Six decades of environmental resource valuation in Canada: A synthesis of the literature

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Abstract

This paper synthesizes Canada's environmental valuation literature over the last six decades. Focusing on primary valuation benefit estimates, we link multiple research outputs from the same data collection effort to obtain an accurate measure of unique studies. We identify a total of 269 unique valuation studies conducted in Canada between 1964 and 2019. The number of valuation studies conducted per year has not increased since 1975 and the median data collection year is 1996. Stated preference methods are the most popular valuation approaches being used in more than 50% of studies and this share has increased to over 80% within the last decade. We discuss numerous gaps in our knowledge for certain environmental resources and regions, in particular Canada's three Northern territories. The paper provides information on the state of environmental valuation research in Canada and identifies future research needs.

Keywords: Non-market valuation, ecosystem services, stated preference, revealed preference

1. Introduction

Canada is richly endowed with natural assets. Its large landmass, three adjacent oceans, and diverse ecosystems are home to over 4,000 vascular distinct plants, 130 trees, 48,000 invertebrates, and 200 distinct mammal species (Gray et al. 1993). Wetlands, as one of the most effective life-support habitats globally, is an excellent example of this biodiversity. Canada has roughly 1.5 million square kilometres of wetlands, accounting for 16 percent of its total landmass and one-quarter of the world's remaining wetlands (National Wetlands Working Group 1997). They form the interface between terrestrial and aquatic biomes and, in doing so, support substantial concentrations of birds, reptiles, amphibians, fish, invertebrates, and mammals (Parish and Looi 1999).

Canada's natural resources are essential components of the country's economic activity, from tourism to resource extraction. In 2019, natural resource industries accounted for 16.9 percent of Canada's nominal Gross Domestic Product (GDP). Over 48 percent of all merchandise exports are natural assets, and resource-based sectors constitute 1.9 million jobs in Canada (Natural Resources Canada 2020). The market value of Canada's natural resources, such as oil and gas, fisheries, and timber, are well-documented, tracked, and analyzed.

Besides their impact on formal economic metrics, Canada's natural assets also provide numerous non-market benefits through ecosystem services such as carbon sequestration, wildlife habitat, soil protection, and aesthetic beauty. While typically lacking attached market prices, these ecosystem services can still have substantial economic value to society. We know relatively little about the economic value of Canada's ecosystem services (Olewiler 2017). Understanding the economic value of these environmental resources is challenging and requires the use of non-market valuation methods. Non-market valuation techniques break down into two general categories: stated and revealed preference (Champ, Boyle, and Brown 2017). Stated preference (SP) methods use structured conversations with consumers to ask questions on the trade-offs people are willing to make between environmental or health outcomes and money to gauge preference. Revealed preference (RP) methods use data on actual decisions people make to understand preferences and values for non-market outcomes.

The purpose of this paper is to synthesize the environmental valuation research in Canada. To do so, we compile the most complete database on Canadian primary non-market valuation studies to date, including both published academic research and grey literature reports. We focus on primary valuation research that estimates the economic benefits of nature. We exclude benefit transfer and secondary valuation studies to avoid double counting original valuation efforts. We also exclude studies estimating the costs of conserving nature as this provides information on the 'supply side' of nature rather than the 'demand side.' We link multiple research outputs to the same underlying study to provide a more reasonable assessment of the valuation effort. We categorize the research by data collection year, valuation method, type of environmental resource that is being valued, and geographic location.

We identify a total of 269 unique environmental valuation studies conducted in Canada between 1964 and 2019. The research is generally dated, with half of all studies collecting data before 1996. There is no evidence that the number of studies conducted per year is increasing. Examining the geographic distribution of studies across Canada reveals that Ontario, Alberta, and British Columbia are home to the most valuation studies. Most striking is the paucity of studies in Canada's three Northern territories. We present the full database of studies as supplemental material in Appendix A.

We contribute to the literature by examining the extent of environmental valuation research (Adamowicz 2004; Petrolia et al. 2020). Adamowicz (2004) examines the global environmental valuation research from the mid-1970s to 2003 and finds rapid growth in environmental valuation publications over time. Most notable is that the growth of environmental valuation outpaces the growth in overall academic publishing over this time. His literature search also reveals that contingent valuation is the most popular valuation technique, followed by the hedonic price method. Petrolia et al. (2020) also find increasing growth in non-market valuation studies published in the literature from 1974 to 2019. Our paper differs from these two papers in four respects. First, we focus on Canada rather than global trends. Second, we focus on primary valuation studies producing an economic estimate of the benefit of nature. This avoids the inclusion of theoretical papers, review papers, papers estimating the cost of supplying ecosystem services, and benefit transfer research. Third, we include both

peer-reviewed publications as well as grey literature research. Many valuation studies are reported in graduate student theses and government reports and incorporating this research is important to understand the true extent of environmental valuation research. Fourth, we focus on unique valuation studies to avoid double counting research outputs that use the same underlying data. Many studies result in multiple research outputs such as theses, conference presentations, and journal articles. By only grouping research into unique studies, we obtain a more reliable assessment of the state of research.

The database we construct as part of this study can inform researchers, policymakers, and analysts of the state of environmental valuation literature in Canada. As the demand for environmental valuation research continues to grow in benefit-cost analyses, damage resource assessments, green taxation, and green accounting, there is a need to understand better the full economic value of the benefits Canadians receive from environmental resources. This information can complement existing efforts to value Canada's natural capital that focus on the market benefits from natural resources (International Institute for Sustainable Development 2018). For example, Statistics Canada includes measures of natural capital for market goods such as timber and oil and gas, but do not yet take into consideration non-market values for metrics of ecosystem services. Broadening our understanding of nature's benefits are an important component in ensuring Canada's sustainable development into the future.

2. Building the Canadian environmental valuation database

We conduct a systematic review of the primary environmental valuation literature in Canada using the following 4 steps.

Step 1: Search Procedures

The search process begins with a review of environmental valuation databases. We start with the Environmental Valuation Reference Inventory (EVRI), as it is by far the largest database of economic valuation

research of the environment.[1] The database contains over 5,000 environmental valuation entries and is freely available at the web address (https://www.evri.ca/). The purpose of EVRI is to help researchers assess the state of environmental valuation research on a particular topic, location, or method. We download data from the database and filter to exclude any non-Canadian research. Doing so distills the number of entries from 5,116 down to 307 Canadian-specific entries.

We supplement the EVRI data with searches of several other databases, including the Marine Ecosystem Service Partnership (MESP), Environmental and Recreational (Non-Market) Values from National Ocean Economics Program (NOEP), the Ecosystem Service Valuation Database (ESVD) and the Economic Value of Wildlife in Alberta database (Rush, Philips, and Adamowicz 1996). Furthermore, we conduct an extensive search of several other academic and grey literature databases as well as specific environmental and resource economics journals for additional research.[2]

Identified research outputs in French and English are considered, with no date restrictions. We include grey literature research, such as dissertations/theses, conference papers, working papers, and other non-peer-reviewed documents. We assess the abstracts of research papers and download full texts if studies are potentially viable. Furthermore, we request from the authors directly those whose full texts are unpublished or can otherwise not be obtained. The references of these retrieved articles are screened to elicit any other prospective papers. We identify a total of 474 potential entries as a result of our search process.

Step 2: Selection Criteria

[1] EVRI development is a joint partnership between Environment Canada and the United States Environmental Protection Agency (EPA), with additional co-sponsors including the World Bank, European Union, and Government of Quebec.

[2] These databases include: Google Scholar, AgEcon Search, EconPapers, and the Wiley Online Library. Specific journals include: Agricultural & Resource Economics Review, American Journal of Agricultural Economics, Canadian Journal of Agricultural Economics, Canadian Journal of Forest Research, Canadian Water Resources Journal, Ecological Economics, Energy Economics, Environmental & Resource Economics, Forest Policy & Economics, Journal of Agricultural & Applied Economics, Journal of Agricultural & Resource Economics, Journal of Agricultural Economics, Journal of Environmental Economics & Management, Journal of Environmental Management, Journal of Forest Economics, Land Economics, Resource & Energy Economics. We use the following keywords and their combinations: *Canada, non-market, ecosystem services, travel cost, revealed preference, environmental, benefit-cost/cost-benefit analysis, nature recreation, contingent valuation, random utility, willingness-to-pay/accept, wetland, economic valuation/value/impact, stated preference, hedonic price, averting behaviour/expenditures, ecological [goods and services], and use/non-use value.*

We vet the remaining 474 entries to ensure that they satisfy the following inclusion criteria. Any entry must sufficiently:

1. **Focus on Canada.** We concentrate on research that provides Canada-specific monetary value estimates. We exclude global entries, entries that group Canada with the United States and Mexico, and entries that only mention Canada in passing. This process results in the removal of 7 studies from the database.

2. **Conduct primary valuation research.** We include entries that use a primary valuation method (revealed preference, stated preference, or market-based measure) to provide a novel value estimate. We exclude entries that use secondary valuation methods as well as entries that focus on economic impacts. Secondary valuation methods such as benefit transfer or synthesis entries apply existing valuation estimates to new contexts. Benefit transfer can be an important, fast, and cost-effective policy support tool. However, in this paper, we focus on primary valuation methods. Therefore, we remove 33 benefit transfer entries. For similar reasons, we remove 11 entries focused on economic impact analyses (EIA) and 18 entries that use other non-valuation methods.

3. **Estimate benefits.** This paper aims to focus on the benefits people receive from nature, not the costs of conserving nature. Thus, we exclude entries that focus on the supply side of ecosystem service provision. For example, many entries use stated or revealed preference methods to estimate the willingness-to-accept (WTA) of landowners to preserve environmental resources on their land. These values represent the costs, not benefits, of nature. We remove a total of 27 cost estimation entries.

4. **Assess environmental resources.** We only include entries that focus on environmental resources or the relationship between environmental quality and human health. We exclude 7 purely non-environmental entries comprising of 2 that focus purely on human health and capital, 4 on market goods, and 1 on financial valuations.

The review of these prospective entries ultimately results in the removal of 103 entries that we exclude from the final database, leaving 371 entries for evaluation. Studies found in the EVRI database comprise 62 of the 103 studies we remove, with entries we find in our search process accounting for the remaining 41.

Step 3: Identifying Unique Studies

The next step uses the 371 research outputs and groups similar entries together to identify unique studies. While the inclusion process ensures that any remaining studies are environmental valuation work conducted in Canada, many entries are variants of each other and use the same underlying data. For example, a study may lead to a graduate student thesis or working paper as well as a journal publication[3] or the same SP survey may be used for entries two journal publications.[4] As this paper aims to understand how much we know about the economic value of environmental resources in Canada, we argue that not accounting for these multiple research outputs from the same study can lead to double counting and inflate the actual amount of original research conducted.

In this paper, we define a study as a unique data collection effort. Conversely, entries are any research output from an original study, including journal articles, papers, and presentations resulting in multiple entries for the same study. We group entries to be from the same study if they meet the following three conditions: i) they use the same data, ii) they use the same valuation method, and iii) they consider the same environmental resource. We assign a unique identification number to each original study which can have multiple research outputs.

We review all collected research and group entries by unique studies to obtain a more accurate representation of the state of environmental valuation literature in Canada. Identifying unique studies is a time-intensive task and involves judgement on behalf of the authors. Therefore, we provide all the entry groupings by

[3] An example of this grouping of entries is the 2009 conference paper entitled "Estimates of Passive Use Values of Wetland Restoration and Retention in Southern Manitoba" and the 2011 journal article "The Economic Benefits of Wetland Retention and Restoration in Manitoba" (Boxall, Gabor, and Pattison 2009; Pattison, Boxall, and Adamowicz 2011). Both research outputs draw from the same survey data and use contingent valuation methods to estimate consumer willingness-to-pay for wetland conservation and restoration in Manitoba. If we count each entry separately, we would conclude that there are two stated preference valuation studies of wetlands in Manitoba when in fact they are the same study.

[4] An example of this equivalency is the 1996 journal article "Willingness To Pay for Water Quality and Supply Enhancements in the Grand River Watershed" and the 2003 journal article "Estimating Willingness to Pay for Improved Water Quality in the Presence of Item Nonresponse Bias," two research outputs from the same study that both rely on the same stated preference survey (Brox, Kumar, and Stollery 1996; 2003).

unique study as supplemental material in Appendix A. The final sample includes 269 unique primary valuation studies once we account for these similar entries.

Step 4: Data Extraction of Study Attributes

We extract the title, authors, province/national, data collection year, valuation method, and environmental resource for each unique primary valuation study. The first category is the province the study takes place. The vast majority of studies focus on a single province, but some cover more than one province or the whole country. We classified studies as national in scope if they only provided a single value for all of Canada/Canadians. Some national studies provided a provincial breakdown for the valuation estimates, and in this case the study would be included in each of the provinces considered subtotals. For studies that provided valuation estimates for the recreation value of an activity on a province-by-province basis this would also count in each province's subtotals. In both later examples, the study would still only be counted as one unique study for the aggregate totals. This is the reason that adding up the number of studies in each province results in a larger number than the total number of unique studies.

We use the data collection year rather than publication year as the most relevant time stamp for the study. For studies conducted over multiple years, a hedonic price study that uses a decade of house price data for example, we use the simple average as the data year. The data collection year is not available for 27 studies, but we do know the research publication year. To impute these missing data years, we calculate the average difference between publishing and data collection years for the rest of the studies. For the studies with missing data collection years, we take the year the research publication year and subtract the average difference of 4 years to approximate the data collection year.

We consider six main categories of valuation methods. We use three revealed preference (RP) method categories, including hedonic pricing method (HPM), averting expenditures method (AEM), and travel cost method (TCM). HPM uses prices for related market goods to understand the value for multi-attribute market goods to isolate and reveal non-market features included in its total value. Likewise, AEM uses data on people's behaviour and expenditures to reveal their values to avoid environmental harms and adverse health risks. TCM

uses the resources people give up travelling to sites as proxies for prices to derive demand curves and estimate welfare measures for natural areas and non-market activities.

We use two broad categories of stated preference (SP) methods – contingent valuation (CVM) and choice experiments (CE) – to encompass a myriad of nomenclatures describing different methods, including choice modeling, attribute-based methods, conjoint choice, contingent rankings, contingent behaviour, and several other labels. All of these methods share the same basic approach of using questionnaires to elicit preference information from individuals. We followed the categorization described by Carson and Louviere (2011) but we recognize that the distinction between the different SP methods has become increasingly blurred (Lloyd-Smith, Zawojska, and Adamowicz 2020) and there is some subjectivity in categorizing studies as strictly CVM or CE.[5] We code 8 studies that include both a separate CVM and CE elicitation format as both CVM and CE.

We group all market price method (MKT) studies into one category. These include actual expenditures, replacement costs, and productivity change methods. Some studies use multiple valuation methods (e.g., combined stated and revealed preference studies) and these studies are counted by all of the different methods used.

We also group studies by the type of environmental resource under evaluation in the research. We use 13 different categories based on the EVRI database, including agricultural, endangered species, mammals, human health, freshwater, drinking water, wetlands, estuarine and marine, birds, fish, air and weather, parks and open spaces, and forests. These categories are not mutually exclusive; many studies value more than one environmental resource.

3. The current state of environmental valuation research in Canada

[5] For example, Boxall et al. (2012) note that their approach is "a stated preference tool that is somewhat a hybrid between contingent valuation and a choice experiment with multiple species recovery program options and choices framed as referenda". Vossler et al. (2012) use multiple independent binary choice questions with varying attributes. We classify these two studies as CE.

We identify a total of 269 unique primary valuation studies from the 474 entries found in our search process. This decrease comes from removing 103 entries that do not conform to our inclusion criteria and grouping similar research outputs into the 269 unique studies found in the final database. Appendix A contains the full database and is grouped by province and arranged by descending data collection year. We highlight national studies first. To avoid duplication, we also categorize multi-province studies only once in a separate section.

3.1 When were environmental resources valued?

Previous assessments of non-market valuation literature uses research output year to assess trends (Adamowicz 2004; Petrolia et al. 2020). We argue that it is useful to examine research trends using the data collection effort because the year the data was collected better represents when the environmental resource was valued and avoids research lags between data collection and publication. Furthermore, in terms of using the study to inform policy or tin a benefit transfer exercise, data collection year is again the more pertinent time period. We collect both research output year for the 371 research outputs and the data collection year for the 269 unique studies and examine trends for both sets of data. We first present results for the data collection effort year and then discuss the research output year.

Figure 1 presents the non-market valuation data collection effort in Canada by year. Data collection for the earliest Canadian valuation study dates to 1964. The sample includes studies with data collection years up to the year 2019. The median year for data collection is 1996, which indicates that 50% of studies are more than 20 years old. Environmental valuation efforts in Canada started in the 1960s with 7 studies and this small number continued into the 1970s with 10 studies. Canada's valuation collection efforts begin in earnest during the 1980s with 51 studies. The 1990s see a substantial increase in studies, with the decade yielding the highest number of studies at 89. Valuation efforts slowdown in the 2000s, with 65 studies. This downward shift continues into the 2010s, which produced only 47 studies. The solid line in Figure 1 represents the 5-year moving average and suggests that valuation efforts have seen no marked increases since the early 1990s, with a

decline in the most recent decade. However, given the time lag between data collection year and research publication (which averaged 4 years in our sample), some caution is required in interpreting numbers in the last few years. There may be current primary valuation research conducted during this time period that has yet to be published or made publicly available.

Figure 2 shows research trends using the number of research outputs per year. The later rise in annual research output compared to Figure 1 reflects the publication time lag. Furthermore, we see that research outputs remain fairly constant between the mid-1990s until the mid-2010s in contrast to Figure 1.

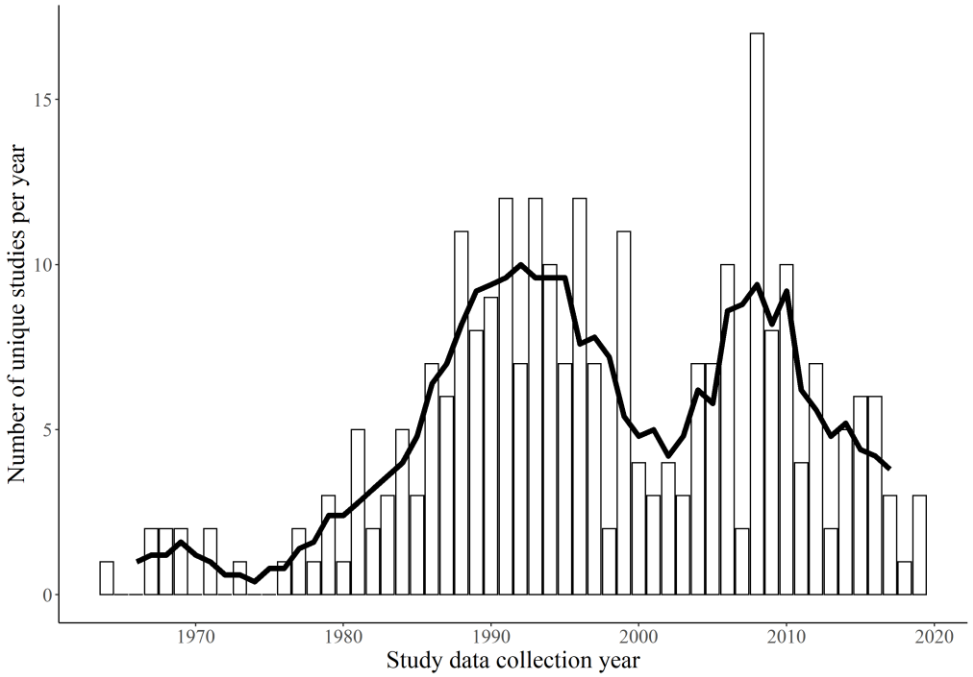

Figure 1 Annual number of unique valuation studies in Canada between 1964 and 2019 (black line represents 5-year moving average)

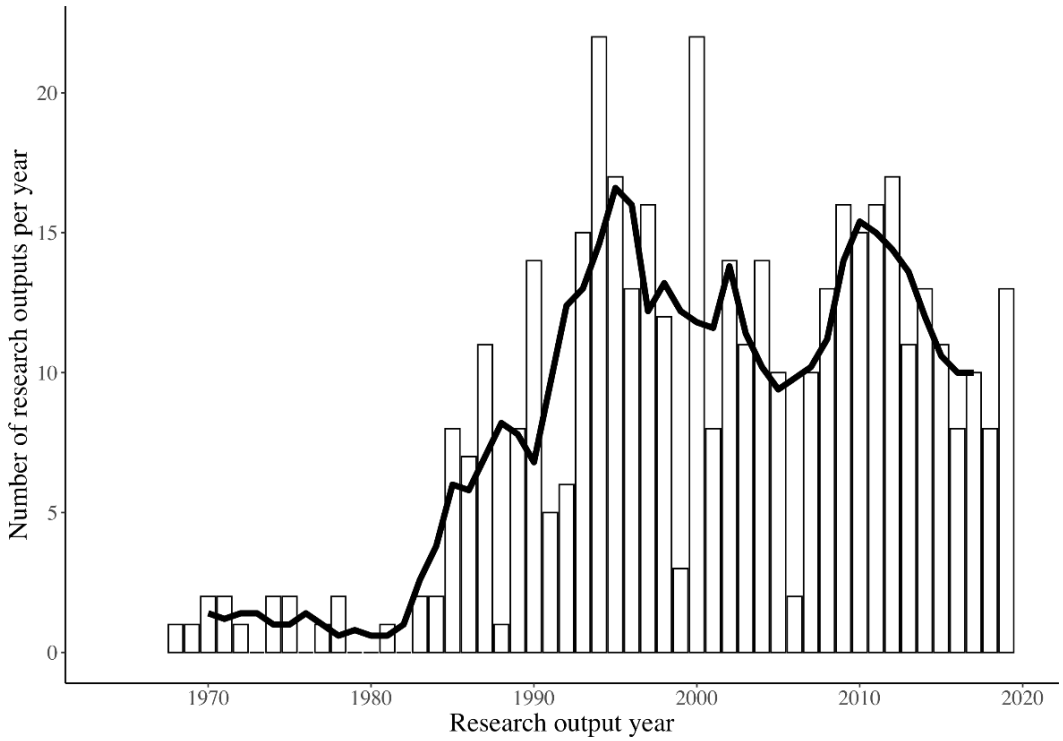

Figure 2 Annual number of research outputs in Canada between 1964 and 2019 (black line represents 5-year moving average)

To formally test the presence of trends in the data we conduct a linear trend regression analysis.[6] The results are presented in Table 1. The dependent variable is either the number of unique studies each year or the number of research outputs each year. Given the paucity of studies conducted during the 1960s and 1970s, we restrict the analysis to the period starting in 1980. The year variable has been coded starting at 0 for the first period (i.e. year 1980 = 0, year 1981 = 1, etc). Furthermore, as noted above, some caution is required in interpreting numbers for the most recent years due to the lag between conducting data collection and producing an initial research product and thus we only examine studies up to and including 2015. To assess the sensitivity of these time period assumptions, we also conduct the analysis using a larger year time period between 1975 and 2019. The results of the linear trend regression analysis using only unique studies and the data collection year in columns one and two show that the year coefficient is not statistically different from zero and confirms that there is no overall trend during the time period. However, the analysis using the research output year do show a statistically significant positive trend in valuation research with research outputs increasing at a rate of 0.19 per year. These divergent results underline the importance of carefully considering how the quantity of environmental valuation research is defined.

Table 1 Linear Trend Analysis of Environmental Valuation Studies in Canada

	Only unique studies (n=269)		All research outputs (n=371)	
Year	0.04	0.05	0.19	0.19
	(0.06)	(0.04)	(0.08)	(0.06)
Constant	6.02	4.65	5.40	3.50
	(1.22)	(1.12)	(1.72)	(1.49)
Time period	1980 to 2015	1975 to 2019	1980 to 2015	1975 to 2019
Observations	36	45	36	45
R^2	0.01	0.03	0.13	0.20

The dependent variable is the number of studies/output per year. Standard errors are shown in parentheses. The Year variable has been coded starting at 0 for the first year in each period.

[6] We recognize that the linear trend analysis may suffer from serial dependence in error terms and traditional standard error corrections for serial correlations are challenged in small samples. We also conduct a Mann-Kendall nonparametric trend test and find similar results as the linear trend analysis.

3.2 How are environmental resources valued?

We next consider the use of different valuation methodology in Canada's non-market literature. Figure 3 shows the number of studies that employ each of the 6 valuation methods. Many studies utilize more than one method and thus these totals do not sum to 269. CVM is the most common valuation approach used in Canada and is involved in almost 50 percent of all environmental valuation studies. The second most popular approach is the use of TCM methods followed closely by the MKT and CE. There are only 23 hedonic price method studies in Canada and 5 AEM studies.

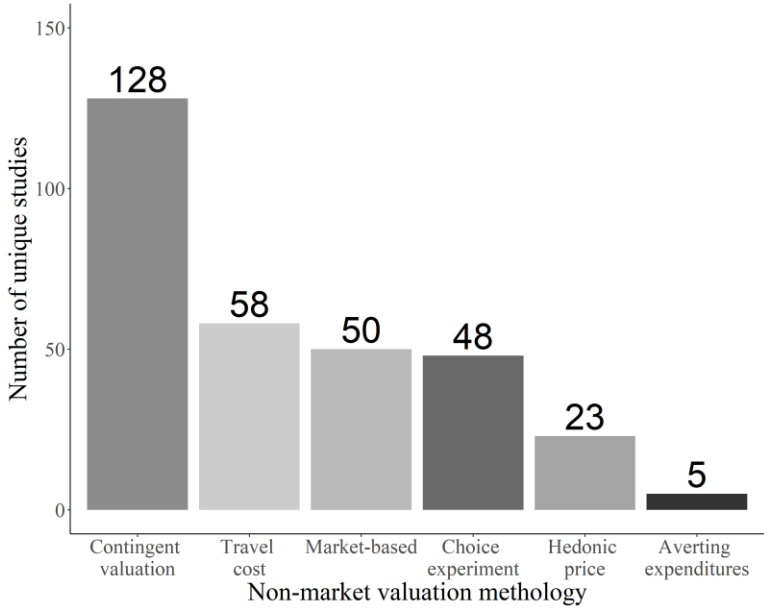

Figure 3 Non-market valuation methodology ranking by prevalence

We next examine how the use of these methods have changed over time and group studies by decade to obtain a better sense of trends. Figure 4a reports the percentage of studies that use each of the 6 non-market valuation methods for 1960-1979, as well as the 1980s, 1990s, 2000s, and 2010s. We group the 1960s and 1970s together due to the small number of studies overall. CVM remains the most popular method across all time periods. TCM methods were used in over one-third of all studies during the 1960s and 1970s but this proportion declines over time, especially post 2000. MKT methods were also more popular earlier in the decades than most recently. Figure 4a also highlights the rise in popularity of choice experiments. The first CE in Canada took place in the 1990s. By the 2010s, CEs had become tied with CVM as the most popular method implemented.

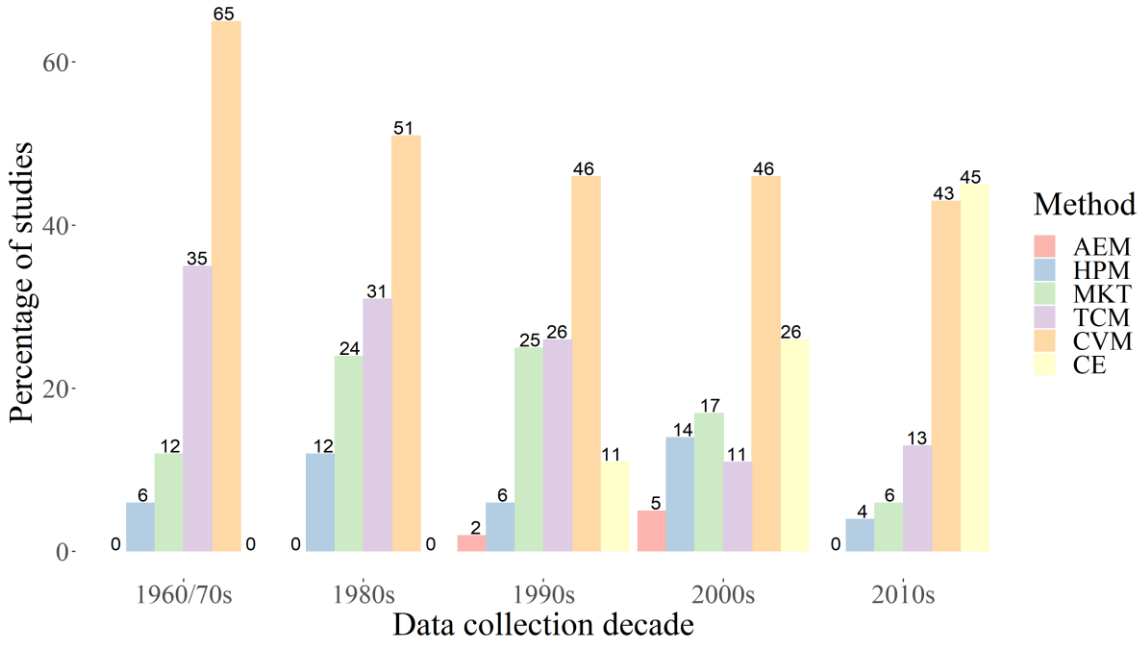

Figure 4a

Figure 4b:

The numbers represent the percentage of studies in each decade using a specific valuation method. Note that these percentages exceed 100 percent as many studies employ more than one method. The total number of unique studies is presented below the decade label. CVM = contingent valuation, CE = choice experiment, TCM = travel cost method, HPM = hedonic price method, AEM = averting expenditure method, SP = stated preference, RP = revealed preference, MKT = market-based method.

Figure 4 The relative use of non-market valuation methods in Canada over time

Figure 4a also shows that the diversity of methods used in the 1980s and 1990s has given way to SP methods being the dominant method by the 2010s. The rise of SP methods and the decline of other methods is more clearly shown in Figure 4b, which groups the individual methods into RP, SP and MKT-based categories. In the 1980s, SP, RP, and MKT methods appear in 51%, 43%, and 24% of all studies, respectively. Each decade has witnessed a decline in the proportion of studies employing RP and MKT methods to lows of 15% for RP and 6% for MKT by 2010s. On the other hand, by the 2010s, SP methods are present in 81% of valuation studies.

Given the rise of SP methods in Canadian environmental valuation studies, we next examine how the use of alternative elicitation formats has changed over time. In addition to CE vs CVM differences, there are many types of CVM questions such open-ended responses, single binary choice, double-bound binary choice, payment card formats, and iterative bidding. There have been many studies comparing alternative SP elicitation formats and we know more about the relative incentive compatibility properties of these questions (Vossler and Zawojska 2020). The single binary choice format as recommended by the NOAA 1993 blue ribbon panel (Arrow et al. 1993) has perhaps the most clear incentive compatibility properties while the open-ended response format is less likely to elicit truthful responses (Johnston et al. 2017).

We categorize the 128 studies that use the CVM into these five elicitation format types (open-ended, single binary choice, double-bound binary choice, payment card and iterative bidding). Figure 5 shows the use of specific CVM elicitation formats and CE designs by decade. The initial implementations of the CVM until the 1990s predominately used the open-ended format. During the 1990s, the single binary choice and open-ended formats were tied for the most popular format. By the 2000s, the use of the open-ended format substantially decreased and single binary choice methods remained the most popular CVM elicitation format. Iterative bidding formats were used between 1979 and 1999 and were always the least popular format in the decades they were used. The use of the payment card elicitation format starting in the 1980s has remained steady and is the most second popular CVM elicitation method since the year 2000. Double-bound binary choice questions rose in popularity in the 1990s but the use of this format has since tapered off. This provides

some evidence that practitioners have largely abandoned open-ended CV questions in Canada and have move towards more choice based formats.

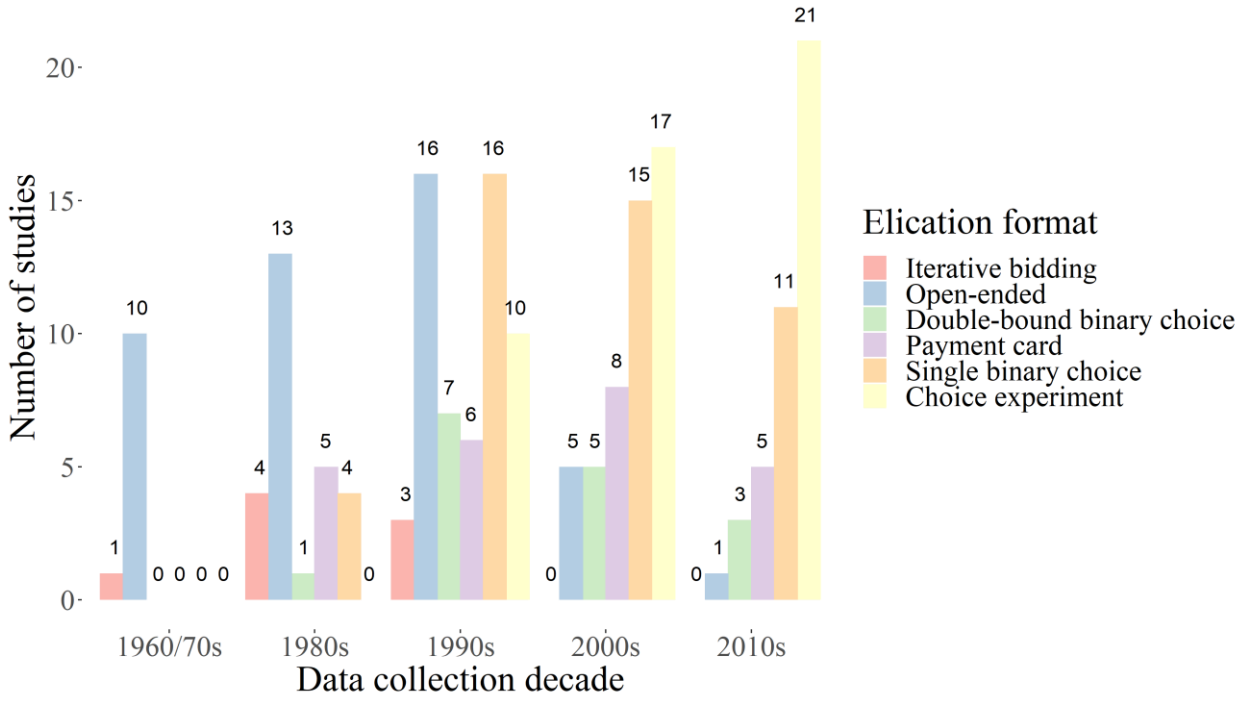

Figure 5 The use of alternative stated preference elicitation methods in Canada over time

3.3 What environmental resources have been valued?

Figure 6 shows the number of unique studies valuing each of the 13 environmental resource categories found in the EVRI database. Most studies value more than one environmental resource, and thus these numbers add up to substantially more than the total number of unique studies. Freshwater is the most valued environmental resource in the database, with 100 studies. This abundance is due to the varied ways that water interacts with other environmental resource categories (i.e. fish through fishing, drinking water, wetlands) as 65 of these studies also value a complementary environmental resource. Fish, parks and open spaces, and mammals are also all valued in at least 50 studies. Estuarine and marine areas are the second-least valued environmental resource, with 18 studies, followed by air and weather valuation with only 14 studies across Canada.

Figure 6 also shows the temporal trends in valuation studies for environmental resource categories throughout the decades. The environmental resources relatively more researched in the earlier periods experience a decline in valuation efforts in more recent time periods. For example, the studies valuing mammals decrease from 20 between 1990 and 1999 to 6 between 2000 and 2010. Similarly, the number of studies valuing forests decline from 20 to 13 over these same time periods. Some environmental resource categories see increases in valuation efforts over time. With the exception of air and weather, environmental resources with relatively few valuation studies in earlier decades see an increase in valuation efforts in later ones. Most significantly, the 6 agricultural valuation studies between 1980 and 1999 increase to 16 between 2000 and 2019.

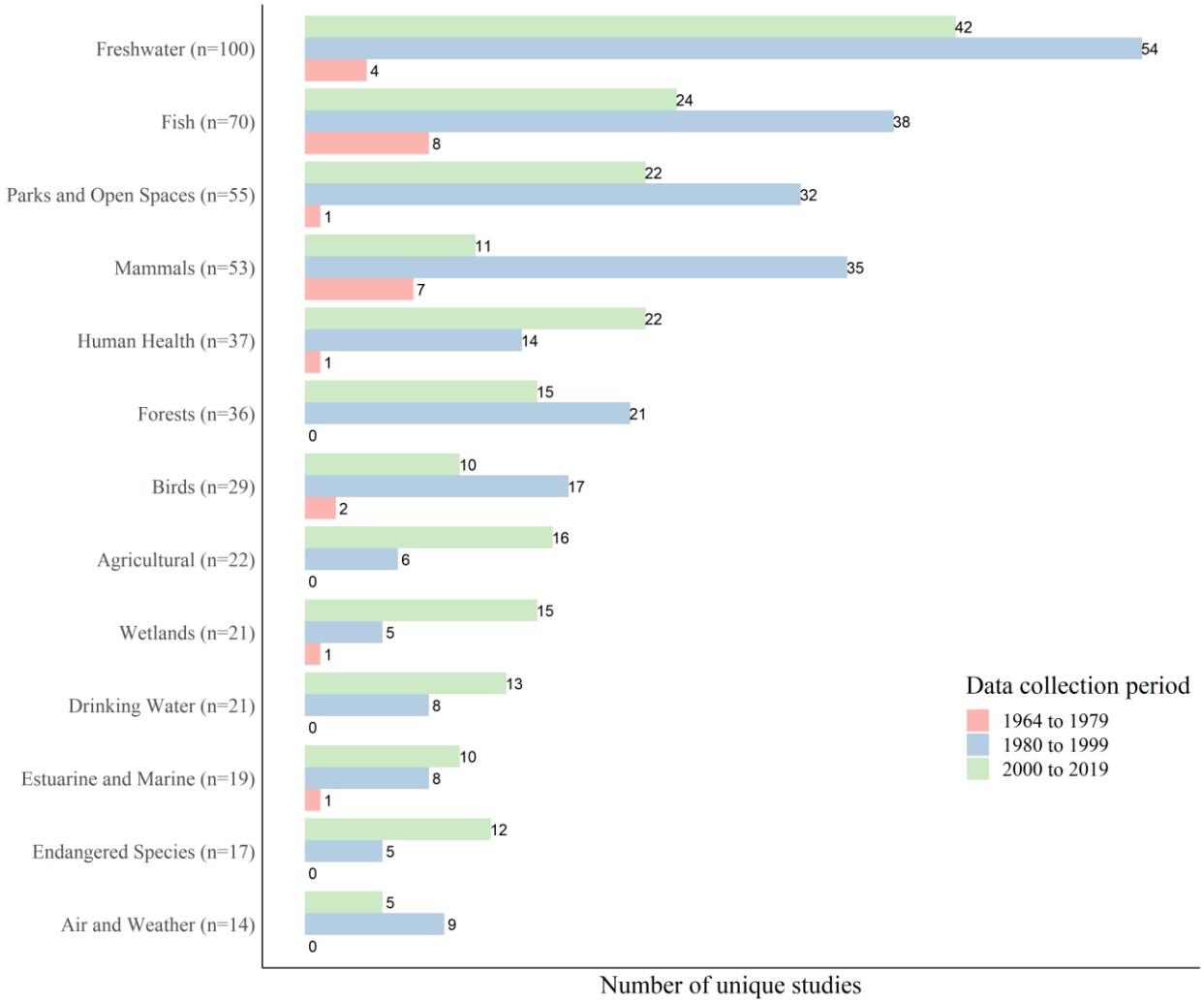

Figure 6 Valuation studies across environmental resource categories over time

3.4 Where are environmental resources being valued in Canada?

Table 2 reports the geographic breakdown on the total number of studies in Canada. To better understand the relative number of valuation studies across Canada, we also include relative study counts by provincial population and land area size. We use 2016 census data for population and provincial landmass estimation to evaluate total studies relative to inhabitants and area. This information allows us to calculate the number of studies per 1 million people and per 1 million square kilometres to better understand if certain areas of Canada are relatively over- or under-studied. For example, Prince Edward Island has 14 unique studies, representing 98 studies per 1 million people and 2,462 per 1 million km^2. Across all of Canada, there are around 8 studies per 1 million people and 30 studies per 1 million km^2. The greatest number of studies have been conducted in Ontario, followed by Alberta and British Columbia. Perhaps more striking is where there are relatively few studies. Few studies have been conducted in the Yukon and Northwest Territories. There are no environmental valuation studies conducted in Nunavut.

Table 2 Relative provincial study rankings by population and area

Province	Number of studies	Studies per 1,000,000 people	Studies per 1,000,000 (km^2)	Population (2016 census)	Land area (km^2)
British Columbia	53	11	57	4,648,055	922,503
Alberta	56	14	87	4,067,175	640,330
Saskatchewan	33	30	56	1,098,352	588,244
Manitoba	17	13	31	1,278,365	552,371
Ontario	59	4	65	13,448,494	908,699
Quebec	29	4	21	8,164,361	1,356,625
New Brunswick	20	27	280	747,101	71,389
Nova Scotia	19	21	359	923,598	52,942
Prince Edward Island	14	98	2,462	142,907	5,686
Newfoundland and Labrador	13	25	35	519,716	370,514
Northwest Territories	3	72	3	41,786	1,143,794
Yukon	2	56	4	35,874	474,713
Nunavut	0	0	0	35,944	1,877,779
Canada	269	8	30	35,151,728	8,965,589

Note: The population figures are from the 2016 census. The last row reports the total number of unique non-market valuation studies in Canada. The total number of unique studies is more than the Canada aggregate total because we count multi-province studies only once, to be consistent with our reporting.

Figure 7 shows the number of unique valuation studies conducted in each province and territory in Canada over time. For all provinces, more studies were conducted during the 20-year period between 1980 and 1999 than between 2000 and 2019. Figure 8 shows the number of studies by environmental resource for each of the provinces, as well as the territories and national studies. In the rest of this section, we briefly discuss each province separately, starting in the west with British Columbia and ending with the territories.

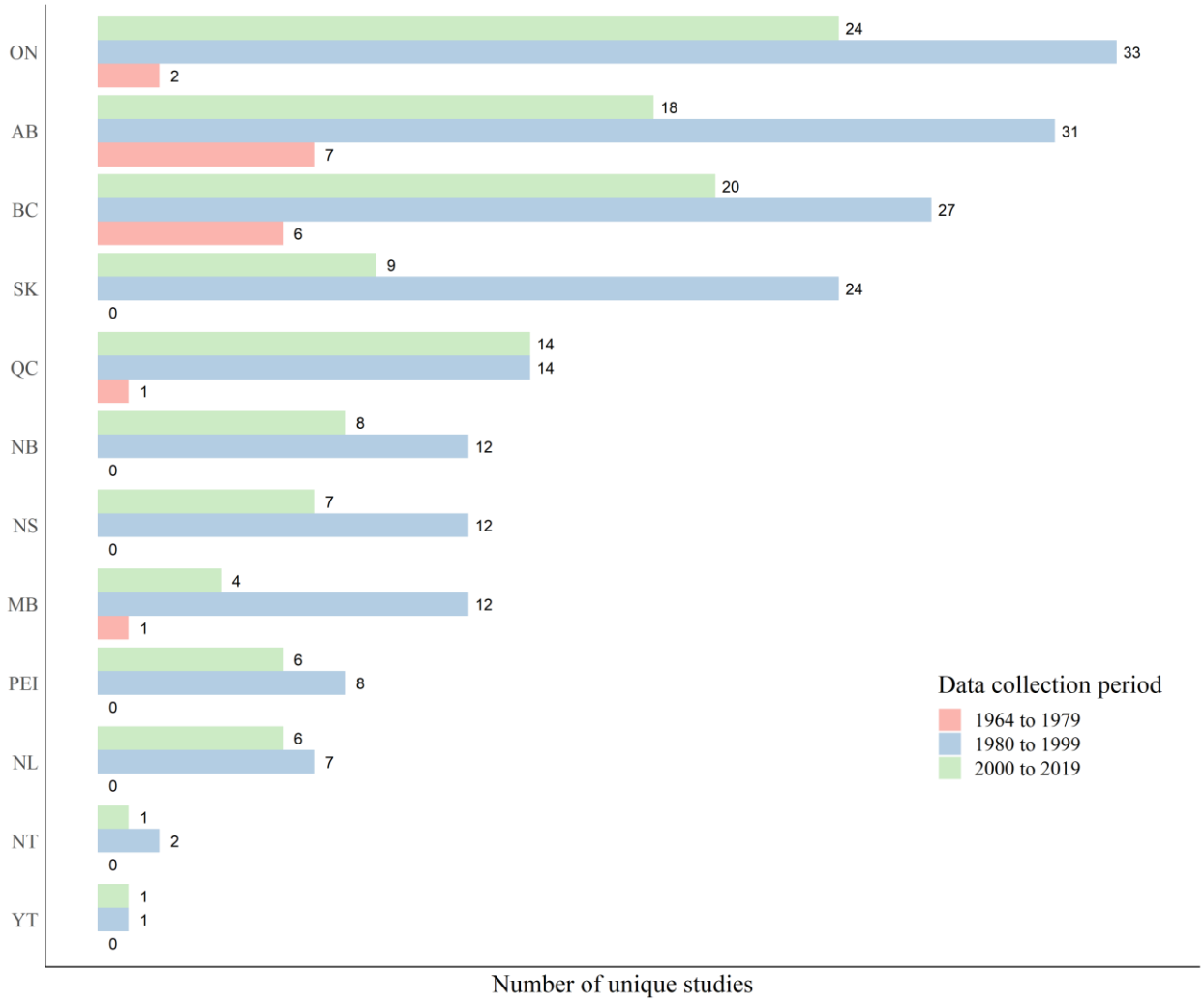

Figure 7 Geographic distribution of valuation studies over time

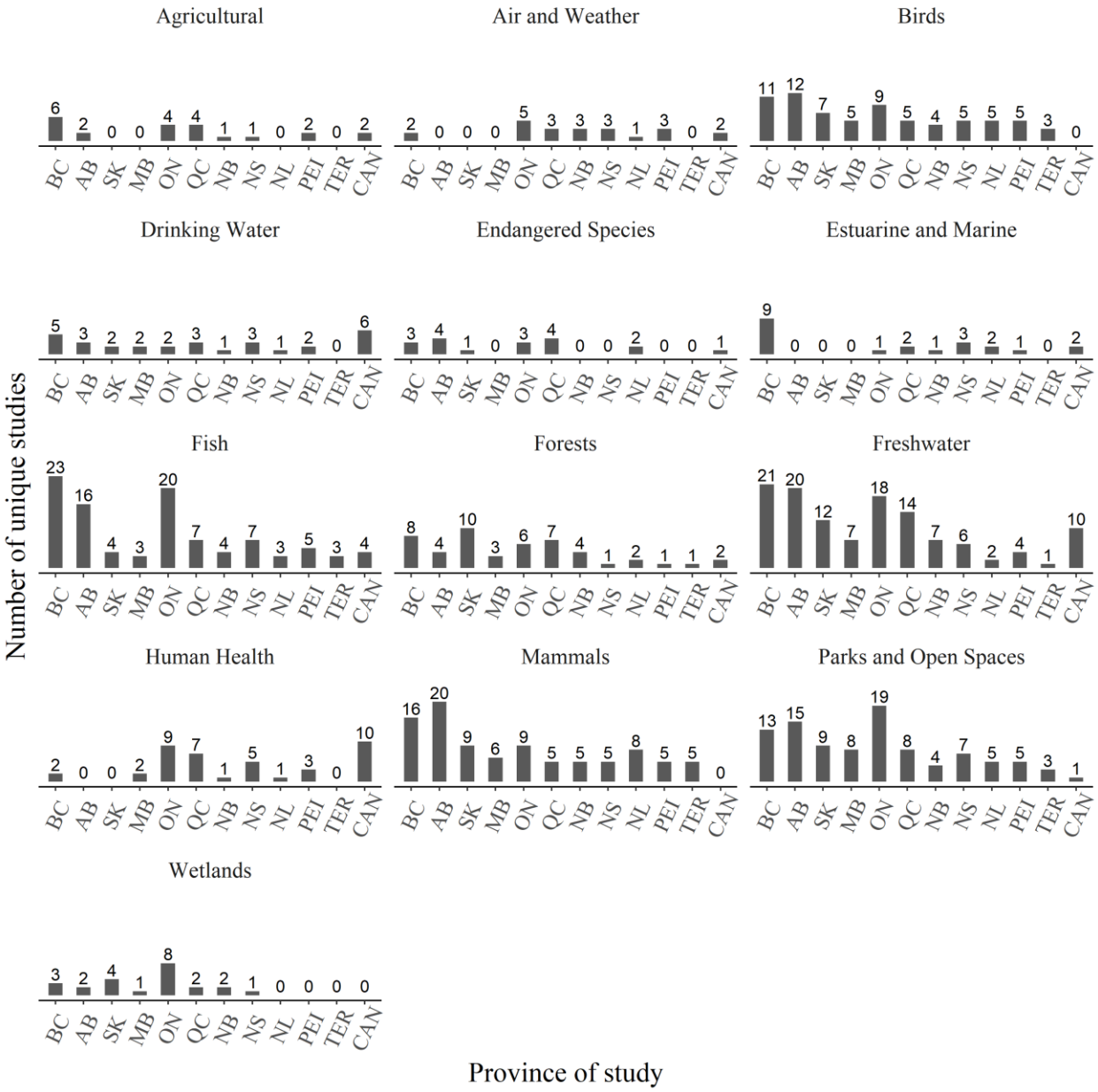

Figure 8 Geographic distribution of non-market valuation studies by environmental resource

British Columbia has a total of 53 environmental valuation studies, making it the province with the third-most studies and is above the national average based on the per capita and per land area measures. The number of studies conducted in British Columbia declines slightly over time in the last twenty years compared to the previous period. British Columbia is fairly well represented across the different environmental resources and has the most agricultural, fish, drinking water, and estuarine and marine studies of each province. British Columbia has the most freshwater valuation work, with 21 studies conducted in the province.

Alberta is the province with the second-highest number of non-market studies, with 56. The province has around double the average number of studies on a per capita basis and almost triple the average number of studies per land area. The number of studies conducted in Alberta has fallen over 40% from the first twenty-year period before the year 2000 to the latter two-decade period. Alberta has many recreation-based studies that value fish, freshwater, mammals, birds, and parks and open spaces. The province also ties with Ontario for the most studies examining endangered species.

Saskatchewan has 33 environmental valuation studies and is well represented on a per capita basis and per land area. However, the studies are generally dated, and only 9 of these studies have taken place within the last 20 years, representing an almost two-thirds decline from the previous period. Saskatchewan has the most studies focused on forests in the country. Other environmental resources well represented are freshwater, mammals, and parks and open spaces.

Manitoba has relatively fewer studies than its neighbouring prairie provinces with 17 overall but still roughly double the national average on a per capita basis and almost exactly the national average on a per land area basis. Similar to Saskatchewan, only a small number of studies (4) have been conducted within the last 20 years. Furthermore, just one of these more recent studies has focused explicitly on Manitoba. The province is well represented in parks and open spaces studies.

Ontario has a total of 59 studies making it the province with the highest number of valuation publications. Given its large population, it is below average on a per capita basis but above average on a land area basis. Of these studies, 24 are conducted in the last 20 years, representing a roughly 25% decline from the previous 20-year period. Ontario generally ranks first or close to first across all environmental valuation categories, most notably in wetlands, air and weather, human health, and parks and open spaces.

Quebec has 29 studies and, while tying with Ontario as the most undervalued province on a per capita basis, the province ranks much lower on a per land area basis. However, Quebec is one of the few provinces to not see a drop in valuation studies from the 1980-1999 time period to the 2000-2019 time period, with 14 studies in each. In terms of environmental resource categories, Quebec is generally well represented, with at

least one study in each category, and has the second-highest number of human health and third-highest number of forest studies.

New Brunswick has 20 non-market valuation studies. Its smaller population and land area mean the province has over three times the average number of studies per capita and around nine times per land area. New Brunswick has had 8 studies conducted within the last 20 years, a fall from the 12 in the preceding 20-year period. There are 7, 5, and 4 studies that consider the province's freshwater, mammals, and forests, respectively, making these New Brunswick's most valued assets.

Nova Scotia has 19 non-market valuation studies with similar per capita valuation efforts to Newfoundland and Labrador, but with higher levels of studies per land area. Only 7 of these studies have been conducted in the last 20 years. Nova Scotia has relatively high numbers of studies on parks and open spaces, fish, human health, and freshwater.

Prince Edward Island has 14 non-market valuation studies. However, it ranks as the most-valued province or territory when considering the number of studies by both population and land area. Prince Edward Island has seen a small decline of 2 studies between 1980 to 1999 and 2000 to 2019. There are 5 studies on fish, mammals, birds, and parks and open spaces, making these the assets most often under consideration in the province.

Newfoundland and Labrador has a total of 13 studies conducted in the province. This number ranks well above the national average on a per capita basis and slightly higher than the national average on a land area basis. The number of studies decreases from 7 to 6 between 1980-1999 and 2000-2019 periods. In terms of environmental resources, Newfoundland and Labrador has 8 studies that value mammals and 5 that value parks and open spaces and birds.

The Territories have 5 valuation studies conducted collectively across the three Northern territories, with 2 in the Yukon and 3 in the Northwest Territories. Not a single valuation study has been done in Nunavut, despite it being Canada's largest partitioned landmass. These areas have the lowest number of studies per land area across Canada. Both Yukon studies and two of the Northwest Territories studies are part of national survey

data that value recreation opportunities and the associated environmental resources. The older, exclusively Northwest Territories study dates to 1995 and uses stated preference methods to estimate the passive use value of four remote wilderness parks. This work represents the first estimate of an existence value for a national park in Canada (Jensen and Bourgeron 2012).

4. The demand and supply of environmental valuation research in Canada

One open question is whether the lack of recent environmental valuation research in Canada is driven by limits on the supply of, or demand for, these types of studies. We examine both here. To assess the potential supply of non-market valuation research in Canada, we calculate the number of active valuation practitioners through time. We define a valuation practitioner as any author that has conducted at least two valuation studies in Canada during the past 55 years. We use an admittedly arbitrary two-study threshold to mitigate the influence of people conducting one-off studies. There are a total of 88 authors conducting two or more environmental valuation studies in Canada in the data. To understand when these authors are active, we use the years of their first and last studies and assume that the author is active between these two bookends. On average, authors are active for 9 years. Figure B1 in Appendix B presents the result of this calculation. Figure B1 shows a substantial increase in research capacity for environmental valuation studies during the 1980s. The increase peaked during the 1990s and plateaued during the 2000s, before dropping at the beginning of the 2010s. Once again, given potential research publication lags, caution is required in interpreting the most recent year's data. However, the trends clearly show no increase in non-market valuation research capacity in Canada since the 1990s and arguably a slight decrease.

There is little evidence that the demand for environmental valuation research has decreased over time. The federal government implemented a policy in 1999 mandating a benefit-cost analysis must be carried out for all significant regulatory proposals including assessing impacts on the environment (Treasury Board of Canada Secretariat 2007). What is interesting to note is that the directive was implemented right at the end of the decade

with the most environmental valuation studies conducted. Since the year 2000, the number of studies conducted per decade has declined. Policymakers often have to use the benefit transfer method due to time and resource pressures, but this method relies on a substantive body of studies to draw on. Many of the benefit-costs analyses conducted since this directive have not included any monetized benefit estimates. For example, a review of 54 regulatory impact assessment statements for species at risk listings in Canada found that only one included a monetary benefit estimate compared to all 54 including cost estimates (Schultz, Darling, and Côté 2013). Similarly, Donahue and Devlin (2016) report that only 5 out of 12 recent benefit-cost analyses of chemical health regulatory impact assessment statements between 2006 and 2015 include monetized benefits impacts. In their review of the economics of oil sands, Heyes et al. (2018) find that there is a lack of credible valuation estimates of air quality, water quality, wildlife and other environmental impacts that could be incorporated into a benefit-cost analysis of these projects. Even when valuation estimates are incorporated into analyses, the estimates themselves are often quite dated. For example, the federal government does regularly incorporate the economic value of externalities in regulatory analysis using in the Air Quality Benefits Assessment Tool (AQBAT) and the Air Quality Valuation Model (AQVM2) but the valuation estimates used in these tools predominately come from studies conducted in the 1980s and 1990s. Facilitating the producers and consumers of these value estimates to work in close collaboration is important to ensure the research is grounded in best practices and remains policy relevant.

5. Conclusion

This paper synthesizes the environmental valuation literature in Canada over the last 6 decades. We derive 269 unique primary valuation studies from 371 research outputs identified in total. Our results show that while the number of Canadian environmental valuation research outputs per year is increasing over time, the annual number of unique valuation studies is not. Canada's valuation efforts peaked during the 1990s for almost all environmental resource categories and geographic areas and exhibited downward trends into the 2010s. The

consequence of the lack of recent studies is that over half of all studies are conducted over 20 years ago. While there is nothing inherently invalid about these older studies, the field has seen advances in best practices for the use of non-market valuation methods (Johnston et al. 2017; Lupi, Phaneuf, and von Haefen 2020; Bishop et al. 2020; Evans and Taylor 2020). Furthermore, people's behaviour, preferences and values change over time as well as the state of the environment (Costa and Kahn 2003). For these reasons, we conclude that updating older, well-used value estimates is important.

One limitation of the analysis is that we do not account for any scope, scale, or quality differences across studies beyond the categories detailed above. Implicitly, we have assumed that each individual valuation study has the same weight which masks many differences in applications. A study that values recreation at one provincial park carries the same weight as a study that values all provincial parks in a province. Similarly, a study that valued one environmental change scenario and a study that valued a dozen also are both counted as one. Some SP studies might use sample sizes less than one hundred while others use samples in the thousands. Furthermore, we do not attempt to assess the underlying quality of the study and to the extent these studies follow best practice guidelines in the literature.

Our results can be compared to existing global analyses of trends in environmental literature (Adamowicz 2004; Petrolia et al. 2020) but there are a couple important caveats to keep in mind with these comparisons. First, both of the existing reviews use all research outputs rather than unique studies. This caveat is important given the conflicting results on time trends between using all research outputs and unique studies found in this analysis. Furthermore, the Petrolia et al. (2000) only examined peer-reviewed articles and included *"any article including one or more of the above keywords, meaning articles that use or merely reference NMV [non-market valuation]".* Thus, they exclude all unpublished research and include benefit transfer studies as well as more conceptual articles that did not necessarily produce a novel benefit estimate. Second, the timeframes of analysis are different and most notably Adamowicz (2004) only examines studies up to 2003. With these caveats in mind, both existing review papers find an increase in non-market valuation research per year which is in contrast to our results using unique valuation studies.

We also find a growing disparity between the use of SP and other non-market valuation methods in Canada. Over half of the studies in our database utilize SP for valuation, and four out of five valuation studies within the last decade use SP methods. Certain RP approaches, such as the HPM and the AEM, have had comparatively little use in Canada. One of the reasons for the relatively small number of RP applications is the lack of easily accessible RP data sets in Canada. Housing transaction data is not generally public in Canada and is expensive to purchase.[7] In contrast, the recent availability of national-scale data on house price data in the United States through firms such as Zillow have allowed researchers to dramatically reduce the cost of accessing data required for hedonic price analyses. Canadian recreation behaviour and expenditure data is also limited and national surveys are intermittent.[8] Adamowicz (2004) find that papers that use hedonic price or travel cost methods have increased although, at a lower rate than the increase in SP papers. Petrolia et al. (2020) report that hedonic price studies are increasing at a rate of around seven per year since 1990. Without access to easily accessible sources of RP data in Canada, valuation practitioners have shown through their choices a clear preference for collecting new SP data rather than RP data. This imbalance highlights not only the need for additional non-market research but also the difficulty in gathering RP data Canada.

The results by environmental resource and region in Canada also reveal substantial differences in what is being valued and where. Wetlands, estuaries, and marine environments are some of the least-valued environmental resources. However, even freshwater – the most-valued resource category – mirrors the lagging data collection trend; over half of these studies draw from data gathered before the turn of the century. Regions with the most absolute valuation work also have few relative studies when accounting for population and landmass. Despite having some of the richest endowments of natural resources in the country, the territories have a particular scarcity of environmental valuation research.

[7] As an example, one provincial provider of housing data in Canada quotes $7 per housing transaction for the full set of structural housing characteristics.

[8] The federal and provincial governments have conducted several national recreation surveys. The first three iterations were dubbed the *Survey on the Importance of Wildlife to Canadians (SIWC)*. Later, it expanded in scope and was renamed the *Survey on the Importance of Nature to Canadians (SINC)*. The most recent version conducted in 2012 was named the Value of Nature to Canadians (VNC) survey.

There are substantial opportunities to expand our understanding of the benefits Canadians receive from nature. While it is hard to make the case that any environmental resource is over studied from, we identify three main cross-cutting research themes that we feel are understudied. First, there is almost no environmental valuation research in Canada that account for the values and preferences of Indigenous people. Economic valuation is only one framework to interpret the human-nature relationship and valuation practitioners have much to learn from Indigenous Peoples and communities about Indigenous ways of knowing and values and how this knowledge can enrich our understanding of people's relationship with nature. This is a largely unexplored research area in Canada, although one exception is Haener et al (2001) who use the TCM to analyze trip decisions of Indigenous hunters. Second, research is needed on valuing specific environmental damage events and incidences such as oil spills. The federal government has recently moved towards assessing environmental fines by the amount of actual damages caused by the incident, but this assessment relies on having primary value estimates to use in the analysis. For example, as part of the National Energy Board's (NEB) assessment of the Enbridge Northern Gateway, the Board mentioned the importance of ecosystem services and the potential for incorporating economic valuation into its assessment. However, the ecosystem service valuation evidence submitted to the NEB panel were mostly estimated using unit transfer and relying on per hectare values. This evidence was rejected by the NEB Panel because these impacts were not well quantified and did not rely on appropriate methods (Pastén, Olszynski, and Hantke-Domas 2018). The lesson is that the courts will consider values for non-market impacts, but the valuation requires rigorous and appropriate methods to generate a useful number instead of just a number. Third, more recent valuation studies are needed on understanding the human health implications of environmental quality changes. This includes both updating specific economic values of mortality risk reductions relevant for air quality as well as newer areas such as the value of mental health improvements from local greenspaces. Human health impacts, and mortality impacts in particular, often constitute over 90% of the monetized benefits of air quality regulations (U.S. Environmental Protection Agency 2011). As previously stated, Canada's health value estimates used in policy tools rely on studies conducted 20 to 35 years ago and updating these numbers is a worthwhile endeavor. The COVID-19

pandemic starting in 2020 has increased the demand for local greenspaces but there are few studies evaluating their economic value to communities.

The economic value of nature in Canada goes far beyond its impact on formal economic metrics such as GDP, tax revenue, and jobs. Environmental resources valuation can play an important role in understanding these non-market benefits and informing the ongoing economy versus environment debate in national discourse. Policymakers often face difficult trade-off decisions surrounding economic development and the environment. Some people in society prioritize stewardship over all else, while others prioritize economic growth. As Baker and Ruting (2014) note, "the former… effectively assigns an infinite value to environmental outcomes, while the latter assigns a value of zero." Somewhere in-between these two extremes is the measurable amount that the non-market valuation methods aim to estimate. Environmental valuation is one approach to meaningfully include the natural environment's full economic value in these important policy decisions.

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Appendix A and Appendix B

(See separate document)