Collaboration via co-authorship trends in Government of Canada forestry research

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ABSTRACT

As part of its long history, the Canadian Forest Service (CFS) has a mandate to collaborate and share its scientific research. Publishing peer-reviewed scientific literature is an important part of this process. Using a database of CFS publications over the past fifty years, we highlight the continuing publication record of this sector of the Canadian government. The average number of authors reported in the CFS bookstore increased from 1.4 authors per article in the 1960s and 1.5 in the 1970s to just under five authors per publication from 2010 to 2018. Our work also illustrates challenges with longitudinal analysis of citation databases. In particular, use of a popular citation database resulted in significantly fewer articles authored by one person, and significantly more articles with twenty or more authors compared to the publicly available CFS “bookstore” of publications. Based on our findings, we outline a number of recommendations for use of citation data to inform collaboration research.

Keywords: citation analysis, co-authorship, research productivity, forestry

RÉSUMÉ

Dans le cadre de sa longue histoire, le Service canadien des forêts (SCF) a comme mandat de collaborer aux travaux de recherche et de partager les résultats de ces derniers. La publication dans des ouvrages scientifiques révisés par des pairs constitue un important élément de ce processus. Au moyen d'une base de données sur les publications du SCF réparties sur les cinquante dernières années, nous avons mis en évidence la persistance des publications de ce secteur du gouvernement du Canada. Le nombre moyen d'auteurs relevé dans la bibliothèque du SCF est passé de 1,4 auteurs par article au cours des années '60 et de 1,5 auteurs au cours des années '70, pour atteindre presque 5 auteurs par article entre 2010 et 2018. Notre étude a également noté les défis associés à l'analyse longitudinale des bases de données de citations. Dans les faits, l'utilisation d'une base courante de citations a relevé un nombre significativement plus faible d'articles produits par un seul auteur, et significativement plus d'articles produits par plus de vingt auteurs lors d'une comparaison avec la liste publique des « titres » offerts par le SCF. En fonction des résultats obtenus, nous présentons plusieurs recommandations reliées à l'utilisation des bases de citations portant sur la diffusion des recherches effectuées en partenariat.

Mots clés : analyse de citations, corédaction, productivité en recherche, foresterie

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Introduction

Research collaborations have become a management imperative. The National Academies of Sciences, Engineering and Medicine state that the greatest challenges facing humanity require insights from multiple disciplines (Institute of Medicine, 2005). The United Nations Educational, Scientific and Cultural Organization (UNESCO 2015) described “co-operation and collaboration between scientists” as a hallmark of world class science, and concluded that “scientists now live in a hyper-connected world” (2015, p. 3). As measured by co-authorship, collaboration has been on the rise: for instance, *Nature* reported that its Letters now have four times as many authors as they did 60 years ago (Adams 2012).

In Canada, a number of studies have examined the research contribution of industry, university, and government sectors. A 2015 report from the United Nations Educational, Scientific and Cultural Organization (UNESCO) noted decreasing Canadian government participation in research (UNESCO 2015; see as well Kinder and Welsh 2012). A recent PLOS ONE article by Larivière *et al.* (2018) concluded that there has been a rise in partnerships between university and other sectors in Canada, but a reduction in basic (as opposed to applied) research publications from government and the private sector.

In part, the recorded decline in government share of research can be linked to a number of debates that have shaped the Canadian research environment related to the role of government science. In 1988, the Canadian National Advisory Board on Science and Technology (NABST 1988) recommended shifting resources to industry-based research from government science. By the mid-1990s, the NABST stated that the “federal government should promote partnerships and collaboration among S & T stakeholders” (NABST 1995). “Innovation systems” were encouraged to reflect interactions between the sectors, as exemplified by the Networks of Centres of Excellence (Atkinson-Grosjean 2006). The focus on applied research increased between 2009 and 2014 with policy shifts at the National Research Council (Council of Canadian Academies 2018) and earlier at NSERC (as illustrated in Cozzarin 2006).

However, arguably not all federal government departments experienced the same type of decline noted by Kinder and Walsh (2012) regarding the NRC. For instance, the Government of Canada has a long-standing role in forest science with the Canadian Forest Service (CFS) being the main player. CFS is a sector within Natural Resources Canada (NRCan), a federal government department that deals with a broad suite of natural resource issues. Current elements in the CFS research program include the study of native and non-native forest insects and diseases, aspects of forest fire behaviour and management, science in support of sustainable forest management, climate change mitigation and adaptation in the forest context, and cumulative effects of anthropogenic and non-anthropogenic disturbances on forests (NRCan 2019).

Measuring collaboration

The measurement of collaboration, according to Abramo *et al.* (2009), is typically done using either a qualitative approach (through case studies), or a quantitative approach via “analysis of co-authorship of scientific papers published

in international journals and indexed in specialist databases” (p. 156). However, some authors have argued against the use of citation databases to track trends across research fields, institutions, countries, or time periods (Harzing and Alakan-gas 2016; Calver *et al.* 2017). Calver *et al.* (2017) urged attention to “errors and idiosyncrasies in individual databases that affect data retrieval and conclusions” (p. 19).

Purpose of the current paper

In this paper, we present an empirical analysis of the historical contribution of the CFS to assess the extent to which the federal government contribution towards forestry science has remained consistent over time, or whether this field has declined as other agencies as documented at the NRC. Consistent with other research, we have focused on co-authorship trends as a metric for collaboration.

For our analysis, we use the Canadian Forest Service Publications Database which is a repository of publications authored or co-authored by CFS employees (the CFS “bookstore”). This paper includes: a) a description of trends over time in collaboration at the CFS from 1966 to 2018; and, b) an assessment of whether Scopus data (Elsevier 2019) provides a complete picture of co-authorship at the CFS by comparing CFS records (i.e., the CFS “bookstore”) to Scopus data for CFS-affiliated authors. In so doing, we illustrate challenges associated with longitudinal analysis of citation databases, and provide several conclusions for use of Scopus, particularly when pulling records by affiliation.

Methods

The available CFS bookstore of publications from 1966 to 2018 (<https://cfs.nrcan.gc.ca/publications>) was used if the publication was a journal article. CFS series items, contributions to proceedings, monographs, book chapters, and “miscellaneous” items from the CFS bookstore were not included. A review of the CFS bookstore indicates that a relatively small number of publications classified in CFS as journal articles were more similar to magazines or newsletters rather than peer-reviewed journals (listed in Table 1). Because we were primarily interested in journal articles, we removed the publications listed in Table 1 from subsequent analyses.

The CFS bookstore data was linked by journal title to journal category, as published by SCImago (2019). The SCImago portal categorizes journals into 313 subject categories and ranks 31 971 journals. In cases where the CFS-recorded journal name differed from the SCImago data, the CFS-recorded journal name was edited to match SCImago. We also extracted data from Elsevier (2019) Scopus scientific literature citation database if at least one of the authors listed was affiliated with CFS. Scopus data were retained for the analysis if the publication was identified as an article, article in press, editorial, letter, note, review, or a short survey. Books, book chapters, conference papers and erratum were excluded from the Scopus analysis.

R Core Team (2017) was used for developing the box-and-whisker plots. SAS software, Version 9.4 of the SAS System for Windows was used to merge Scopus, SCImago, and CFS data. A one-way (ANOVA) was conducted on: a) number of authors by publication decade; and, b) number of authors in CFS versus Scopus data. Chi-square tests of significance were requested in SAS (PROC FREQ) for analyses of

categorical data including journal concentration by time period. A t-test was implemented on the average number of authors per article by data source, and Pearson's correlation coefficient was calculated between journal rank and number of authors.

Two linear regressions were carried out to test the explanatory contribution of year of publication as a predictor for number of authors. The form of the first regression model is:

$$\hat{y}_i = \beta_0 + \beta_1 x_i + \varepsilon_i$$

Where $\hat{y}_i$ = the number of authors for the i th journal article; β_0 = the intercept; β_1 = year of publication; and ε_i is the error term reflecting all other factors affecting the dependent variable.

Because authors such as Harzing and Alakangas (2016)

Table 1. Non-peer reviewed publications in the CFS database

Journal	Number of CFS-affiliated articles, 1966–2018
<i>Bimonthly Research Note(s)/ Progrès forestie, Canadian Forestry Service Research Note, Bi-Monthly Research Bulletin, Bi-monthly Progress Report, Rev. Bimest. Rech.</i>	186
<i>Canadian Silviculture</i>	11
<i>Reforestation Notes</i>	3
<i>Milieu</i>	32
<i>Mosquito News</i>	7
<i>Le Soleil</i>	7
<i>Evergreen</i>	2
<i>Atlantic Forestry Review</i>	9
<i>BC Forest Professional</i>	4
<i>l'Aubelle</i>	10
Total	262

conclude that publication patterns often differ by discipline, a second regression incorporated binary predictor variables indicating publication in SCImago journal subject categories with more than 500 CFS articles. The SCImago journal rank as a predictor was included for the number of authors in the second regression model.

Results

CFS publications by journal

There are 10 857 records in the CFS bookstore classified as journal articles from 1966 to 2018. The CFS publication record used for this analysis extends for five decades. Table 2 presents journals with more than 20 articles affiliated with CFS between 1966 and 2018, or more than 10 articles in the past twenty years. There are twenty-two journals with one or more CFS-affiliated articles in each decade between the 1960s and the 2010s (bolded rows in Table 2). For example, *The Canadian Entomologist*, *The Forestry Chronicle*, *The Journal of Invertebrate Pathology*, *Phytoprotection* and *Forest Science* have articles in each decade between 1966 and 2018. However, the share of journals with CFS representation every decade is declining as a proportion of all CFS articles, representing 52.5% from 1970 to 1979, compared to 25.6% in 2000 to 2009.

Number of authors per article

The average number of authors reported in the CFS bookstore increased from 1.4 per article in the 1960s and 1.5 in the 1970s to just under five authors per publication from 2010 to 2018, a significant difference by decade ($F = 437.28$, $p < 0.0001$, Fig. 1). Only 11% of articles from 2010 to 2019 were written by one person while 30% of articles published during this period were authored by six or more people. Of the 35 articles recorded in the CFS bookstore with 20 or more authors, 29 of them were published after 2010.

Fig. 2 shows a relatively constant (linear) increase over time in the number of authors. As well, Fig. 3 illustrates the average number of authors per article for the most common journal categories. As can be seen from Fig. 3, a trend towards increasing number of authors is evident across all six journal

Fig. 1 Number of authors by publication decade

Table 2. Journals with more than 20-CFS authored/co-authored articles from 1966 to 2018, or more than 10 CFS articles published after 2000. The columns represent the number of CFS-authored (co-authored) articles by decade from 1966 to 2018. Rows that contain bolded text represent journals with articles in each time period

Journal	1966–69	1970–79	1980–89	1990–99	2000–09	2010–18	Total
<i>Canadian Journal of Forest Research</i>	–	199	231	268	228	148	1074
Canadian Entomologist	127	246	170	146	104	67	860
Forestry Chronicle	54	124	143	204	214	93	832
<i>Canadian Journal of Botany</i>	105	136	82	52	42	–	417
<i>Forest Ecology and Management</i>	–	2	9	64	113	121	309
Journal of Invertebrate Pathology	42	67	16	19	15	11	170
<i>Canadian Journal of Plant Pathology</i>	–	2	32	48	34	8	124
Phytoprotection	11	25	28	16	26	4	110
Forest Science	15	19	14	24	16	19	107
<i>Environmental Entomology</i>	–	5	18	30	19	32	104
Journal of the Entomological Society of British Columbia	21	13	34	19	9	5	101
<i>Journal of Environmental Science and Health</i>	–	4	37	58	1	–	100
Plant Disease Reporter/Plant Disease/Plant Disease Report	42	22	15	9	7	3	98
Phytopathology	8	20	14	25	20	7	94
<i>Tree Physiology</i>	–	–	3	41	39	8	91
Canadian Journal of Zoology	7	42	25	10	3	3	90
<i>Ecological Modelling</i>	–	–	6	11	39	33	89
<i>Remote Sensing of the Environment</i>	–	–	1	4	38	46	89
<i>Canadian Journal of Remote Sensing</i>	–	1	4	19	33	31	88
Canadian Journal of Soil Science	4	16	13	17	29	9	88
Journal of Economic Entomology	5	12	15	12	13	23	80
Canadian Journal of Microbiology	15	30	13	8	6	1	73
<i>Journal of Chemical Ecology</i>	–	3	16	23	11	11	64
Mycologia	14	14	5	10	7	4	54
Journal of Insect Physiology	1	6	5	14	13	12	51
<i>Journal of Geophysical Research</i>	–	–	1	14	14	17	46
<i>New Forests</i>	–	–	4	25	8	8	45
<i>European Journal of Forest Pathology</i>	–	9	10	21	2	1	43
Silvae Genetica	2	5	14	16	5	1	43
<i>Water, Air and Soil Pollution</i>	–	2	13	21	6	–	42
<i>Agricultural and Forest Meteorology</i>	–	–	2	8	14	16	40
Entomologia Experimentalis et Applicata	1	1	6	11	7	14	40
Soil Science Society of America Journal	3	6	9	4	7	10	39
<i>Forestry</i>	–	1	2	5	10	19	37
<i>International Journal of Remote Sensing</i>	–	–	1	6	18	12	37
<i>Northern Journal of Applied Forestry</i>	–	–	4	22	10	1	37
Plant and Soil/Plant Soil	3	6	7	8	7	5	36
<i>Canadian Journal of Chemistry</i>	2	9	9	12	1	–	33
<i>Pesticide Science</i>	–	–	15	18	–	–	33
<i>Soil Biology and Biochemistry</i>	–	2	7	8	8	8	33
Annals of the Entomological Society of America	3	18	2	4	3	2	32
New Phytologist	1	4	7	5	7	8	32
<i>Scandinavian Journal of Forest Research</i>	–	–	3	10	11	8	32
<i>Canadian Field-Naturalist</i>	3	5	13	6	4	–	31
<i>Insect Biochemistry and Molecular Biology</i>	–	1	–	13	11	5	30
<i>Journal of General Virology</i>	–	1	–	9	15	5	30
<i>Ecology</i>	4	10	–	2	9	4	29
<i>Journal of Applied Entomology</i>	–	–	1	11	11	3	26
<i>Theoretical and Applied Genetics</i>	–	–	4	16	6	–	26
Canadian Journal of Plant Science	4	7	2	2	5	4	24
<i>Phytochemistry</i>	1	8	8	5	2	–	24
Canadian Plant Disease Survey	1	10	6	1	4	1	23
<i>Journal of Experimental Botany</i>	–	9	1	7	1	4	22
<i>Physiologia plantarum</i>	–	1	6	12	3	–	22
Emerging Journals (no articles before 1990)							
<i>International Journal of Wildland Fire</i>	–	–	–	15	37	51	103
<i>Zookeys</i>	–	–	–	–	17	67	84
<i>Forests</i>	–	–	–	–	–	53	53
<i>Global Change Biology</i>	–	–	–	1	16	34	51
<i>PLoS ONE</i>	–	–	–	–	1	49	50

Table 2. (continued)

Journal	1966–69	1970–79	1980–89	1990–99	2000–09	2010–18	Total
<i>Forest Pathology</i>	–	–	–	–	20	16	36
<i>Ecological Applications</i>	–	–	–	6	8	21	35
<i>Environmental Reviews</i>	–	–	–	4	10	18	32
<i>Environmental Monitoring and Assessment</i>	–	–	–	9	16	6	31
<i>Molecular Ecology</i>	–	–	–	2	8	12	22
<i>BC Journal of Ecosystems and Management</i>	–	–	–	–	16	5	21
<i>Ecosystems</i>	–	–	–	–	5	15	20
<i>Tree Genetics & Genomes</i>	–	–	–	–	6	13	19
<i>Ecosphere</i>	–	–	–	–	–	18	18
<i>Écoscience</i>	–	–	–	1	6	10	17
<i>Remote Sensing</i>	–	–	–	–	–	16	17
<i>Zootaxa</i>	–	–	–	–	5	11	16
<i>Landscape Ecology</i>	–	–	–	1	3	12	16
<i>Biological Invasions</i>	–	–	–	–	3	10	13
<i>Global Ecology and Biogeography</i>	–	–	–	–	2	11	13
<i>Environmental Research Letters</i>	–	–	–	–	–	12	12
<i>Biogeosciences</i>	–	–	–	–	1	11	12
Total of Journals Listed	499	1123	1106	1492	1468	1326	7015
All CFS Publications	727	1711	1554	2259	2416	2229	10 896
% of Total CFS-Affiliated Articles	68.6%	65.6%	71.2%	66.0%	60.8%	59.5%	64.4%

Fig. 2 Number of authors by publication year using the CFS Bookstore

subject categories considered. Journals categorized into Global and Planetary Change had the highest average number of authors for CFS-affiliated articles (5.3 authors per publication) from 2010 to 2018.

Journal rank was correlated to the number of authors, with better quality journals having a greater average number of authors ($r=-0.196$, $p<.0001$). Restricting the analysis to 2010 to 2018, the correlation between journal rank and number of authors is similar ($r=-0.1508$, $p<.0001$).

The results of the regression model are presented in Table 3. For the simpler model which included only year of publication for the article registered in the CFS bookstore, the regression model accounted for 16.1% of the variability in the data.

The regression model was statistically significant ($F=2039.0$, $p<.0001$). In comparison, introducing journal rank and common CFS journal subject categories (as defined by SCImago), did not produce a substantial improvement in the predictive ability of the regression model. The expanded regression model produced an r^2 of 0.166 ($F=209.11$, $p<.001$), essentially equivalent to the more parsimonious model. This analysis, as well as Fig. 3, suggests that the relationship between year of publication and number of authors does not differ markedly across the subject areas included in the regression model.

Comparison of CFS to Scopus data

A comparison of Scopus and SCImago journals to those in the CFS bookstore identified that several publications with substantial contributions from the CFS were not in either SCImago or Scopus. As summarized in Table 4, neither SCImago nor Scopus included specialized publications such as *The Entomological Society of British Columbia*, *Proceedings of the Entomological Society of Ontario*, the *Annales de la Société Entomologique du Québec*, *Manitoba Entomologist*, and the *Journal of the Acadian Entomological Society*. Peer reviewed publications such as *Insecta Mundi*, *Molecular Ecology Notes*, *Belgian Journal of Entomology*, and *Biotechnologie, Agronomie, Société et Environnement* also did not link to Scopus or SCImago journals. Other publications such as the *Canadian Plant Disease Survey* did not return publications from Scopus, but do provide some significant historical contributions concerning the occurrence and severity of plant and tree diseases in Canada (Canadian Phytopathological Society 2019).

In total, 1706 articles in the CFS bookstore published from 1966 to 2018 did not match a SCImago or Scopus journal title (15.7%). From 2002 to 2017, 324 publications did not match either a SCImago or Scopus journal (8.1% of 3993 journal

articles listed in the CFS bookstore), of which 75 are contained in Table 1. These articles represent an important, legitimate part of the publication record, particularly for analysis of co-authorship.

Data on affiliation were not available for many CFS articles until after 2000 (Fig. 4). As a result, we limited our anal-

ysis using Scopus data to fifteen years from 2002 to 2017, as the coverage is relatively high over this time period. From 2002 to 2017, there are 4058 CFS-affiliated records in Scopus, or 65 more than recorded by CFS. This might be due in part to differences in the recorded year of publication, or with respect to which articles are considered primarily affiliated

with the CFS (as opposed to a CFS author contributing to a Food and Agriculture Organization report, for instance). The coverage of CFS articles in Scopus varied from year to year.

Comparing CFS to Scopus data from 2002 to 2017, the Scopus record was more likely to contain articles authored by 20 or more people (50 articles) compared to the CFS record (29 articles). Of the fifty articles in Scopus with 20 or more authors, only 28 were in the CFS record ($\chi^2 = 5.80$, $p = .016$). Instead, the CFS contained a greater number of articles authored by one person (395) compared to Scopus (205), a statistically significant difference ($\chi^2 = 58.90$, $p < .0001$).

Considering journals listed in Table 4 from 2002 to 2017, the average number of authors was three, compared to 4.5 in journals listed in SCImago or Scopus, significantly fewer

Fig. 3 Average number of authors on CFS-affiliated publications by decade by top journal subject categories

Table 3. Regression results for two models. The independent variable for Model 1 was the number of authors per article and the year of publication only. Model 2 independent variables included year of publication, journal rank, and a flag for the most common SCImago journal categories

	y: Number of Authors					
	Model 1			Model 2		
	Coefficient Estimate	t-value	p	Coefficient Estimate	t-value	p
Intercept	-159.77	-44.29	<.0001	-153.061	-31.69	<.0001
X1: Year of Publication	0.0817	45.16	<.0001	0.079	32.67	<.0001
X2: Journal Rank	–	–	–	-0.000069	-9.03	<.0001
X3-Forestry category	–	–	–	-0.715	-8.21	<.0001
X4 – Insect Science category	–	–	–	-0.442	-3.74	0.0002
X5-Plant Science category	–	–	–	-0.266	-2.40	0.01
X6-Global and Planetary Change category	–	–	–	0.144	1.12	0.26
X7-Biology category	–	–	–	0.095	0.74	0.46
Model R-Square	–	0.1610	–	–	0.1657	–
Adjusted R-Square	–	0.1609	–	–	0.1649	–
Root Mean Squared Error (RMSE)	–	2.828	–	–	3.02649	–

Table 4. Number of CFS-authored (co-authored) articles in non-Scopus journals

Journal	Number of CFS-affiliated articles	
	1966–2018	2002–2017
<i>Entomological Society of British Columbia</i>	101	9
<i>Proceedings of the Entomological Society of Ontario</i>	57	11
<i>Annales de la Société Entomologique du Québec</i>	35	0
<i>Manitoba Entomologist</i>	21	0
<i>Forêt et conservation (from 1966-1979)</i>	43	0
<i>BC Journal of Ecosystems and Management</i>	27	27
<i>Journal of the Acadian Entomological Society</i>	8	8
<i>Insecta Mundi</i>	6	4
<i>Belgian Journal of Entomology</i>	4	2
<i>Biotechnologie, Agronomie, Société et Environnement</i>	2	2
<i>ALCES</i>	3	2
<i>Open Journal of Forestry</i>	5	5
<i>Canadian Plant Disease Survey/ Inventaire des maladies des plantes au Canada</i>	23	5
Total	335	75

Fig. 4 Number of CFS-affiliated publications by year, as identified by SCOPUS and the CFS Bookstore

($t=102,66$, $p<0.0001$). As a result, the differences in coverage between Scopus and the CFS bookstore impact conclusions about the average number of authors per publication. Relying entirely on Scopus data would produce a bias towards a greater number of authors compared to the CFS record.

Discussion

Collaboration in science has become a management imperative to many organizations. Canada's federal science-based

departments and agencies are no exception. The CFS is but one modestly sized part of the federal government science family, but its reach is large given the complexity and geographic scope of environmental and forest management issues addressed by the sector. Here we have documented the CFS research enterprise using CFS data over a roughly fifty year span. As well, we have compared the CFS bookstore data to Scopus data.

Our analysis indicates that, given the sparsity of the Scopus record over much of the CFS publishing record, conclusions drawn about trends over time from this citation database should be interpreted with caution. Several publications such as proceedings from provincial associations are not listed by Scopus or by SCImago, yet reflect important periodicals related to forest science. Compared to the CFS record, Scopus contains significantly more papers authored by twenty or more people, and fewer papers authored by one person.

Our data are consistent with a relatively constant NRCan publication record noted by the Council of Canadian Academies (2018), and consistent with the traditional role played by the Canadian Federal Government in forestry noted by Larivière *et al.* (2018). Our data show that the CFS has produced over 1000 CFS-authored or co-authored papers from 1970 to 2018 published in the *Canadian Journal of Forest Research*, as well as over 800 articles in *The Canadian Entomologist* and *The Forestry Chronicle*. This represents a significant contribution to these Canadian journals.

Increasing authorship fractionalization is clearly evident in the CFS' own data. We showed a three-fold increase in the number of authors per publication over the past fifty years. Such increasing collaboration is consistent with trends such as the one noted by *Nature* (Adams 2012), and with imperatives issued by bodies such as UNESCO and the Institute of Science. Given the Federal Government's roles in science and policy nationally and internationally, this evolution is not surprising. However, use of citation databases should be used with some caution. Particularly for co-authorship analysis, it appears that attention should also be paid to lower ranking journals which may present preliminary investigations which in turn lead to more structured collaborative studies. For research on collaboration alone, there is an argument that the journals produced by the Societies of Entomology should be added to the Scopus record. Our future investigations will look at these and other publications in the "grey literature" to investigate the role of research outside citation databases to determine what impact some of these studies might have had on policy decisions.

Based on our findings, we recommend the following considerations when using Scopus data:

- 1) Data extractions from Scopus that rely on affiliation should be scrutinized for completeness of the record, particularly prior to 2000. As Fig. 4 shows, while journals are present in the Scopus data, extracting records based on affiliation fields may result in a limited data pull. As Sco-

pus updates are introduced (e.g., Elsevier 2015), this time period may expand back in time; and,

- 2) Evidence of collaborations can be found in records of conferences, working papers, and in particular for entomology research, at the regional Societies of Entomology. Peer reviewed articles are one example of collaborations, but particularly for tracking emerging partnerships, it may be more useful to consider joint contributions in publications not tracked in Scopus. This will be the subject of our next exploration of collaboration at CFS.

Certainly, it is the sum total of the entire written historical legacy and interpersonal relations between agencies that influence the impact of science-based products. Impact of research activities on social, environmental and economic conditions is (arguably) the end goal of science investments. Better understanding the nuanced linkages between publications, collaborative science and impact in the non-science world will ultimately promote greater knowledge uptake. Co-discovery during collaboration produces knowledge that is owned and used by multiple partners. Our future efforts will investigate qualitative examples of research uptake in the CFS context.

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