	4.4%	0.9%	3.1%	2.6%	0.4%	0.0%	0.9%
Health and Env. Toxicology	1980-1989	6.0%	5.1%	5.1%	3.4%	0.0%	1.7%	0.0%	0.0%	2.6%	0.9%	0.0%	0.9%	0.0%	0.9%
	1990-1998	6.1%	2.3%	9.6%	3.8%	1.9%	1.5%	3.1%	0.0%	5.0%	3.8%	0.0%	0.8%	2.7%	0.4%
All Specialties	1980-1989	**3.2%**	**2.1%**	**1.5%**	**1.2%**	**0.7%**	**1.6%**	**0.9%**	**1.2%**	**0.7%**	**0.4%**	**0.8%**	**1.0%**	**0.1%**	**1.0%**
	1990-1998	**4.2%**	**3.0%**	**3.2%**	**3.3%**	**3.3%**	**2.4%**	**2.3%**	**2.2%**	**2.1%**	**2.3%**	**1.7%**	**1.0%**	**1.4%**	**0.7%**
TOTAL	1980-1998	**3.8%**	**2.6%**	**2.5%**	**2.5%**	**2.2%**	**2.1%**	**1.7%**	**1.8%**	**1.6%**	**1.5%**	**1.4%**	**1.0%**	**0.9%**	**0.8%**

Source: Observatoire des sciences et des technologies (SCI/SSCI)

Environmental Toxicology, Environment Canada had already been working closely with certain institutions from 1980 to 1989, co-authoring 6.0% of its publications with Fisheries and Oceans Canada, and 5.1% with the University of Guelph and the University of Waterloo. During the second half of the period, the level of collaboration with these institutions was maintained and even increased, with the Department co-authoring 6.1% of its publications with Fisheries and Oceans Canada and 9.6% with the University of Guelph. While such efforts fell off with the University of Waterloo, they increased with Agriculture and Agri-Food Canada (5.0%). ■

---

[6] Percentages accompanied by an asterisk do not appear in Table 18 because they refer to institutions other than the top ten. They can, however, be found in Appendix 2.

5 Conclusion

This bibliometric analysis shows that there has been remarkable growth in environmental scientific research worldwide. At the beginning of the 1980s, there were slightly more than 10,000 research publications in the field, whereas by the end of the 1990s, that number had almost doubled.

Ranking third internationally in terms of publication volume and scientific impact, Canada is an important source of new knowledge in the field, with a relative effort considerably higher than the world average as well as the average of the top ten producers. International collaboration by Canada in the field has also made considerable gains, rising from 13% in the early 1980s to more than 30% by the end of the 1990s. Among those countries with which Canada collaborates the most are, in order, the United States, the United Kingdom, Germany, France, Australia and Japan.

Most Canadian environmental science publications focus on three of the seven specialties in question: *General Environment* (25.6% of all publications), *Ecology* (22.8%), and *Water Resources* (16.1%). Representing respectively 15.6% and 13.0% of Canadian articles, *Health and Environmental Toxicology* and *Meteorology and Atmospheric Science* also account for a good proportion of the total. *Environmental Engineering* and the *Social Sciences*, for their part, represent 5% and 2% of all studies in the field.

The university sector largely dominates the field, with two-thirds of all Canadian publications (66.7%) to its credit. The federal government, however, is also a major player, accounting for one-third (31.8%) of national output. Other active institutional sectors are, in order, industry (7.8%), provincial governments (6.5%), and "Other" institutions (2.8%) (mainly non-profit organizations and inter-sectoral research groups).

Among the Canadian institutions examined, Environment Canada constitutes the largest source of new environmental science knowledge (with 2,985 articles during the period in question). The Department is followed by Fisheries and Oceans Canada (1,661 publications), the University of British Columbia (1,524), the University of Toronto (1,293), McGill University (1,142), the University of Alberta (1,046), the University of Waterloo (1,016), the University of Guelph (986), and Agriculture and Agri-Food Canada (797). Environment Canada is also the main partner of the nine other top ten Canadian institutions in the field.

In closing, we should mention that we do not feel that the specialties *Social Sciences*—and, to a lesser extent, *Environmental Engineering*—are well represented, using our methodology. Contrary to the other specialties, where publications are concentrated in a relatively limited number of specialized journals, articles in these two specialties are published in a wide variety of journals more oriented toward individual disciplines than environmental science—journals that were not used for the purposes of this study.

Better coverage of the contribution of *Social Sciences* and *Environmental Engineering* to environmental science would require a specific keyword methodology. This would make it possible to identify not only a greater number of relevant publications, but also the institutions active in these two specialties, as well as the collaborative networks to which they belong.[7]. ■

[7] The OST previously applied such a method to genomics (Genome Canada), applied calculus (the Centre de recherche en calcul appliqué, or CERCA), and aging (Institute of Healthy Aging – Canadian Institutes of Health).

6 Appendices

Appendix 1. Top 40 Canadian Institutions (Rank and Number of Articles) by Specialty, 1980 - 1998

Rank		Ecology		General Environment		Environmental Engineering		Meteorology and Atmospheric Science		Water Resources		Health and Environmental Toxicology		Social Sciences		No. of Publications
		Rk	#	Rk	#	Rk	#	Rk	#	Rk	#	Rk	#	Rk	#	TOTAL
1	Environment Canada	10	(230)	1	(945)	2	(95)	1	(864)	2	(465)	1	(378)	17	(8)	2,985
2	Fisheries & Oceans Canada	2	(457)	2	(421)	17	(30)	6	(137)	3	(386)	3	(227)	29	(3)	1,661
3	University of British Columbia	1	(528)	5	(287)	3	(74)	5	(176)	4	(233)	8	(164)	1	(62)	1,524
4	University of Toronto	4	(317)	3	(342)	7	(46)	3	(219)	6	(155)	7	(191)	3	(23)	1,293
5	McGill University	6	(278)	11	(174)	10	(37)	2	(291)	7	(142)	6	(205)	10	(15)	1,142
6	University of Alberta	3	(332)	8	(231)	1	(116)	7	(105)	5	(185)	22	(56)	4	(21)	1,046
7	University of Waterloo	25	(64)	7	(240)	4	(69)	15	(57)	1	(468)	13	(102)	8	(16)	1,016
8	U. of Guelph	5	(295)	6	(266)	21	(17)	13	(72)	11	(99)	4	(218)	6	(19)	986
9	Agriculture & Agri-Food Canada	12	(150)	4	(288)	25	(15)	9	(95)	28	(33)	5	(216)			797
10	Natural Resources Canada	21	(77)	9	(224)	9	(42)	11	(83)	25	(45)	10	(120)	14	(12)	603
11	Université Laval	8	(248)	16	(109)	16	(32)	24	(20)	16	(66)	21	(59)	19	(7)	541
12	Dalhousie University	7	(255)	27	(62)	41	(5)	15	(57)	8	(116)	40	(23)	16	(9)	527
13	Health Canada	>100	(1)	10	(188)	23	(16)	43	(7)	46	(11)	2	(285)	21	(6)	514
14	McMaster University	29	(47)	17	(108)	14	(34)	14	(58)	9	(111)	9	(132)	10	(15)	505
15	University of Calgary	11	(194)	13	(132)	23	(16)	19	(52)	20	(55)	30	(33)	7	(17)	499
16	University of Manitoba	24	(67)	15	(111)	6	(50)	31	(17)	12	(89)	11	(116)	13	(13)	463
17	University of Saskatchewan	15	(112)	14	(117)	27	(11)	12	(79)	14	(73)	20	(61)	29	(3)	456
18	Simon Fraser University	9	(230)	26	(63)	41	(5)	39	(9)	28	(33)	15	(89)	4	(21)	450
19	York University	22	(68)	20	(85)	33	(7)	4	(180)	24	(46)	28	(37)	12	(14)	437
20	Université de Montréal	17	(98)	19	(89)	13	(36)	31	(17)	16	(66)	12	(109)	15	(10)	425
21	NRC	26	(59)	34	(51)	5	(63)	10	(92)	15	(72)	26	(40)	29	(3)	380
22	Memorial Univ. of Nfld.	14	(146)	35	(44)	8	(42)	29	(18)	13	(75)	25	(41)	47	(1)	367
23	Queen's University	13	(149)	33	(57)	18	(27)	24	(20)	18	(65)	42	(20)	8	(16)	354
24	University of Western Ontario	16	(109)	28	(61)	21	(17)	18	(53)	27	(34)	16	(72)	19	(7)	353
25	University of Victoria	23	(68)	31	(58)	45	(4)	8	(97)	22	(50)	32	(30)	2	(34)	341
26	University of Ottawa	18	(94)	24	(67)	15	(33)	50	(5)	19	(61)	17	(70)	21	(6)	336
27	INRS	36	(28)	22	(82)	10	(37)	43	(7)	10	(100)	23	(56)			310
28	Ont. Min. of the Environment	78	(4)	12	(157)	41	(5)	20	(49)	23	(48)	37	(28)			291
29	UQAM	28	(54)	23	(68)	36	(6)	15	(57)	37	(16)	19	(64)			265
30	University of Windsor	27	(58)	25	(65)	19	(24)	50	(5)	26	(41)	34	(29)	25	(4)	226
31	Trent University	40	(25)	21	(83)	>100	(1)	23	(23)	28	(33)	24	(43)	29	(3)	211
32	Ont. Min. of Natural Resources	20	(80)	18	(101)	65	(2)			49	(10)	59	(7)			200
33	Carleton University	19	(87)	29	(60)	28	(9)	43	(7)	59	(8)	42	(20)	17	(8)	199
34	Université de Sherbrooke	34	(32)	37	(39)	20	(22)	34	(12)	32	(23)	29	(35)			163
35	AECL	71	(5)	30	(59)	36	(6)	29	(18)	21	(52)	44	(18)			158
36	Concordia University	37	(27)	41	(32)	10	(37)	56	(4)	34	(18)	32	(30)	24	(5)	153
37	Dept. of National Defence			80	(6)	45	(4)	21	(30)	74	(5)	13	(102)			147
38	University of New Brunswick	30	(44)	31	(58)	36	(6)	34	(12)	38	(15)	78	(4)	47	(1)	140
39	Alberta Research Council	53	(9)	42	(31)	33	(7)	27	(19)	31	(27)	34	(29)			122
40	University of Regina	37	(27)	50	(18)	26	(14)	>100	(1)	55	(9)	47	(15)	25	(4)	88

Source: Observatoire des sciences et des technologies (SCI/SSCI)

Appendix 2. Inter-Institutional Collaboration* for Top Ten Canadian Institutions, 1980 - 1998**

	Institution 1 / Institution 2	Environment Canada	Fisheries and Oceans Canada	University of British Columbia	University of Toronto	McGill University	University of Alberta	University of Waterloo	Guelph University	Agriculture and Agri-Food Canada	Natural Resources Canada
10 Largest Institutions	**Environment Canada**		1 (6.9%)	1 (3.5%)	1 (4.8%)	1 (6.5%)	1 (3.9%)	1 (7.7%)	1 (7.6%)	1 (5.9%)	1 (5.0%)
	Fisheries and Oceans Canada	1 (3.8%)		2 (2.7%)	8 (1.1%)	5 (2.3%)	2 (2.7%)	2 (3.4%)	3 (2.8%)		10 (1.7%)
	University of British Columbia	9 (1.7%)	4 (2.5%)		9 (0.9%)		3 (2.2%)	9 (1.0%)	10 (0.9%)	12 (1.1%)	3 (2.7%)
	University of Toronto	6 (2.1%)	14 (0.8%)	8 (0.8%)		10 (1.3%)	10 (0.9%)	3 (2.8%)	9 (1.0%)		13 (1.5%)
	McGill University	3 (2.5%)	10 (1.6%)		6 (1.2%)		10 (0.9%)			2 (5.1%)	10 (1.7%)
	University of Alberta	13 (1.4%)	8 (1.7%)	4 (1.5%)	15 (0.7%)			7 (1.2%)		7 (1.8%)	2 (3.6%)
	University of Waterloo	2 (2.6%)	7 (2.1%)	12 (0.7%)	2 (2.2%)		8 (1.1%)		4 (2.5%)		
	University of Guelph	4 (2.5%)	8 (1.7%)		14 (0.8%)			4 (2.5%)		4 (4.0%)	3 (2.7%)
	Agriculture and Agri-Food Canada	10 (1.6%)				3 (3.6%)	6 (1.3%)		2 (3.2%)		5 (2.5%)
	Natural Resources Canada	15 (1.0%)		7 (1.0%)	15 (0.7%)		4 (2.1%)	12 (0.7%)	8 (1.6%)	6 (1.9%)	
Fed.	**Health Canada**				7 (1.2%)						
	National Research Council Canada					4 (2.5%)	10 (0.9%)			3 (5.0%)	
Provincial & Hospital	**Alberta Dept. Environment**						7 (1.2%)				
	Alberta Research Council						9 (1.1%)				
	B.C. Min. of Environment			12 (0.7%)							
	B.C. Min. Forests			5 (1.3%)							
	B.C. Min. Health			12 (0.7%)							
	Ontario Hydro				15 (0.7%)						
	Ontario Min. Agr. Food & Rural Aff.								6 (2.0%)		
	Ontario Min. Labour				15 (0.7%)						
	Ontario Min. Natural Resources				15 (0.7%)			6 (1.4%)	5 (2.1%)		
	Royal Ontario Museum				15 (0.7%)						
	St. Michael's Hospital				15 (0.7%)						
Universities & Research Centres	**Bamfield Marine Station**						5 (1.9%)				
	Dalhousie University		2 (4.9%)								
	INRS		12 (0.9%)			7 (1.8%)				15 (1.0%)	
	IRSST					10 (1.3%)					
	Laurentian University										14 (1.3%)
	McMaster University	8 (1.8%)			3 (1.9%)			11 (0.8%)	10 (0.9%)		
	Memorial University of Nfld.		6 (2.2%)			15 (1.0%)					
	Queens University			10 (0.7%)	9 (0.9%)						14 (1.3%)
	Ryerson Polytechnic University				15 (0.7%)						
	Simon Fraser University			6 (1.2%)						9 (1.4%)	7 (2.2%)
	Trent University				5 (1.6%)						
	University of Calgary						13 (0.7%)				
	Université Laval		5 (2.3%)			8 (1.7%)				8 (1.6%)	8 (2.0%)
	University of Manitoba		3 (3.8%)	12 (0.7%)			13 (0.7%)	5 (1.6%)	14 (0.7%)	10 (1.3%)	
	Université de Montréal					2 (4.7%)					
	University of New Brunswick										14 (1.3%)
	University of Ottawa			10 (0.7%)	13 (0.9%)					5 (2.3%)	
	University of Saskatchewan	11 (1.5%)								12 (1.1%)	
	Université de Sherbrooke					6 (2.0%)					
	University of Victoria		14 (0.8%)								8 (2.0%)
	University of Western Ontario							12 (0.7%)			
	UQAM					8 (1.7%)					
	UQAR		11 (1.1%)								
	Wilfred Laurier University							12 (0.7%)			
	York University	5 (2.2%)			4 (1.7%)	12 (1.2%)			14 (0.7%)		
U.S. Fed.	**NASA**	12 (1.4%)									5 (2.5%)
	US Dept of Agriculture / Agr. Res. Ctr.									10 (1.3%)	
	US Geological Survey							8 (1.1%)			
	US Nat. Ctr for Atmospheric Research	14 (1.1%)			9 (0.9%)	12 (1.2%)					
	US Nat. Oceanic & Atmos. Adm.	7 (2.0%)				14 (1.1%)					
U.S. Universities	**Indiana University**			12 (0.7%)							
	Oregon State University									15 (1.0%)	
	Texas A&M Univ. Syst.								12 (0.8%)		
	University of California, Davis			12 (0.7%)							
	University of Nebraska									12 (1.1%)	
	University of Texas								12 (0.8%)		
	University of Washington		14 (0.8%)	3 (1.6%)							
Others	**CSIRO**			8 (0.8%)							
	Woods Hole Oc. Inst.		12 (0.9%)								
	Intera. Informat. Tech.										10 (1.7%)
	Intermap. Informat. Tech. Ltd.										14 (1.3%)
	Conestoga Rovers & Assoc. Ltd.							10 (0.9%)			
	Stanley Ind. Consultants. Ltd.						15 (0.6%)				

Source: Observatoire des sciences et des technologies (SCI/SSCI)

* This matrix presents the 15 main co-workers in importance of the 10 most productive institutions in environmental sciences in Canada.

** Number of Institution-1 articles co-autored with Institution-2, divided by the number of articles by Institution-1.

Appendix 3. Environmental Science Journals (317) Classified by Specialty

Ecology

- ACTA OECOLOGICA-INTERNATIONAL JOURNAL OF ECOLOGY
- ACTA OECOLOGICA-OECOLOGIA APPLICATA
- ACTA OECOLOGICA-OECOLOGIA GENERALIS
- ACTA OECOLOGICA-OECOLOGIA PLANTARUM
- ADVANCES IN ECOLOGICAL RESEARCH
- ADVANCES IN MICROBIAL ECOLOGY
- AFRICAN JOURNAL OF ECOLOGY
- AMERICAN MIDLAND NATURALIST
- AMERICAN NATURALIST
- ANNUAL REVIEW OF ECOLOGY AND SYSTEMATICS
- AQUATIC MICROBIAL ECOLOGY
- AUSTRALIAN JOURNAL OF ECOLOGY
- AUSTRALIAN JOURNAL OF MARINE AND FRESHWATER RESEARCH
- AUSTRALIAN WILDLIFE RESEARCH
- BIOCHEMICAL SYSTEMATICS AND ECOLOGY
- BIOTROPICA
- CANADIAN FIELD-NATURALIST
- ECOGRAPHY
- ECOLOGICAL BULLETINS
- ECOLOGICAL MONOGRAPHS
- ECOLOGICAL RESEARCH
- ECOLOGICAL STUDIES
- ECOLOGY
- ENVIRONMENTAL BIOLOGY OF FISHES
- FEMS MICROBIOLOGY ECOLOGY
- FRESHWATER BIOLOGY
- FUNCTIONAL ECOLOGY
- GLOBAL ECOLOGY AND BIOGEOGRAPHY
- GLOBAL ECOLOGY AND BIOGEOGRAPHY LETTERS
- HOLARCTIC ECOLOGY
- INVESTIGACION PESQUERA
- JOURNAL OF ANIMAL ECOLOGY
- JOURNAL OF CHEMICAL ECOLOGY
- JOURNAL OF ECOLOGY
- JOURNAL OF EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY
- JOURNAL OF FRESHWATER ECOLOGY
- JOURNAL OF VECTOR ECOLOGY
- JOURNAL OF WILDLIFE MANAGEMENT
- MARINE AND FRESHWATER RESEARCH
- MARINE ECOLOGY-PROGRESS SERIES
- MARINE ECOLOGY-PUBBLICAZIONI DELLA STAZIONE ZOOLOGICA DI NAPOLI I
- MICROBIAL ECOLOGY
- MOLECULAR ECOLOGY
- NATURAL HISTORY
- NEW ZEALAND JOURNAL OF ECOLOGY
- NEW ZEALAND JOURNAL OF MARINE AND FRESHWATER RESEARCH
- OECOLOGIA
- OIKOS
- ORYX
- PEDOBIOLOGIA
- PLANT CELL AND ENVIRONMENT
- PLANT ECOLOGY
- POLAR BIOLOGY
- PROCEEDINGS OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA
- RESEARCHES ON POPULATION ECOLOGY
- REVUE D ECOLOGIE ET DE BIOLOGIE DU SOL
- REVUE D ECOLOGIE - LA TERRE ET LA VIE
- SARSIA
- SOUTH AFRICAN JOURNAL OF WILDLIFE RESEARCH
- STUDIES ON NEOTROPICAL FAUNA AND ENVIRONMENT
- TERRE ET LA VIE - REVUE D ECOLOGIE APPLIQUEE
- THEORETICAL POPULATION BIOLOGY
- TRANSACTIONS OF THE NORTH AMERICAN WILDLIFE AND NATURAL RESOURCES CONFERENCE
- TRENDS IN ECOLOGY & EVOLUTION
- VEGETATIO
- VIE ET MILIEU-LIFE AND ENVIRONMENT
- WILDLIFE MONOGRAPHS
- WILDLIFE RESEARCH

General Environment

- AGRICULTURAL WASTES
- AGRICULTURE AND ENVIRONMENT
- AGRICULTURE ECOSYSTEMS & ENVIRONMENT
- AGRO-ECOSYSTEMS
- AMBIO
- ANNALI DI CHIMICA
- ANNUAL REVIEW OF ENERGY AND THE ENVIRONMENT
- ANTARCTIC SCIENCE
- ARCTIC
- BIOCYCLE
- BIOGEOCHEMISTRY
- BIOLOGICAL CONSERVATION
- BIOLOGY AND ENVIRONMENT-PROCEEDINGS OF THE ROYAL IRISH ACADEMY
- CATENA
- CHEMOSPHERE
- COASTAL ZONE MANAGEMENT JOURNAL
- CONSERVATION & RECYCLING
- CONSERVATION BIOLOGY
- CRC CRITICAL REVIEWS IN ENVIRONMENTAL CONTROL
- CRITICAL REVIEWS IN ENVIRONMENTAL CONTROL

- CRITICAL REVIEWS IN ENVIRONMENTAL SCIENCE AND TECHNOLOGY
- CURRENT CONTENTS/AGRICULTURE BIOLOGY & ENVIRONMENTAL SCIENCES
- ECOLOGICAL APPLICATIONS
- ECOLOGICAL ENGINEERING
- ECOLOGICAL MODELLING
- ECOSYSTEM HEALTH
- ENVIRONMENTAL CONSERVATION
- ENVIRONMENTAL GEOLOGY
- ENVIRONMENTAL GEOLOGY AND WATER SCIENCES
- ENVIRONMENTAL MANAGEMENT
- ENVIRONMENTAL POLLUTION
- ENVIRONMENTAL POLLUTION SERIES A - ECOLOGICAL AND BIOLOGICAL
- ENVIRONMENTAL POLLUTION SERIES B - CHEMICAL AND PHYSICAL
- ENVIRONMENTAL RESEARCH
- ENVIRONMENTAL SCIENCE & TECHNOLOGY
- ESTUARIES
- FOREST ECOLOGY AND MANAGEMENT
- GEOMICROBIOLOGY JOURNAL
- GLOBAL BIOGEOCHEMICAL CYCLES
- INTERNATIONAL JOURNAL OF ENVIRONMENTAL ANALYTICAL CHEMISTRY
- IRRIGATION SCIENCE
- JAPCA-THE INTERNATIONAL JOURNAL OF AIR POLLUTION CONTROL AND HAZARDOUS WASTE MANAGEMENT
- JAPCA-THE JOURNAL OF THE AIR & WASTE MANAGEMENT ASSOCIATION
- JOURNAL OF APPLIED ECOLOGY
- JOURNAL OF ARID ENVIRONMENTS
- JOURNAL OF BIOGEOGRAPHY
- JOURNAL OF COASTAL RESEARCH
- JOURNAL OF ENVIRONMENTAL MANAGEMENT
- JOURNAL OF ENVIRONMENTAL QUALITY
- JOURNAL OF ENVIRONMENTAL SCIENCES
- JOURNAL OF ENVIRONMENTAL SYSTEMS
- JOURNAL OF FORESTRY
- JOURNAL OF GREAT LAKES RESEARCH
- JOURNAL OF RANGE MANAGEMENT
- JOURNAL OF SOIL AND WATER CONSERVATION
- JOURNAL OF THE CHARTERED INSTITUTION OF WATER AND ENVIRONMENTAL MANAGEMENT
- JOURNAL OF THE INSTITUTION OF WATER AND ENVIRONMENTAL MANAGEMENT
- MOUNTAIN RESEARCH AND DEVELOPMENT
- POLAR RESEARCH
- RESOURCE RECOVERY AND CONSERVATION
- RESOURCES AND CONSERVATION
- SCIENCE OF THE TOTAL ENVIRONMENT
- SOIL USE AND MANAGEMENT
- URBAN ECOLOGY
- WATER AIR AND SOIL POLLUTION
- WILDLIFE SOCIETY BULLETIN

Environmental Engineering

- AEROSOL SCIENCE AND TECHNOLOGY
- APPLIED CATALYSIS A-GENERAL
- APPLIED CATALYSIS B-ENVIRONMENTAL
- CIVIL ENGINEERING FOR PRACTICING AND DESIGN ENGINEERS
- COLD REGIONS SCIENCE AND TECHNOLOGY
- DESALINATION
- EFFLUENT & WATER TREATMENT JOURNAL
- ENVIRONMENTAL PROGRESS
- ENVIRONMENTAL TECHNOLOGY
- ENVIRONMENTAL TECHNOLOGY LETTERS
- INDOOR AIR-INTERNATIONAL JOURNAL OF INDOOR AIR QUALITY AND CLIMATE
- JOURNAL AMERICAN WATER WORKS ASSOCIATION
- JOURNAL OF ENVIRONMENTAL ENGINEERING-ASCE
- JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING
- JOURNAL OF HAZARDOUS MATERIALS
- JOURNAL OF HYDRAULIC ENGINEERING-ASCE
- JOURNAL OF IRRIGATION AND DRAINAGE ENGINEERING-ASCE
- JOURNAL OF THE AIR & WASTE MANAGEMENT ASSOCIATION
- JOURNAL OF THE ENVIRONMENTAL ENGINEERING DIVISION-ASCE
- JOURNAL OF WATER RESOURCES PLANNING AND MANAGEMENT-ASCE
- JOURNAL OF WATERWAY PORT COASTAL AND OCEAN ENGINEERING-ASCE
- OZONE-SCIENCE & ENGINEERING
- PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS-WATER MARITIME AND ENERGY
- REMOTE SENSING OF ENVIRONMENT
- STOCHASTIC HYDROLOGY AND HYDRAULICS
- WATER & WASTES ENGINEERING
- WATER SUPPLY & MANAGEMENT
- WATER - ENGINEERING & MANAGEMENT

Meteorology and Atmospheric Science

- AGRICULTURAL AND FOREST METEOROLOGY
- ANNALES GEOPHYSICAE-ATMOSPHERES HYDROSPHERES AND SPACE SCIENCES

- ARCHIV FUR METEOROLOGIE GEOPHYSIK UND BIOKLIMATOLOGIE SERIE A-METEOROLOGIE UND GEOPHYSIK
- ARCHIV FUR METEOROLOGIE GEOPHYSIK UND BIOKLIMATOLOGIE SERIE B-KLIMATOLOGIE UMWELTMETEOROLOGIE STRAHLUNGSFORSCHUNG
- ARCHIVES FOR METEOROLOGY GEOPHYSICS AND BIOCLIMATOLOGY SERIES A-METEOROLOGY AND ATMOSPHERIC PHYSICS
- ARCHIVES FOR METEOROLOGY GEOPHYSICS AND BIOCLIMATOLOGY SERIES B-THEORETICAL AND APPLIED CLIMATOLOGY
- ATMOSPHERE-OCEAN
- ATMOSPHERIC ENVIRONMENT
- ATMOSPHERIC ENVIRONMENT PART A-GENERAL TOPICS
- ATMOSPHERIC ENVIRONMENT PART B-URBAN ATMOSPHERE
- ATMOSPHERIC RESEARCH
- AUSTRALIAN METEOROLOGICAL MAGAZINE
- BOUNDARY-LAYER METEOROLOGY
- BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY
- CLIMATE DYNAMICS
- CLIMATIC CHANGE
- DYNAMICS OF ATMOSPHERES AND OCEANS
- INTERNATIONAL JOURNAL OF BIOMETEOROLOGY
- INTERNATIONAL JOURNAL OF CLIMATOLOGY
- IZVESTIYA AKADEMII NAUK FIZIKA ATMOSFERY I OKEANA
- IZVESTIYA AKADEMII NAUK SSSR FIZIKA ATMOSFERY I OKEANA
- JOURNAL OF AEROSOL SCIENCE
- JOURNAL OF APPLIED METEOROLOGY
- JOURNAL OF ATMOSPHERIC AND OCEANIC TECHNOLOGY
- JOURNAL OF ATMOSPHERIC AND SOLAR-TERRESTRIAL PHYSICS
- JOURNAL OF ATMOSPHERIC CHEMISTRY
- JOURNAL OF CLIMATE
- JOURNAL OF CLIMATE AND APPLIED METEOROLOGY
- JOURNAL OF CLIMATOLOGY
- JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES
- JOURNAL OF THE AIR POLLUTION CONTROL ASSOCIATION
- JOURNAL OF THE ATMOSPHERIC SCIENCES
- JOURNAL OF THE METEOROLOGICAL SOCIETY OF JAPAN
- METEOROLOGICAL MAGAZINE
- METEOROLOGISCHE RUNDSCHAU
- METEOROLOGY AND ATMOSPHERIC PHYSICS
- MONTHLY WEATHER REVIEW
- PAPERS IN METEOROLOGY AND GEOPHYSICS
- QUARTERLY JOURNAL OF THE ROYAL METEOROLOGICAL SOCIETY
- RADIO SCIENCE
- RIVISTA DI METEOROLOGIA AERONAUTICA
- TELLUS
- TELLUS SERIES A-DYNAMIC METEOROLOGY AND OCEANOGRAPHY
- TELLUS SERIES B-CHEMICAL AND PHYSICAL METEOROLOGY
- THEORETICAL AND APPLIED CLIMATOLOGY
- WEATHER AND FORECASTING
- ZEITSCHRIFT FUR METEOROLOGIE

Water Resources

- ACTA HYDROCHIMICA ET HYDROBIOLOGICA
- ADVANCES IN WATER RESOURCES
- AGRICULTURAL WATER MANAGEMENT
- ARCHIV FUR HYDROBIOLOGIE
- GROUND WATER
- HYDROBIOLOGIA
- HYDROLOGICAL SCIENCES JOURNAL - JOURNAL DES SCIENCES HYDROLOGIQUES
- INTERNATIONAL HYDROGRAPHIC REVIEW
- INTERNATIONAL REVIEW OF HYDROBIOLOGY
- INTERNATIONALE REVUE DER GESAMTEN HYDROBIOLOGIE
- JOURNAL OF CONTAMINANT HYDROLOGY
- JOURNAL OF GEOPHYSICAL RESEARCH-OCEANS
- JOURNAL OF HYDROLOGY
- JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
- JOURNAL WATER POLLUTION CONTROL FEDERATION
- MARINE ENVIRONMENTAL RESEARCH
- MARINE POLLUTION BULLETIN
- NORDIC HYDROLOGY
- PROGRESS IN WATER TECHNOLOGY
- RESEARCH JOURNAL OF THE WATER POLLUTION CONTROL FEDERATION
- SCHWEIZERISCHE ZEITSCHRIFT FUR HYDROLOGIE-SWISS JOURNAL OF HYDROLOGY
- WATER ENVIRONMENT RESEARCH
- WATER POLLUTION CONTROL
- WATER RESEARCH
- WATER RESOURCES BULLETIN
- WATER RESOURCES RESEARCH
- WATER SA

- WATER SCIENCE AND TECHNOLOGY
- ZEITSCHRIFT FUR WASSER UND ABWASSER FORSCHUNG-JOURNAL FOR WATER AND WASTEWATER RESEARCH

Health and Environmental Toxicology

- AMERICAN INDUSTRIAL HYGIENE ASSOCIATION JOURNAL
- AMERICAN JOURNAL OF INDUSTRIAL MEDICINE
- ANNALS OF OCCUPATIONAL HYGIENE
- AQUATIC TOXICOLOGY
- ARCHIVES OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY
- ARCHIVES OF ENVIRONMENTAL HEALTH
- AVIATION SPACE AND ENVIRONMENTAL MEDICINE
- BRITISH JOURNAL OF INDUSTRIAL MEDICINE
- BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY
- ECOTOXICOLOGY
- ECOTOXICOLOGY AND ENVIRONMENTAL SAFETY
- ENVIRONMENTAL AND MOLECULAR MUTAGENESIS
- ENVIRONMENTAL CARCINOGENESIS & ECOTOXICOLOGY REVIEWS- PART C OF JOURNAL OF ENVIRONMENTAL SCIENCE AND HEALTH
- ENVIRONMENTAL CARCINOGENESIS REVIEWS-PART C OF JOURNAL OF ENVIRONMENTAL SCIENCE AND HEALTH
- ENVIRONMENTAL HEALTH PERSPECTIVES
- ENVIRONMENTAL MUTAGENESIS
- ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY
- ENVIRONMENTAL TOXICOLOGY AND PHARMACOLOGY
- ENVIRONMENTAL TOXICOLOGY AND WATER QUALITY
- EUROPEAN JOURNAL OF PHARMACOLOGY-ENVIRONMENTAL TOXICOLOGY AND PHARMACOLOGY SECTION
- FLUORIDE
- INDUSTRIAL HEALTH
- INTERNATIONAL ARCHIVES OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH
- JOURNAL OF ENVIRONMENTAL HEALTH
- JOURNAL OF ENVIRONMENTAL PATHOLOGY AND TOXICOLOGY
- JOURNAL OF ENVIRONMENTAL PATHOLOGY TOXICOLOGY AND ONCOLOGY
- JOURNAL OF ENVIRONMENTAL SCIENCE AND HEALTH PART A- ENVIRONMENTAL SCIENCE AND ENGINEERING
- JOURNAL OF ENVIRONMENTAL SCIENCE AND HEALTH PART A- TOXIC/HAZARDOUS SUBSTANCES & ENVIRONMENTAL ENGINEERING
- JOURNAL OF ENVIRONMENTAL SCIENCE AND HEALTH PART B- PESTICIDES FOOD CONTAMINANTS AND AGRICULTURAL WASTES
- JOURNAL OF ENVIRONMENTAL SCIENCE AND HEALTH PART C- ENVIRONMENTAL CARCINOGENESIS REVIEWS
- JOURNAL OF OCCUPATIONAL AND ENVIRONMENTAL MEDICINE
- JOURNAL OF OCCUPATIONAL MEDICINE
- JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH
- JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH-PART A
- JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH-PART B-CRITICAL REVIEWS
- MICROBIAL ECOLOGY IN HEALTH AND DISEASE
- MUTATION RESEARCH-ENVIRONMENTAL MUTAGENESIS AND RELATED SUBJECTS
- MUTATION RESEARCH-GENETIC TOXICOLOGY AND ENVIRONMENTAL MUTAGENESIS
- OCCUPATIONAL AND ENVIRONMENTAL MEDICINE
- RADIATION AND ENVIRONMENTAL BIOPHYSICS
- REVIEWS OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY
- SCANDINAVIAN JOURNAL OF WORK ENVIRONMENT & HEALTH
- TOXICOLOGICAL AND ENVIRONMENTAL CHEMISTRY
- ZENTRALBLATT FUR HYGIENE UND UMWELTMEDIZIN

Sociale Sciences

- ALTERNATIVES-PERSPECTIVES ON SOCIETY TECHNOLOGY AND ENVIRONMENT
- EARTH ISLAND JOURNAL
- ECOLOGICAL ECONOMICS
- ECOLOGY LAW QUARTERLY
- ECUMENE
- ENERGY JOURNAL
- ENERGY POLICY
- ENVIRONMENT
- ENVIRONMENT AND URBANIZATION
- ENVIRONMENTAL & RESOURCE ECONOMICS
- ENVIRONMENTAL CLAIMS JOURNAL
- ENVIRONMENTAL ETHICS
- ENVIRONMENTAL HISTORY
- ENVIRONMENTAL POLICY AND LAW

- ENVIRONMENTAL VALUES
- GLOBAL ENVIRONMENTAL CHANGE-HUMAN AND POLICY DIMENSIONS
- HARVARD ENVIRONMENTAL LAW REVIEW
- HUMAN AND ECOLOGICAL RISK ASSESSMENT
- HUMAN ECOLOGY
- INTERNATIONAL JOURNAL OF SUSTAINABLE DEVELOPMENT AND WORLD ECOLOGY
- JOURNAL OF AGRICULTURAL & ENVIRONMENTAL ETHICS
- JOURNAL OF ARCHITECTURAL AND PLANNING RESEARCH
- JOURNAL OF ENERGY AND DEVELOPMENT
- JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT
- JOURNAL OF ENVIRONMENTAL PSYCHOLOGY
- MARINE POLICY
- NATURAL RESOURCES FORUM
- NATURAL RESOURCES JOURNAL
- POPULATION AND ENVIRONMENT
- RESOURCE AND ENERGY ECONOMICS
- RESOURCES AND ENERGY
- RESOURCES POLICY
- SOCIETY & NATURAL RESOURCES
- TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT
- WORLD WATCH

Appendix 4. Definition of the Relative Weighed Impact Factor (RWIF)

Although very few indicators make it possible to measure the impact of scientific research, one has acquired a certain amount of legitimacy as concerns research evaluation: the average relative impact factor. The Institute for Scientific Information (ISI) calculates an impact factor for each journal listed in the *Science Citation Index* (SCI) and *Social Science Citation Index* (SSCI). The formula is as follows:

Impact Factor

$$\frac{\text{The number of citations received during one year for the papers published in a journal during the two previous years}}{\text{The number of papers published in the same journal during the two previous years}}$$

The impact factor is used to measure the expected impact of the publications of a given group of researchers. It does have certain limits, however, especially as regards comparability. As we know, publishing and citation practices vary considerably from one discipline to the next, and the impact factor does not make it possible to conduct an interdisciplinary comparison. Here is a fictitious example that illustrates these remarks. Let us say that McGill University publications have an impact factor of 3 in gastro-enterology and of 2.5 in anesthesiology. At first glance, articles in the field of gastro-enterology would seem to have more impact than those in anesthesiology. However, these figures are not comparable unless they can be put into perspective. McGill gastro-enterologists should not be compared directly with their anesthesiology counterparts, but rather to gastro-enterologists from other universities in Quebec, Canada and the world who publish in the same journals.

The OST's relative weighed impact factor (RWIF) corrects these limitations. The RWIF makes it possible to conduct interdisciplinary as well as interdepartmental, inter-institutional, interprovincial, and international comparisons. In the above example, we must divide the impact factor for the two specialties by the average impact of Canadian publications (if, that is, we wish to compare Canada to McGill University) in each specialty. The relative impact factor for McGill's publications would therefore be 0.7 in gastro-enterology (3 divided by the Canadian average of 4.4) and 1.3 in anesthesiology (2.5 divided by 1.9). These relative data allow us to conclude that, in comparison with other Canadian scientists in their respective specialties, McGill anesthesiologists have a

Relative Weighed Impact Factor (RWIF)

$$\sum \left(\frac{\text{Group X's impact factor in discipline Y}}{\text{Canada's impact factor in discipline Y}} \times \frac{\text{Group X's number of publications in discipline Y}}{\text{Group X's total number of publications}} \right)$$

greater impact than their counterparts in gastro-enterology—a finding that runs counter to what absolute impact factors lead one to believe.

To obtain an indicator that synthesizes the overall impact of an institution, we must weight the relative impact factor for each specialty in accordance with the number of publications in that specialty in relation to all publications issued by the institution. If, for example, McGill University was active in the two specialties previously mentioned, and the latter represented 30 and 70 publications respectively, we would assign a weighted value of 0.21 to the impact of articles on gastro-enterology (0.7 x 30/100) and a weighted value of 0.91 to those on anesthesiology (1.3 x 70/100). By adding these two numbers, we would then obtain an average relative impact factor of 1.12, which means that the expected impact of all McGill publications is higher than the average for all Canadian publications taken as a whole.

Recent work has enabled us to apply the indicator to the following countries for 1998 (see table). As can be seen, Canada ranks sixth in terms of its RWIF, just behind the United Kingdom and ahead of France and Germany.

International Relative Weighed Impact Factor (WRIF), 1998

Country	RWIF
United States	**1.20**
Switzerland	**1.11**
Israel	**1.07**
The Nertherlands	**1.06**
United Kingdom	**1.05**
Canada	**1.04**
Denmark	**1.01**
Belgium	**0.99**
France	**0.99**
Finland	**0.98**
Sweden	**0.98**
Germany	**0.98**
Spain	**0.97**
Australia	**0.97**
Italy	**0.95**
Hong Kong	**0.94**
Singapore	**0.94**
Austria	**0.93**
Republic of Ireland	**0.93**
Norway	**0.92**

Source: Observatoire des sciences et des technologies

Observatoire des sciences et des technologies
3465, Durocher Street, Montreal, Quebec, H2X 2C6
Telephone: (514) 499-4074 Fax: (514) 499-4065
www.ost.qc.ca