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Environment Canada's Scientific Research Publications 1980-1997



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Science Policy Branch
Environment Canada

Document de travail n° 6

Direction de la politique scientifique
Environnement Canada

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Environment Canada's Scientific Research Publications 1980 - 1997

**Science Policy Branch
Environment Canada**

**Observatoire des sciences et des technologies
Université du Québec**

March 2000

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SUMMARY

- ❑ Environment Canada's overall production of scientific research articles grew rapidly during the early 1980s, declined at the beginning of the 1990s, then increased again after 1992. (p. 8)
- ❑ Environment Canada's articles show an increase in international and Canadian collaboration rates between 1980 and 1997. In the latter year, over 30% of the Department's scientific research articles were co-authored with foreign scientists, over 50% with scientists at other Canadian institutions. (p. 12)
- ❑ The United States is Environment Canada's major source of international research collaborations, with half of the Department's foreign collaborations. (p. 13)
- ❑ The academic sector provides Environment Canada's largest pool of Canadian research partners with over 60% of these collaborations. (p. 14)
- ❑ Environment Canada's scientific research publications are mostly in the fields of Biology (30% in 1997) and of Earth & Space Sciences (53%). (p. 16)
- ❑ In the field of Earth & Space Sciences, Environment Canada's publications are mainly in two sub-fields: Environmental Science, and Meteorology & Atmospheric Science. In each of these areas, the Department is a major contributor to Canadian research. (p. 18)
- ❑ A listing of the top 72 Canadian researchers in these two sub-fields between 1993 and 1997 shows that 32% are Environment Canada scientists and another 18% are scientists in other federal departments - that is 50% are federal scientists. (p. 18)
- ❑ In the sub-field of Environmental Science, Environment Canada's scientists were responsible for 20% (1980-1997) of Canadian research articles - by far the single largest contributor. Canada was the third largest producer in the world of research articles in Environmental Science. (pp. 20-23)
- ❑ In the sub-field of Meteorology & Atmospheric Science, Environment Canada's scientists were responsible for 33% (1980-1997) of Canadian research articles - by far the single largest contributor. Over this period, Canada was the fifth largest producer in the world of research articles in Meteorology & Atmospheric Science. During 1990-1997, Canada was the second largest producer. (pp. 24-27)
- ❑ Environment Canada's publications in the sub-fields of Environmental Science and of Meteorology & Atmospheric Science are comparable in quality to those of all Canadian scientists publishing in these areas. (p. 28).
- ❑ In the field of Biology, Environment Canada's production is distributed over a wider range of sub-fields than in Earth & Space Sciences. The Department's Biology publications have experienced a major decline since the early 1990s. (p. 30)

INTRODUCTION

This report gives a quantitative overview of Environment Canada's production of scientific knowledge from 1980 to 1997. It is a follow up to an earlier bibliometric study of the Department's research publications in 1995 (Science Policy Branch Working Paper #1), providing a longer-term perspective on this type of publication.

The report focuses on one important output of the Department's scientific research effort, the scientific research publication. The results shown here are drawn from a bibliometric database containing publications from some 4,000 scientific journals indexed by the Institute for Scientific Information. These are considered to be the most important and the most prestigious peer-reviewed journals. They reflect the most significant scientific achievements and are also the most widely cited (80% of the world's citations). For the purposes of this study, they also provide a good basis for comparisons.

The scientific publications of Environment Canada indexed in the database represent only a portion of all of the Department's publications. (A sample of three research units for 1995 showed that 20%, 25% and 82% of all of their publications were included in the database.) Much worthwhile scientific work is disseminated to a number of audiences through other types of scientific publications such as highly specialized journals, strictly Canadian journals and, in particular, informal publications generally known as "grey literature" (conference and convention proceedings, research reports, internal periodicals, etc.).

All of Environment Canada's scientific publications, whether included in the database or not, are a major product of the Department's scientific effort. They are the prime mechanism for delivering the results of the Department's research to others. That research is conducted in the public interest, is focused on the environment, and has as its goals the support of public policy, the provision of services to Canadians and the development of environmental technologies. While the scientific research publications in the database are not the only output of the Department's scientific effort, they are one that can be captured quantitatively relatively easily. The results provide reliable indicators of the extent of Environment Canada's research effort and of its network of scientific collaborators.

SOURCE OF INFORMATION

The data used in this report have been generated by the *Observatoire des sciences et des technologies*, a research group at the Université du Québec. This group maintains a database of Canadian authors.

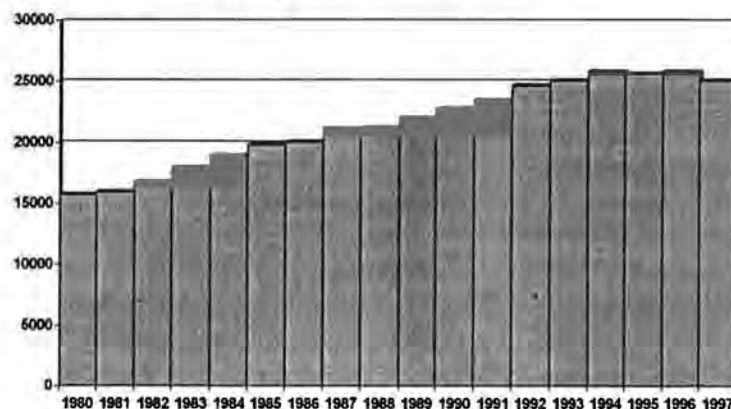
The database includes approximately 2,800 Canadian institutional addresses, and is derived from the *Science Citation Index*, produced by the Institute for Scientific Information. Each year the Institute adds to its databases the contents of the approximately 4,000 scientific journals it assesses as the most prominent. A list of these journals can be found in *Science Citation Index, 1995 Guide and List of Source Publications* (Institute for Scientific Information, Philadelphia, PA).

The Observatoire has standardised the way addresses appear in every article written by Canadian researchers between 1980 and 1997. This procedure also involved a standardisation of the names of institutions and cities in order to compute precise statistics. In addition, each institution received a code that corresponds to a sector of activity: university and college, hospital, government (federal or provincial), industry, and other. Finally, each journal was assigned a field (biology, biomedical research, chemistry, clinical medicine, earth and space science, engineering and technology, mathematics, physics), each field being composed of 108 sub-fields (or specialities), a degree of application (applied or fundamental) and an impact factor. The first three types of information were obtained from the classification produced by CHI Inc. for the National Science Foundation of the United States, and the fourth from the Journal Citation Reports produced by the Institute for Scientific Information.

CANADIAN SCIENTIFIC RESEARCH PUBLICATIONS

The number of Canadian scientific publications has grown considerably over the last few decades, from approximately 16,000 per year at the beginning of the 1980s to over 25,000 in the mid-1990s (Figure 1). This growth allowed Canada to increase its participation in world production from 4.2% in the early 1980s to nearly 5.0% in the early 1990s (Figure 2). However, with increased world growth in publications between 1990 and 1997 (from 475,000 articles to 555,000 articles), the recent stabilization of Canadian production has created a decline in its relative position on the world scene (from 5.0% to 4.5%).

**Figure 1: Canadian Publications 1980-1997
(numbers of articles)**



Source: Observatoire des sciences et des technologies

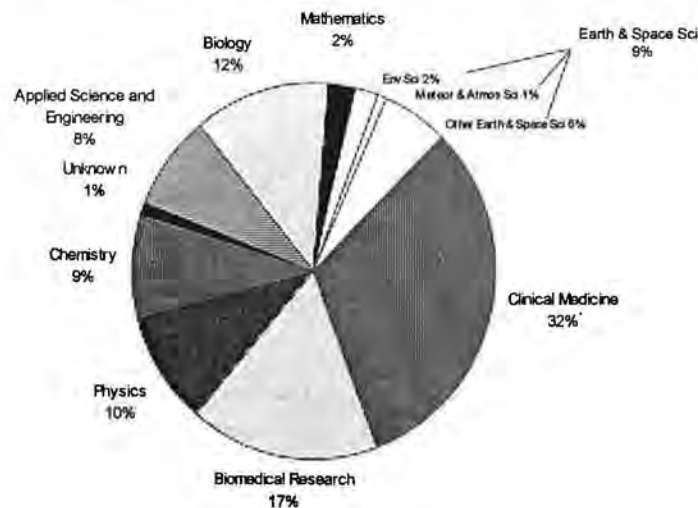
Figure 2: Canadian Articles as Percentage of Global Scientific Production, 1980 -1997



Source: Observatoire des sciences et des technologies

Figure 3 shows the distribution of Canadian scientific research articles by field in 1997 (total = 25,093). The shares of the sub-fields of Environmental Science (2%) and of Meteorology & Atmospheric Science (1%) are indicated within the Earth & Space Sciences field.

Figure 3: Distribution of Canadian Publications by Field, 1997

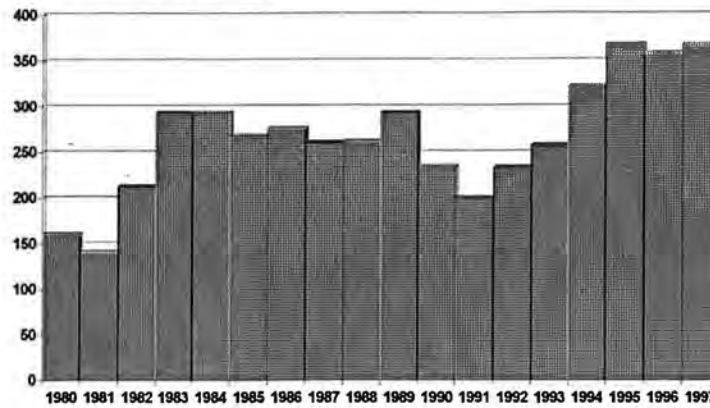


ENVIRONMENT CANADA'S RESEARCH PUBLICATIONS

The overall volume of scientific articles published by Environment Canada has fluctuated during the last few decades (Figure 4). After some remarkable growth during the early 1980s, production stabilized at approximately 280 articles per year until 1989. A sharp decline then occurred until 1991, followed by a new growth phase.

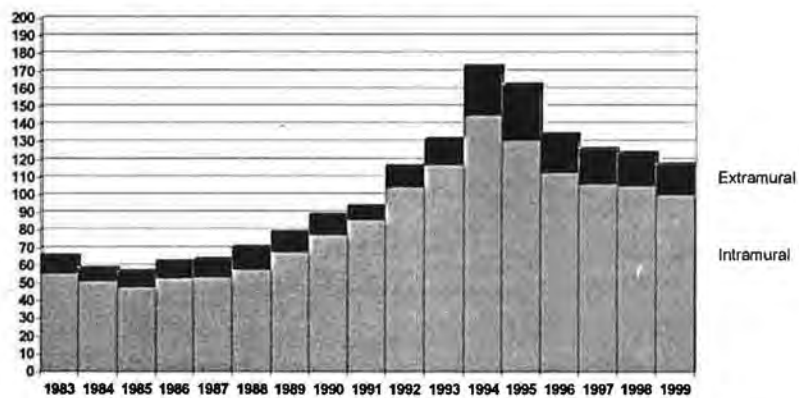
Environment Canada's expenditures on R&D declined in the early 1980s, then rose from 1985 to 1994, and have declined since then (Figure 5).

**Figure 4: Environment Canada Publications 1980-1997
(number of articles)**



Source : Observatoire des sciences et des technologies

**Figure 5 : Environment Canada Natural Science R&D
Expenditures (millions of dollars)**



Source: Statistics Canada

Since the overall production of the federal government has remained relatively stable at approximately 3,200 articles per year between 1985 and 1997, Environment Canada's share of the overall volume of federal publications has generally followed the same pattern as its volume of publications (Figure 6 compared with Figure 4). The marked growth of the early 1980s gave way to a strong decline in the early 1990s, followed by a new phase of growth throughout the 1990s.

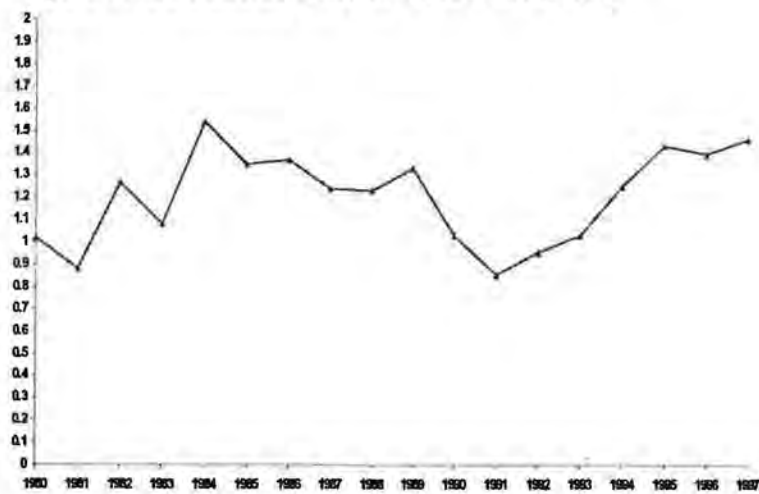
A similar pattern is shown when Environment Canada's scientific research articles are compared to the total number of Canadian research articles (Figure 7).

Figure 6: Environment Canada Articles as % of Federal Articles



Source: Observatoire des sciences et des technologies

Figure 7: EC Articles as % of Canadian Articles

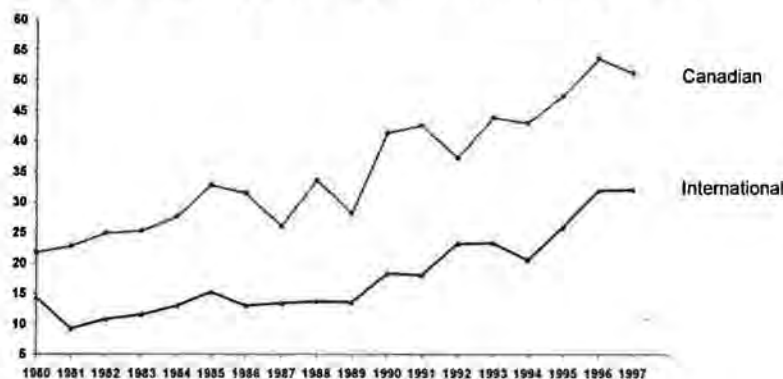


Source: Observatoire des sciences et des technologies

ENVIRONMENT CANADA'S COLLABORATORS

For the past two decades, Environment Canada scientists have been progressively enhancing their level of collaboration with international and Canadian partners. Between 1980 and 1997, the ratio of articles written with international collaboration rose from 14% to 32% (Figure 8). Over the same period, the ratio of Departmental articles co-authored with Canadian partners grew from 21% to 51%.

Figure 8: Percentage of Environment Canada Articles Co-Authored with Canadian and International Partners



Source: Observatoire des sciences et des technologies

International Collaborators

Environment Canada scientists have authored a growing number of articles in collaboration with foreign researchers (Figure 8). These articles accounted for 12.6% of all articles produced by the Department from 1980 to 1985, but 26.6% of all articles produced from 1992 to 1997. Not surprisingly, the largest number of collaborators were from the United States (about half the total), followed by the United Kingdom, Germany, France, Japan, Switzerland and Australia (Table 1). Over the last few decades, the Department's international collaborators have diversified, with countries other than the US and the UK playing a larger role - note, for example, the growth of "Others" in the following table.

Table 1: Environment Canada International Collaborations, by major partner and by six-year period, 1980-1997

	1980-1985	1986-1991	1992-1997	TOTAL
Articles (total number)	1 370	1 528	1 905	4 803
Articles with international collaboration	172	226	506	904
<i>% of articles with international collaboration</i>	<i>12.6%</i>	<i>14.8%</i>	<i>26.6%</i>	<i>18.8%</i>
Number of collaborations*	195	278	671	1 144
United States	115	147	315	577
United Kingdom	19	21	43	83
Germany	4	15	50	69
France	15	13	29	57
Japan	3	7	29	39
Switzerland	7	8	13	28
Australia	4	6	18	28
Sweden	1	3	19	23
Russia	0	2	19	21
Netherlands	1	3	14	18
Norway	4	5	8	17
China	0	6	9	15
Denmark	3	2	9	14
Italy	1	5	8	14
New Zealand	3	7	2	12
Chile	0	4	8	12
Others (n=32)	15	24	78	117

* The "Articles with international collaboration" row (row 2) is based on the number of foreign countries involved in the production of each of the articles. That is why the total collaborations figure ("Number of collaborations", row 4) is higher.

Source: Observatoire des sciences et des technologies

Canadian Collaborators

As noted earlier, the ratio of Departmental articles co-authored with Canadian partners grew from 21% to 51% between 1980 and 1997 (Figure 8). The university sector represents by far the largest pool of Canadian collaborators for Environment Canada researchers, accounting for 61.1% of co-authors for the entire 1980-1997 period (Figure 9, Table 2). Other federal government laboratories (17.5%), private sector laboratories (9.7%) and provincial government laboratories (7.7%) accounted for the second, third and fourth largest groups of partners, respectively.

**Figure 9: Environment Canada's Canadian Collaborators
(% of EC Canadian Collaborations)**

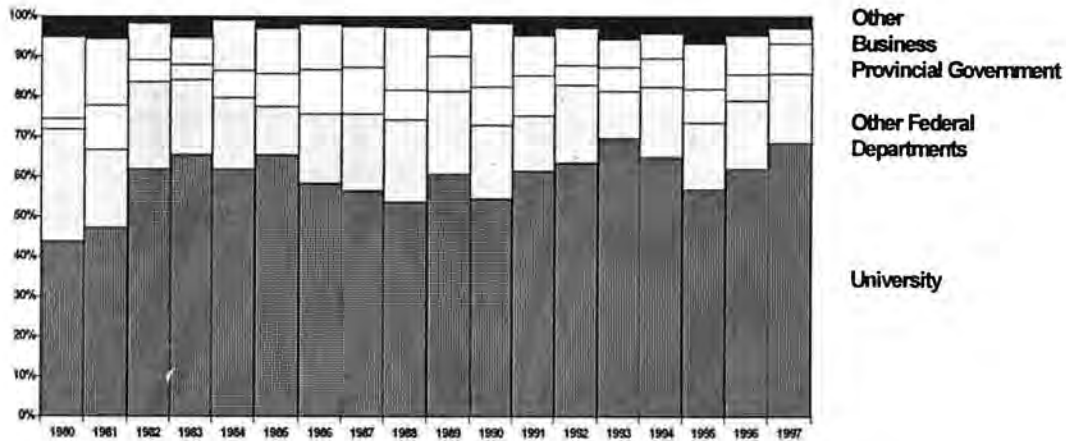


Table 2: Environment Canada Collaboration with Canadian Partners, by institutional sector of partners, 1980-1997

Year	University	Federal	Provincial	Business	Hospital	Other	Total Collaborations %	N	No. Articles N
1980	43.6%	28.2%	2.6%	20.5%		5.1%	100.0%	39	35
1981	47.2%	19.4%	11.1%	16.7%		5.6%	100.0%	36	32
1982	61.8%	21.8%	5.5%	9.1%	1.8%		100.0%	55	53
1983	65.3%	18.7%	4.0%	6.7%		5.3%	100.0%	75	74
1984	61.8%	18.0%	6.7%	12.4%		1.1%	100.0%	89	81
1985	65.3%	12.2%	8.2%	11.2%		3.1%	100.0%	98	88
1986	58.2%	17.3%	11.2%	11.2%		2.0%	100.0%	98	87
1987	56.4%	19.2%	11.5%	10.3%		2.6%	100.0%	78	68
1988	53.7%	20.4%	7.4%	15.7%		2.8%	100.0%	108	88
1989	60.4%	20.9%	8.8%	6.6%		3.3%	100.0%	91	83
1990	54.4%	18.4%	9.6%	15.8%		1.8%	100.0%	114	97
1991	61.4%	13.9%	9.9%	9.9%		5.0%	100.0%	101	85
1992	63.3%	19.4%	5.1%	9.2%	1.0%	2.0%	100.0%	98	87
1993	69.4%	11.9%	6.0%	6.7%	1.5%	4.5%	100.0%	134	113
1994	65.0%	17.2%	7.4%	6.1%		4.3%	100.0%	163	138
1995	56.5%	16.8%	8.4%	11.2%	0.9%	6.1%	100.0%	214	174
1996	61.7%	17.2%	6.6%	9.7%	0.4%	4.4%	100.0%	227	191
1997	68.2%	17.5%	7.4%	3.7%		3.2%	100.0%	217	187
80-97	61.1%	17.5%	7.7%	9.7%	0.3%	3.6%	100.0%	2 035	1 761

Source: Observatoire des sciences et des technologies

ENVIRONMENT CANADA PUBLICATIONS BY FIELD

The vast majority of Environment Canada's scientific research publications are in the fields of Biology and, particularly, of Earth and Space Sciences (Figure 10, Table 3). For instance, in 1997 over 80% of the articles published by Departmental scientists appeared in reviews associated with these two fields - approximately 30% in Biology and 53% in Earth and Space Sciences. Chemistry, Biomedical Research, Clinical Medicine and Engineering fell far behind with 6% or less of publications apiece. This is quite different from the situation in 1980 where Biology accounted for 50% of the Department's research publications and Earth and Space Sciences 34%.

Figure 10: Environment Canada Scientific Research Articles, By Field (% of total EC articles)

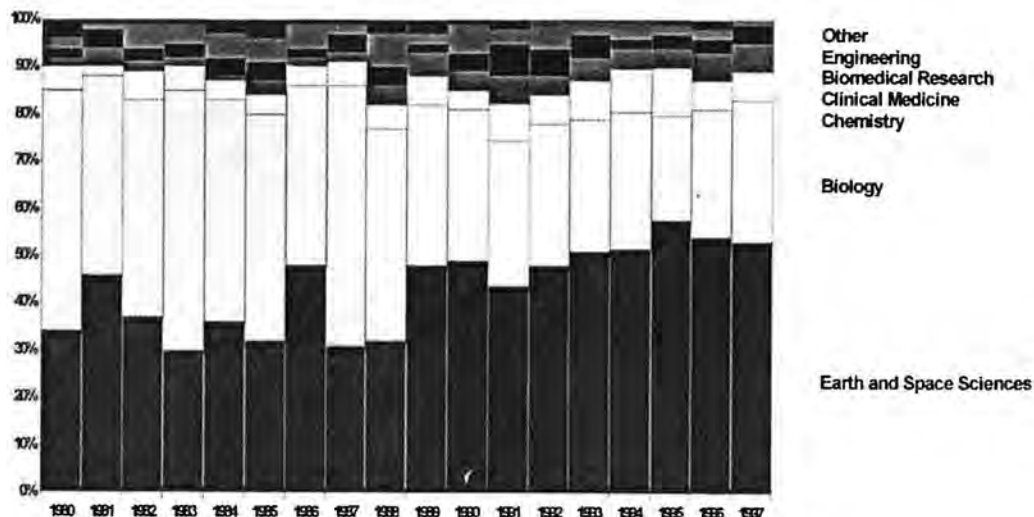


Table 3: Environment Canada Scientific Research Publications, By Major Field, 1980-1997

	Biology	Biomedical Research	Chemistry	Clinical Medicine	Earth & Space Sciences	Engineering	Math	Physics	Unknown Field	TOTAL
year										
1980	81	3	8	3	55	4	1	5	1	161
1981	59	6	3	6	63	2	1	1	0	141
1982	100	6	12	4	78	10	0	3	0	213
1983	160	10	16	7	88	12	1	0	0	294
1984	136	12	11	4	105	15	0	10	0	293
1985	132	12	11	7	89	15	0	2	0	268
1986	104	5	12	5	136	13	0	1	0	276
1987	144	10	12	6	81	5	0	2	1	261
1988	118	10	12	10	84	19	0	9	0	262
1989	103	7	18	16	141	7	1	1	0	294
1990	75	9	9	10	118	13	1	0	0	235
1991	62	13	15	12	89	5	0	4	0	200
1992	70	13	14	10	114	13	0	0	0	234
1993	72	14	21	12	131	7	0	1	0	258
1994	91	17	28	12	159	13	0	2	0	322
1995	79	10	36	17	212	7	1	5	0	367
1996	96	11	21	22	195	6	0	5	2	358
1997	108	16	22	21	193	5	0	1	0	366
Total	1 790	184	281	184	2 131	171	6	52	4	4 803

Source: Observatoire des sciences et des technologies

Earth and Space Sciences

In the field of Earth & Space Sciences, most Environment Canada publications fall within two sub-fields: Environmental Science, and Meteorology & Atmospheric Science (Table 4). In 1997, for instance, the former accounted for 54% (105/193) of the Department's articles in Earth & Space Sciences, and the latter for 37% (72/193). However, this distribution has shown an evolution over time. In 1980, Environmental Science and Meteorology & Atmospheric Science accounted for 65% (36/55) and 15% (8/55) respectively of the Department's publications in the field of Earth & Space Sciences.

The significant contribution of Environment Canada scientists to these two sub-fields is also shown through a review of the top (defined by quantity of output in the database used for this report) Canadian researchers in these areas. A listing of the top 72 Canadian researchers in Environmental Science and in Meteorology & Atmospheric Science between 1993 and 1997 shows that 32% are Environment Canada scientists and another 18% are scientists in other federal departments - that is 50% of the top 72 are federal scientists.

Table 4: Environment Canada Scientific Research Publications in Earth and Space Sciences, by Sub-Field, 1980-1997

	Astronomy & Astrophysics	Earth Science	Environmental Science	Geology	Meteorology & Atmospheric Science	Oceanography & Limnology	TOTAL
YEAR							
1980	0	6	36	2	8	3	55
1981	0	12	36	0	8	7	63
1982	0	9	55	1	11	2	78
1983	0	14	55	3	10	6	88
1984	1	12	60	4	19	9	105
1985	0	14	54	2	15	4	89
1986	0	8	96	0	22	10	136
1987	0	7	41	2	25	6	81
1988	0	7	52	1	19	5	84
1989	0	7	91	9	30	4	141
1990	0	7	67	0	39	5	118
1991	0	4	48	2	26	9	89
1992	0	3	77	2	29	3	114
1993	0	14	75	0	38	4	131
1994	0	10	85	4	56	4	159
1995	0	16	121	5	66	4	212
1996	0	9	90	4	76	16	195
1997	0	12	105	0	72	4	193
Total	1	171	1 244	41	569	105	2 131

Source: Observatoire des sciences et des technologies

Environmental Science

Definition of Environmental Science

There is no commonly accepted definition of environmental science. The term does not correspond to any single scientific discipline. Rather, it includes those life sciences (biology, forestry, ecology, etc.) and physical sciences (oceanography, geology, atmospheric sciences, etc.) that relate to the environment. Hence, identifying whether a scientific publication or activity is "environmental science" can be a non-trivial exercise, and determining the aggregate environmental science effort can be very complex.

The database used for this report does distinguish environmental science. It does so by classifying certain journals as environmental and therefore all publications in those journals as environmental. Environmental science is one of six sub-fields that constitute the field Earth and Space Sciences (see Table 4).

Clearly, almost all (if not all) of the Department's publications are devoted to the environment. However, the limited approach to identifying environmental science used in the database and in this report does have the advantage of providing a consistent definition which serves as the basis for a comparative picture of Environment Canada's contribution to environmental science relative to other performers of research.

The Department's contribution to Canada's production of new knowledge in Environmental Science is quite significant. Between 1980 and 1997, its researchers authored 20.1% of all Canadian publications in this sub-field (Table 5), helping to make Canada a major world player in this area (Figures 11 and 12). If the publications in Environmental Science of all federal scientists are counted, then the federal share of Canadian articles in this sub-field is 40.2% (1980-1997).

Environmental Science accounts for the fourth largest share of scientific research publications by federal scientists, with 4.6% of the total between 1980 and 1997. Only the sub-fields of Agriculture & Agronomy (11.3%), Botany (7.7%) and Hydrology & Marine Biology (6.1%) are larger.

Figure 11: Environment Canada's Share of Canadian Articles in Environmental Science (numbers of articles)

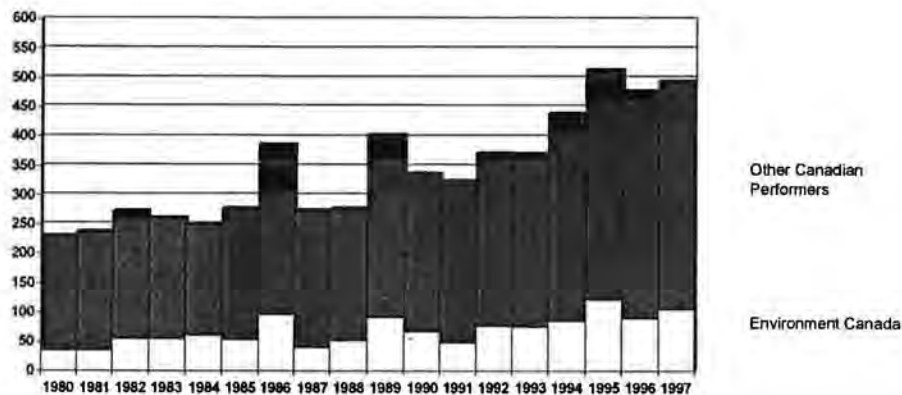


Table 5: Publications by Environment Canada, Canada and the World in Environmental Science, 1980-1997

Year	Environment Canada		Canada		World
	N	%*	N	%**	N
1980	36	15.7%	230	7.6%	3 032
1981	36	15.2%	237	7.0%	3 398
1982	55	20.2%	272	7.9%	3 456
1983	55	21.1%	261	7.6%	3 453
1984	60	23.9%	251	6.7%	3 722
1985	54	19.5%	277	7.5%	3 700
1986	96	24.9%	386	9.5%	4 068
1987	41	15.0%	273	7.0%	3 914
1988	52	18.8%	277	6.7%	4 128
1989	91	22.6%	402	8.7%	4 611
1990	67	19.9%	336	7.3%	4 587
1991	48	14.8%	325	6.6%	4 897
1992	77	20.8%	371	7.0%	5 290
1993	75	20.3%	369	6.9%	5 336
1994	85	19.4%	439	7.4%	5 931
1995	121	23.6%	513	7.9%	6 490
1996	90	18.9%	477	7.4%	6 449
1997	105	21.3%	493	7.4%	6 662
Total	1 244	20.1%	6 189	7.4%	83 124

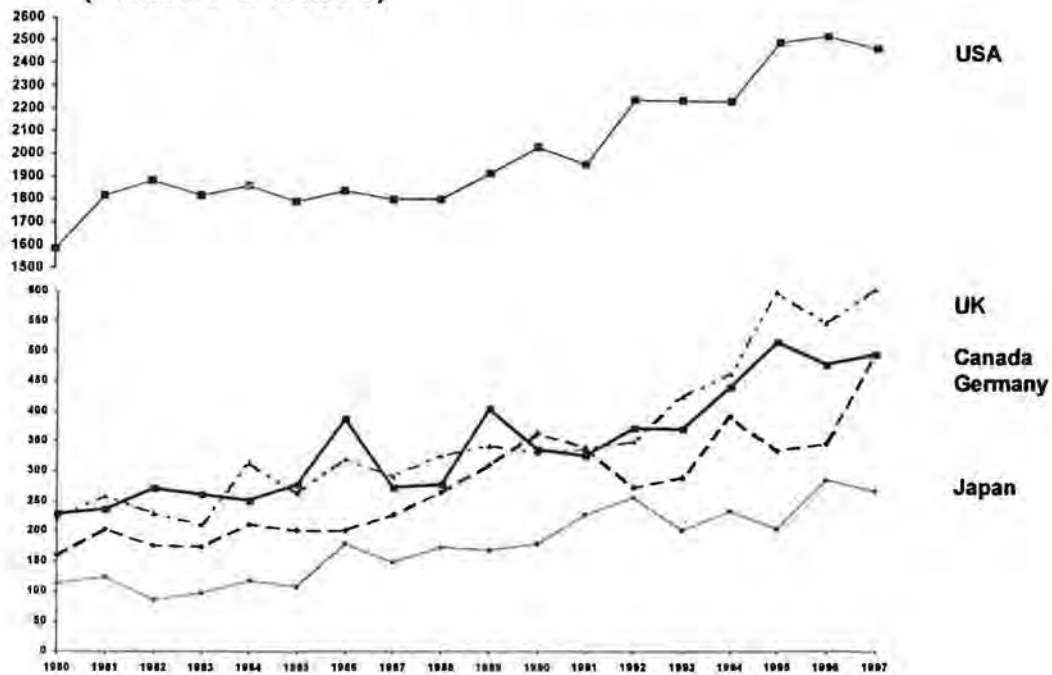
* Environment Canada's share of Canadian Environmental Science publications

** Canada's share of World Environmental Science publications

Source: Observatoire des sciences et des technologies

With 6,189 articles published between 1980 and 1997, Canada ranks as the third largest world producer in Environmental Science, behind the US (36,190) and the UK (6,415) (Figure 12).

**Figure 12: Top 5 Countries in Environmental Science
(numbers of articles)**



Among the 15 leading producers in this field, Canada also shows one of the highest relative efforts, as illustrated by its specialization index for this sub-field (Annex). In 1997, for example, its specialization index was 1.67, ranking behind mid-size producers like South Africa (index = 3.03) and Finland (1.87) but far ahead of major producers such as the United States (1.09), the United Kingdom (1.00), Germany (0.82), Japan (0.40) and France (0.68) (Table 6).

Table 6: Specialization Index – Canada's Position among the World's 15 Largest Producers of Scientific Research Articles in Environmental Science, 1980-1997

	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	No. articles 1980-97
United States	1.46	1.32	1.21	1.08	1.15	1.15	1.05	1.08	1.13	1.09	36 190
United Kingdom	0.86	0.82	0.86	0.82	0.76	0.90	0.87	1.01	0.93	1.00	6 415
Canada	1.79	1.63	1.53	1.38	1.41	1.41	1.53	1.65	1.57	1.64	6 189
Germany	0.70	0.73	1.04	0.91	0.67	0.68	0.82	0.62	0.63	0.82	4 942
Japan	0.58	0.39	0.46	0.53	0.54	0.41	0.42	0.33	0.45	0.40	3 159
France	0.48	0.48	0.70	0.56	0.65	0.65	0.58	0.57	0.63	0.68	2 738
Netherlands	1.17	2.04	1.22	1.48	1.20	1.51	1.48	1.41	1.22	1.49	2 506
India	0.99	1.49	1.74	1.39	1.73	1.25	1.19	1.09	1.13	0.92	2 410
Italy	0.95	0.62	0.64	0.93	0.87	0.78	0.88	0.69	0.71	0.81	2 121
Sweden	0.48	0.95	1.32	1.40	1.17	1.02	1.28	1.74	1.31	1.08	1 885
Australia	0.57	1.07	0.84	0.92	1.07	0.82	1.01	0.91	0.97	1.01	1 809
Spain	0.85	0.44	0.99	1.30	1.17	1.28	1.18	1.13	1.03	1.22	1 539
South Africa	3.15	3.03	2.19	2.47	3.40	2.71	2.58	3.49	2.27	3.03	1 188
Finland	1.03	1.82	1.66	2.01	1.32	1.55	1.78	2.21	1.41	1.87	1 053
Switzerland	0.42	0.63	0.90	0.71	0.69	0.75	0.90	0.92	0.81	1.08	1 024

Source: Observatoire des sciences et des technologies

Meteorology and Atmospheric Science

The contribution of Environment Canada researchers to the development of Meteorology & Atmospheric Science in Canada is even more impressive than in Environmental Science since they account for a third (33.0%) of all scientific research articles in that sub-field published by Canadians between 1980 and 1997 (Figure 13, Table 7). If the contribution of other federal departments is included, then the federal government was responsible for 46.3% of all Canadian articles in Meteorology & Atmospheric Science.

Between 1980 and 1997 the Canadian contribution to global publications in Meteorology & Atmospheric Science more than doubled, rising from 3.3% to 7.8%.

Figure 13: Environment Canada's Share of Canadian Articles in Meteorology & Atmospheric Science (numbers of articles)

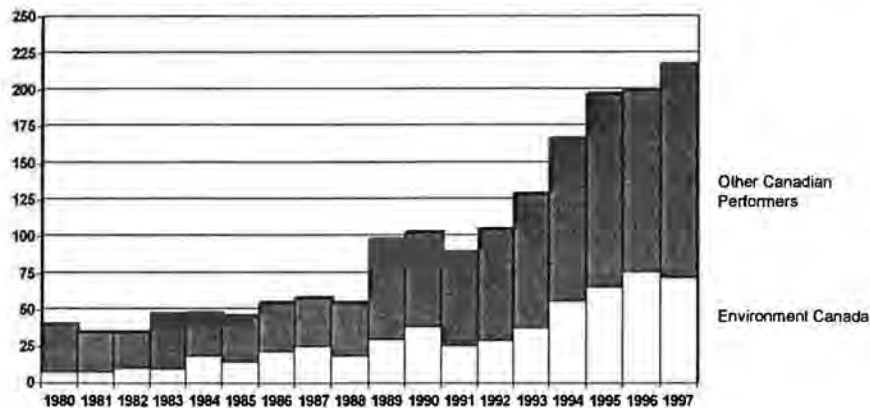


Table 7: Publications by Environment Canada, Canada and the World, in Meteorology and Atmospheric Science, 1980-1997

Year	Environment Canada		Canada		World
	N	%*	N	%**	N
1980	8	20.0%	40	3.3%	1 217
1981	8	22.9%	35	2.7%	1 319
1982	11	31.4%	35	2.6%	1 349
1983	10	21.3%	47	3.6%	1 308
1984	19	39.6%	48	3.1%	1 532
1985	15	32.6%	46	3.2%	1 450
1986	22	40.0%	55	4.0%	1 367
1987	25	43.1%	58	4.2%	1 392
1988	19	34.5%	55	4.2%	1 312
1989	30	30.6%	98	6.7%	1 453
1990	39	37.9%	103	7.0%	1 466
1991	26	29.2%	89	6.4%	1 387
1992	29	27.6%	105	6.4%	1 646
1993	38	29.5%	129	6.8%	1 888
1994	56	33.5%	167	8.7%	1 916
1995	66	33.5%	197	7.7%	2 566
1996	76	38.0%	200	7.5%	2 674
1997	72	33.2%	217	7.8%	2 772
TOTAL	569	33.0%	1 724	5.7%	30 014

* Environment Canada's share of Canadian Meteorology and Atmospheric Science publications

** Canada's share of world Meteorology & Atmospheric Science publications

Source: Observatoire des sciences et des technologies

In the global context, Canada's 1,724 articles between 1980 and 1997 make it the fifth largest performer in this sub-field behind the US (16,598), the USSR/Russia (2,811), the UK (2,163) and Germany (1,830) [Canada is the thicker solid line in Figure 14]. If only 1990-1997 is considered, Canada was the world's second largest producer.

Figure 14: Top 5 Countries in Meteorology and Atmospheric Science (numbers of articles)



The growing Canadian effort in Meteorology & Atmospheric Science is reflected in its specialization index, which has grown from 0.77 in 1980 to 1.73 in 1997 (Annex). Whereas Canada's relative effort in this sub-field was less than the world average (index = 1.00) during the 1980s, its current effort far outstrips the world average (Table 8). Among the 15 major performers in this sub-field, Canada has the second strongest relative effort after Australia (index = 1.98).

Table 8: Specialization Index – Canada's Position among the World's 15 Largest Producers of Scientific Research Articles in Meteorology and Atmospheric Science, 1980-1997

	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	No. articles 1980-97
United States	1.38	1.40	1.56	1.47	1.60	1.62	1.56	1.56	1.70	1.66	16 598
United Kingdom	0.95	0.89	0.79	0.77	0.71	0.81	0.85	0.78	0.83	0.90	2 163
USSR	2.08	1.85	1.49	1.55	2.28						1 998
Germany	0.88	1.10	0.74	0.70	0.79	0.60	0.63	0.83	0.84	0.88	1 830
Canada	0.77	0.69	1.47	1.33	1.28	1.40	1.80	1.61	1.59	1.73	1 724
Australia	1.48	1.46	1.68	1.60	1.70	1.84	1.18	1.72	1.93	1.98	1 189
France	0.27	0.52	0.73	0.68	0.74	0.60	0.66	0.88	0.78	0.89	1 134
Japan	0.18	0.25	0.21	0.20	0.20	0.24	0.60	0.59	0.43	0.46	860
Russia				2.31	1.89	1.56	1.56	1.17	1.09	1.18	813
India	0.70	0.34	0.58	1.00	0.54	0.93	0.85	0.78	0.76	0.85	457
Italy	1.24	0.31	0.42	0.39	0.55	0.41	0.37	0.32	0.34	0.33	442
Netherlands	0.55	0.63	0.33	0.38	0.43	0.61	0.69	0.81	0.55	0.86	415
Sweden	0.30	0.48	0.50	0.67	0.28	0.61	0.74	0.39	0.95	0.64	308
Israel	0.60	0.93	1.10	0.85	0.84	1.10	0.68	0.51	0.70	0.68	298
Switzerland	0.27	0.52	0.48	0.27	0.43	0.57	0.36	0.72	0.81	0.90	265

Source: Observatoire des sciences et des technologies

Quality of Research in these Sub-Fields

The quality of the scientific research publications by Environment Canada scientists in Environmental Science (Table 9) and in Meteorology & Atmospheric Science (Table 10) is comparable to that of publications by all Canadian researchers in these sub-fields.

Quality is measured through an "impact factor" (see Annex). The impact factor is calculated for each scientific journal. It is the average number of citations received over a year for all the articles published in the journal over the course of that and the preceding year. This score is then applied to each of the articles published in the journal. The impact factor is therefore, strictly speaking, a measurement of visibility and awareness, or alternately, the influence of the journals and of the articles they publish. Applied to the publications of a group of researchers, the impact factor is considered a legitimate indicator of research quality.

**Table 9: Environment Canada Impact Factor
in Environmental Science**

Year	Environment Canada		Canada Total	
	no. articles*	Impact Factor	no. articles*	Impact Factor
1980	36	1.1	217	1.0
1985	50	1.2	266	1.1
1990	59	0.9	318	0.9
1991	48	1.2	324	1.1
1992	76	1.3	351	1.2
1993	75	1.2	358	1.2
1994	65	1.3	377	1.2
1995	118	1.4	508	1.3
1996	86	1.5	443	1.5
1997	105	1.4	485	1.4

* Because it is not possible to calculate the impact factor for some journals, the number of articles shown here is usually less than the number shown in Tables 4 and 5.

Source: Observatoire des sciences et des technologies

**Table 10: Environment Canada Impact Factor
in Meteorology and Atmospheric Science**

Year	Environment Canada		Canada Total	
	no. articles	Impact Factor	no. articles	Impact Factor
1980	4	1.9	29	1.6
1985	15	1.5	46	1.4
1990	39	1.3	101	1.3
1991	21	1.4	79	1.3
1992	26	1.3	88	1.2
1993	32	1.5	116	1.5
1994	30	1.4	118	1.4
1995	54	2.1	157	2.1
1996	57	1.7	144	1.6
1997	43	1.7	126	1.7

* Because it is not possible to calculate the impact factor for some journals, the number of articles shown here is usually less than the number shown in Tables 4 and 7.

Source: Observatoire des sciences et des technologies

Biology

In the field of Biology, Environment Canada has been very active with 1,790 articles published between 1980 and 1997 (Table 11). However, since the late 1980s, the Department's production in this field has markedly diminished, particularly in the sub-fields of Botany and Entomology. The average number of articles produced annually by Environment Canada in Biology dropped from 114 during the 1980s to 82 during the 1990s.

The Department's production is rather uniformly distributed in the various sub-fields of Biology. None of the sub-fields account for more than 31% of the field's production, in contrast with Earth & Space Sciences where two sub-fields alone (Environmental Science and Meteorology & Atmospheric Science) account for approximately 85% (Table 4).

The largest share of federal scientific research publications is in the field of Biology. In the period 1980-1997, 35.2% of all federal publications were in this field, twice as many as in the next largest field (Earth & Space Sciences with 17.7%). Biology's share of the federal effort has declined from 38.2% in 1980-1982 to 32.1% in 1995-1997.

The federal government is very active in four of Biology's sub-fields: Agriculture & Agronomy (the largest single sub-field for federal publications, accounting for 11.3% of all federal articles), Botany (the second largest, with 7.7%), Hydrobiology & Marine Biology (the third largest with 6.1%), and Entomology (the eighth largest, with 3.4%). The federal government is also a major Canadian performer in these four sub-fields, representing 47.7% of all Canadian articles in Agriculture & Agronomy, 44.8% in Entomology, 38.2% in Hydrobiology & Marine Biology, and 30.3% in Botany.

**Table 11: Environment Canada Publications in Biology,
by Sub-Field, 1980-1997**

	Agriculture & Agronomy	Botany	Ecology	Entomology	General Biology	General Zoology	Hydrobiology & Marine Biology	Other Zoology	Other Biology	Total
Year										
1980	3	14	14	3	3	6	24	14	0	81
1981	0	17	14	5	5	5	7	6	0	59
1982	7	38	9	15	4	4	15	8	0	100
1983	5	40	17	29	2	13	46	8	0	160
1984	7	40	23	19	4	7	24	12	0	136
1985	8	40	19	22	3	7	24	8	1	132
1986	1	45	9	8	5	11	17	8	0	104
1987	9	24	12	16	4	10	57	12	0	144
1988	9	31	8	14	2	5	39	10	0	118
1989	6	26	14	4	2	5	36	10	0	103
1990	10	8	9	0	1	11	29	7	0	75
1991	6	1	9	2	3	7	25	9	0	62
1992	8	4	9	2	5	6	27	9	0	70
1993	4	6	10	0	4	13	25	10	0	72
1994	6	6	14	6	2	9	36	12	0	91
1995	7	3	10	1	5	5	33	15	0	79
1996	7	2	16	1	1	11	44	14	0	96
1997	9	2	20	0	5	4	44	24	0	108
Total	112	347	236	147	60	139	552	196	1	1 790

Source: Observatoire des sciences et des technologies

ANNEX

DEFINITIONS

SPECIALIZATION INDEX

The specialization index is calculated as follows:

$$\frac{\text{share (\%) of publications of institution X in field Z}}{\text{share (\%) of publications of all institutions in field Z}}$$

The specialization index shows how specialized (i.e., active) an institution is in a particular field in comparison with other institutions. For example:

- Institution A in the university sector has 200 biomedical research publications out of a total of 1,000 publications in all fields (meaning that 20% of its publications are in this field).
- University sector institutions have 3,000 biomedical research publications out of a total of 10,000 publications (30% of publications).

The specialization index of institution A is therefore 0.66 (20% divided by 30%), which shows that this institution is not specialized in this field. In other words, it is less active in this field than the average institution. If the index is greater than 1, the institution is more active in a given field than the average university sector institution in the same field.

IMPACT FACTOR

A journal's impact factor for a given year – 1995, for example – is calculated as follows:

$$\frac{\text{Number of citations received in 1995 for articles that appeared in the journal in 1994 and 1995}}{\text{Number of articles that appeared in the journal in 1994 and 1995}}$$

To calculate the average impact factor, each publication is assigned the impact factor of the journal in which it was published. Institutions whose researchers publish in journals with a high impact factor in a particular field will have a high impact factor in that field.

Working Paper Series

- #1 *Environment Canada's Scientific Research Publications in 1995*
- #2 *Science for Sustainable Development*
- #3 *Communicating Science at Environment Canada: A Brief Review of Lessons Learned from Communications on Acid Rain and the Depletion of the Stratospheric Ozone Layer*
- #4 *The Precautionary Principle, Risk-Related Decision Making, and Science Capacity in Federal Science-Based Regulatory Departments: A Discussion Document*
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- #6 *Environment Canada's Scientific Research Publications 1980-1997*
- #7 *Research & Development and Related Science Activities at Environment Canada*
- #8 *Measuring The Impacts Of Environment Canada's R&D: A Case Study of Pulp & Paper Effluent Research*
- #9 *Measuring The Impacts Of Environment Canada's R&D: A Case Study of Stratospheric Ozone Depletion Research*