



Beyond the local fishing hole: A preliminary study of pan-regional fishing in southern Ontario (ca. 1000 CE to 1750 CE)

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ABSTRACT

During the Late Woodland period in what is now the Canadian province of Ontario, Indigenous peoples met their nutritional needs through a combination of maize horticulture, gathering, hunting, and fishing. Recent research on stable isotopes in human tissue (Pfeiffer et al. 2016) suggests that the protein component in the diet of one of the groups of Iroquoian-speaking peoples in Ontario varies over time and came in part from high trophic level fish taxa. We present a pilot study that examines similar questions by means of zooarchaeological data from > 100 previously analysed zooarchaeological assemblages using Geographic Information Systems (GIS). Our findings indicate differences in the consumption of fish through time. In addition, we observe patterned variation across the landscape of southern Ontario. In areas close to Lake Ontario, the primary high trophic level fishes exploited were members of the family Salmonidae. By contrast, in the Lake Erie drainage, *Sander* spp., in the family Percidae, makes a greater contribution to zooarchaeological samples. These findings suggest that the Indigenous peoples exploiting these fish sources would have faced different challenges with respect to harvest technology and scheduling.

1. Introduction

For some time, it has been evident to zooarchaeologists working with Woodland period faunal material from what is now the province of Ontario, Canada, that, collectively, we have accumulated a large dataset, but that this has rarely been examined from a perspective of more than one or two sites (for exceptions, see Foreman, 2011; Hamalainen, 1981; Needs-Howarth, 1999; Prevec and Noble, 1983; Smith, 1996; Stewart, 2000). This paper is a first attempt at compiling and examining some of the available data to evaluate them in terms of appropriateness for meta-analysis and to determine if they could be used to tackle “big-picture” questions. Big-data analysis has been successfully applied to raw data and derived measures relating to fish assemblages from the West Coast of Canada (McKechnie and Moss, 2016; Orchard and Clark, 2014; Orchard and Szpak, 2015) and Europe (see references in Barrett and Orton, 2016; Gron and Robson, 2016; Häberle et al., 2015; Orton et al., 2014). Furthermore, while zooarchaeology in Ontario has mainly been concerned with examining foodways (e.g., Foreman, 2011;

Junker-Andersen, 1988; Needs-Howarth, 1999; Stewart, 1999), zooarchaeological data are not the only ones that inform on animal-based subsistence; stable isotope analyses of human and animal tissues, such as bone and dentine collagen, can and have been used to address the same questions (Guiry et al., 2017; Guiry and Buckley, 2018; Katzenberg, 1989; Morris et al., 2016; Pfeiffer et al., 2016; Schwarcz et al., 1985; Tourigny et al., 2016; van der Merwe et al., 2003). There is potential for the combined datasets to be used in a complementary fashion, thus partly overcoming the limitations of each. Building on these existing bodies of work, we employ a meta-analysis approach to address three related questions:

1. Can data from zooarchaeological analysis and from stable isotope analysis of human bone be used in a complementary fashion to better elucidate our understanding of human diet in the Woodland period of Ontario, including variations that occur in time and space?
2. If, as has been suggested by Pfeiffer et al. (2016), high trophic level fish were making an important contribution to the diet, can

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zooarchaeological analysis and stable isotope analysis of fish bone help suggest which fish taxa may have been targeted in different places?

3. How are choices in zooarchaeological analysis methods likely to affect our understanding of the use of Salmonids, high trophic level fish of importance in the study region?

2. Background and context

Zooarchaeological assemblages from village sites in Ontario often include tens of thousands of fragments from a range of contexts and can therefore be considered representative of what has preserved at such sites. Furthermore, it is possible to make relatively precise identifications of most vertebrate taxa in the province from non-destructive analysis of the morphology of their skeletal remains, which allows for reconstruction of a detailed picture of the animals and environments with which humans interacted. The zooarchaeological dataset in Ontario has excellent temporal and spatial coverage for the Late Woodland period (ca. 900–1650 CE). However, in Ontario, as elsewhere, taphonomy is a source of bias in zooarchaeology. The processes that are most problematic in this context, though they are variable across the province, are differential transport, disposal, decomposition, and recovery (for a summary, see [Needs-Howarth and Hawkins, 2017](#)). In addition, an issue for all zooarchaeology is that, even though we have numerous ways of quantifying zooarchaeological assemblages, these methods do not and cannot claim to allow us to establish proportional contributions of different animals to the human diet.

The stable carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotope composition of archaeologically preserved human and animal tissues, such as bone and tooth dentine collagen, can reflect isotopically distinctive foods incorporated into the diet and can therefore provide more direct information about past human nutrition and subsistence practices (for a review, see [Katzenberg, 2008](#)). However, this analysis is destructive and is performed directly on human ancestors, something that is a serious concern for Indigenous groups in the region ([Katzenberg, 2001](#)). For this reason, the dataset of ancestors who have been tested for stable isotope composition is comparatively small (for a description of the protocols involved in such sampling, see [Pfeiffer and Lesage, 2014](#)) and isotopic evidence for past human diet has relatively limited temporal and geographic coverage in comparison with the combined zooarchaeological dataset. In this context, it may be possible to use other species, such as dogs ([Guiry, 2012](#); [Guiry and Grimes, 2013](#)), that would have relied primarily on their human keepers for food, as a proxy for human diet, but use of this method is only in the preliminary stages in this region (although see [Glencross et al., 2018](#); [Morris, 2015](#)).

The region examined in this study encompasses Ontario south of the Canadian Shield ([Fig. 1](#)). There are few sites represented from eastern Ontario, in part because of a relative lack of archaeological investigation in that area compared with the urbanized area farther west. Most of the sites date to the Late Woodland, which in Ontario refers to the period in which many Indigenous peoples practiced maize horticulture, in addition to fishing, hunting, and collecting wild plant foods ([Smith, 1997](#)). The Late Woodland is subdivided into a number of archaeological units, mainly based on attributes of material culture. Some of these units have come to be associated with ethno-linguistic groups that were known to be present in the region at the time of European contact. At that time, much of southern Ontario was occupied by different Iroquoian-speaking peoples, namely the Huron-Wendat, the Tionantaté (also referred to as the Petun), and the Attawandaron (also referred to as the Neutral), while Algonkian-speaking peoples occupied the extreme southwest (the people known as the Fire Nation) and the north (the Chippewa and the Odawa) of what is now the province of Ontario ([Fox, 1990](#); [Jamieson, 1990](#); [Lennox and Fitzgerald, 1990](#); [Murphy and Ferris, 1990](#); [Warrick, 2008](#)). We have not attempted to analyse the data with respect to different ethno-linguistic groups or archaeological culture-historical units; instead, we have categorised the sites based on

their estimated age and their location.

Recent work published by [Pfeiffer et al. \(2016\)](#) examines the diet of peoples living in the central part of southern Ontario using stable isotope analysis of collagen from human tooth dentine and bone ([Figs. 1 and 2](#)). The samples analysed were obtained from Huron-Wendat sites from the 17th century and from earlier sites also attributed to the Huron-Wendat based on the interment of ancestors in ossuaries, something that is part of the Huron-Wendat cultural tradition ([Warrick, 2008](#); [Williamson and Steiss, 2013](#)). The study, based on analysis of samples from the sites indicated in [Fig. 1](#), shows that “more positive $\delta^{15}\text{N}$ values occur in the fourteenth and seventeenth centuries, when sites were located near Lake Ontario and Georgian Bay, respectively. The isotope values may reflect greater access to fish at those times” ([Pfeiffer et al., 2016: 522](#)). Here, we test if this statement is supported by faunal data.

A wide range of fish taxa were used by Indigenous peoples in Ontario in the past, as demonstrated by faunal samples (e.g., [Needs-Howarth, 1999](#); [Smith, 1996](#); [Stewart, 1999](#)) and ethnohistory ([Tooker, 1964](#)). The most numerically important groups of fish recovered from archaeological sites are typically (roughly in order of numerical importance): percids (Percidae), suckers (Catostomidae), catfishes (Ictaluridae), salmonids (Salmonidae), temperate bass family (Centrarchidae) and pike family (Esocidae). While the relative contribution of these families varies based on recovery methods, the taxonomic representation remains the same regardless of the screen mesh size used to obtain samples, with the exception of taxa represented exclusively by items that are smaller than the mesh aperture in at least one dimension.

Extensive isotopic research on tissues from ancient and modern fish from regional watersheds has yielded considerable insight into the structure of local aquatic food webs, demonstrating a wide range of $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values corresponding with species' trophic levels and preference for near-shore or offshore habitats ([Brush et al., 2012](#); [Colborne et al., 2016](#); [Fera et al., 2015](#); [Katzenberg, 1989](#); [Kiriluk et al., 1995](#); [Lumb and Johnson, 2012](#); [Pfeiffer et al., 2016](#); [Rush et al., 2012](#); [van der Merwe et al., 2003](#); [Yuille et al., 2012, 2015](#); [Zhang et al., 2012](#)). In this context, as noted by [van der Merwe et al. \(2003\)](#) and [Pfeiffer et al. \(2016\)](#), the relatively high $\delta^{15}\text{N}$ values observed in human bone dating to the 14th and 17th centuries may reflect greater reliance on specific higher trophic level fish taxa. To explore these authors' hypothesis while at the same time achieving a scope suited to a pilot study, we investigated a narrow range of higher trophic level taxa, namely, Atlantic salmon (*Salmo salar*), lake trout (*Salvelinus namaycush*), and whitefishes (*Coregonus* spp.), all in the family Salmonidae, as well as walleye or sauger (*Sander* spp.), in the family Percidae. Although these fish taxa inhabit different environments along the near-shore–offshore continuum, due to restricted spatial distribution of littoral taxa among archaeological assemblages, we could not use the current zooarchaeological meta-analysis to provide an independent line of evidence for evaluating whether or not variation in human $\delta^{13}\text{C}$ may relate, in part, to consumption of different kinds of fish.¹

Walleye and sauger spawn in the spring (early April), at night, in gravel or rubble environments in large, shallow, turbid lakes or slow-flowing rivers ([Scott and Crossman, 1973](#)). They occur in the Great Lakes and in the inland waterbodies throughout the study area, and there is no indication that their distribution would have been different

¹ Feeding ecology is an important source of variation in the $\delta^{13}\text{C}$ values of fish that contributed to past human diet. In particular, fish that foraged for food in near-shore (littoral; higher $\delta^{13}\text{C}$ values) or offshore (pelagic and profundal; lower $\delta^{13}\text{C}$ values) environments should show distinct $\delta^{13}\text{C}$ values because primary producers (phytoplankton and algae) contributing to the base of food webs in these environments are known to have differing stable carbon isotope compositions ([France, 1995](#)). For this reason, a primary axis along which fish $\delta^{13}\text{C}$ values in the Lake Ontario watershed vary will be the environmental conditions preferred by a particular species (e.g., [Colborne et al., 2016](#); [Yuille et al., 2015](#); [Zhang et al., 2012](#)).

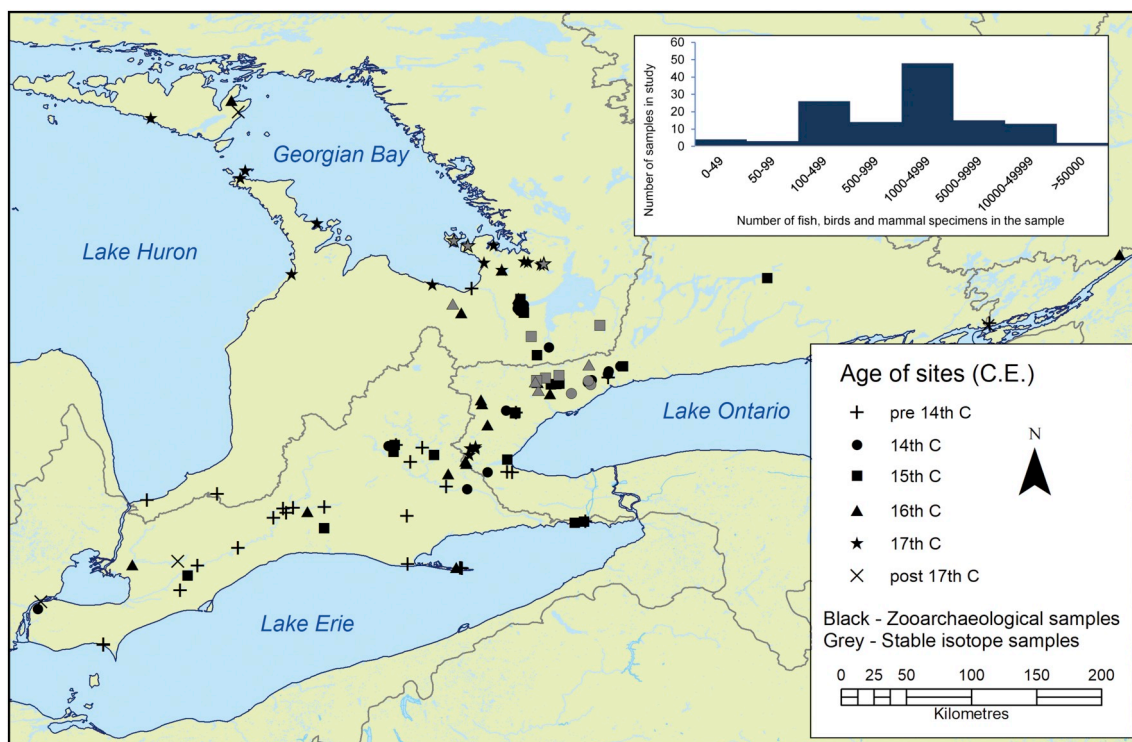


Fig. 1. Locations and dates of zooarchaeological samples and human stable isotope samples discussed in the text. Map data from ESRI, Government of Canada, and Government of Ontario; stable isotope sample locations and dates from Pfeiffer et al. (2016). Grey lines demarcate drainage basins of the different Great Lakes.

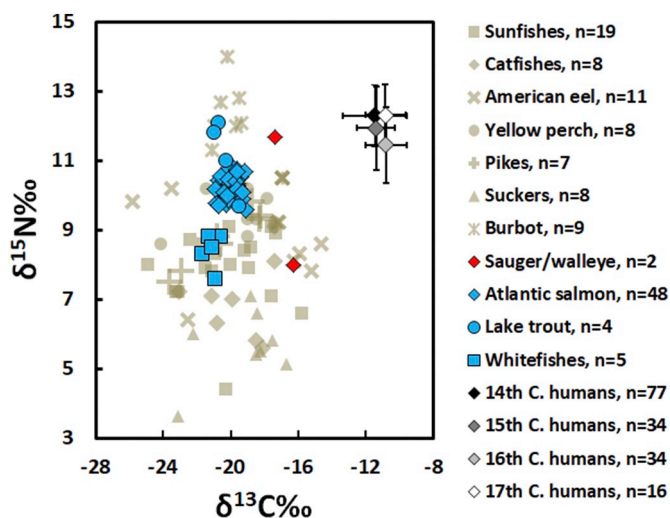


Fig. 2. Human ($n=163$) $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ from previously published studies (Katzenberg, 2006; Pfeiffer et al., 2014; van der Merwe et al., 2003); Fish ($n=129$) from previously published studies (Guiry et al., 2016; Katzenberg, 2006; Pfeiffer et al., 2016; van der Merwe et al., 2003).

Fish data are colour-coded by relevance to this study: Salmonidae are blue, *Sander* are red, and all other taxa are green. Human data are shown as mean values per century (error bars 1σ). For the calculation of mean human $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$, where stable isotope values from both dentine and bone are available, bone data were used, and where multiple stable isotope values are available from the same tooth, an average of these values was used. Note that original raw data from the McKenzie-Woodbridge site described in Pfeiffer et al. 2016 Table 2 (therein cited as being from Van der Merwe et al., 2003) were not locatable. Following Pfeiffer et al. 2016, values for two deciduous teeth, from Damiani (UCT 13706) and Hidden Spring (UCT 13702), were excluded. For fish, $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ from related species were grouped as follows: sunfishes (refers here to the genera *Ambloplites*, *Micropterus*, *Pomoxis*, and *Lepomis*); catfishes (refers here to the genera *Ameiurus* and *Ictalurus*); suckers (refers here to the genus *Catostomus*); whitefishes (refers here to the genus *Coregonus*).

in the time range examined in this study (Holm et al., 2009). They can be caught through the ice; however, as noted by Needs-Howarth and MacDonald (2012), “they would be most efficiently caught with nets during their spawning run, as part of a targeted spring spawning run fishery”, referencing one of the three fisheries proposed by Needs-Howarth and Thomas (1998). In today’s commercial fishery, walleye are caught with gillnets, but Prowse (2008:76) has argued that seine nets were used to capture the walleye at the Bluewater Bridge South site (140–660 C.E.), on the St. Clair River, near the border with Michigan.²

The Salmonidae in Ontario are all fall spawning, but the timing and location of their spawning run differs slightly. Atlantic salmon were a “landlocked” population in Ontario (Guiry et al., 2016), which was restricted to Lake Ontario and extirpated in the 1890s. They “typically spawned in the fall, although spawning migrations up tributary streams may occur anytime from spring to fall [and] some males may remain in the river all winter” (Holm et al., 2009: 283). Their spawning period was longer than that of the other Salmonidae, ranging from the end of September all the way through October. The other large salmonids examined in this study are found in all of the Great Lakes, but not in the inland waterbodies (Holm et al., 2009).³ Lake trout (*Salvelinus namaycush*) spend all their time in the lake and spawn along the open shoreline throughout October. The Great Lakes used to have as many as eight species of *Coregonus*, which also spend all their lives in the lake and spawn in the lake shallows (Holm et al., 2009). Of the two species still present in Lake Ontario today, cisco (*C. artedii*) spawns during the first half of November, whereas lake whitefish (*C. clupeaformis*) spawns

² Osteometrics by Needs-Howarth and MacDonald on the *Sander* spp. from the Peace Bridge site, on the Lake Erie end of the Niagara River, “suggest some kind of size-selective netting gear” (Needs-Howarth and MacDonald, 2012: 89), but the authors argue that, due to recovery bias, small sample size, and lack of comparative data, they cannot determine what kind of gear was used.

³ Brook trout (*Salvelinus fontinalis*) are found in inland waterways in southern Ontario, but as below, most of the *Salvelinus* spp. identifications in the datasets examined are likely to be Lake trout (*Salvelinus namaycush*).

throughout November. *Salvelinus namaycush* and *Coregonus* can be caught through the ice, but, like *Sander*, they would be most efficiently caught during their spawning time, with gillnets.

3. Material and methods

For the purposes of this project, we examined reports on previously analysed assemblages, retrieving from them general information on the age and cultural affiliation of the site, the site type, the recovery methods used by the excavator, the nature of the excavation, the purpose of the analysis (contract or research), and the site location. The faunal data that we collated from these reports include sample size, number of fragments by class, and number of vertebral and non-vertebral elements of three salmonid taxa (*Salmo salar*, *Salvelinus* spp., and *Coregonus* spp.) and one genus of percid (*Sander* spp.). There are few *Salvelinus fontinalis* (brook trout) identifications in the datasets we examined and many *Salvelinus namaycush* identifications, and these two species are not known to hybridize. It is therefore assumed that most of the (limited number of) *Salvelinus* spp. identifications are likely to be *Salvelinus namaycush*. Because the species within the genera *Coregonus* and *Sander* do hybridize and are difficult to distinguish osteologically, and because, in the case of *Coregonus*, none of the reference collections used in the original analyses have the full suite of species, identifications in these genera are mostly at the genus level.

While we estimate that in excess of a thousand analyses on Ontario materials have been completed, the number of datasets examined here is much smaller. Two groups of analyses were intentionally excluded from this pilot project. We excluded analyses carried out as part of a faunal class coursework, because research shows that identifications by inexperienced analysts may be unreliable (Driver, 1991; Gobalet, 2001; Hawkins, 2017; Hawkins and Needs-Howarth, 2017; Lau and Kansa, 2018; Nims and Butler, 2017; Wolverton, 2013), and we excluded analyses that did not identify fish vertebrae below the taxonomic level of class, because previous research involving the taxa typically found on Ontario sites demonstrates that leaving out the vertebrae leads to certain fish taxa being underrepresented in datasets (Needs-Howarth and Hawkins, 2014). Unfortunately, until the mid-1990s, with some exceptions, there was a tendency in Ontario zooarchaeology to not identify fish vertebrae.

We relied heavily on the analyses undertaken by Rosemary Prevec, who was the most prolific consultant zooarchaeologist working in Ontario in the 1980s and 1990s and who always identified fish vertebrae below class where she could. To this we added our own analyses and published ones meeting the criteria stated above. In total, 106 sites contributed data (Fig. 1), for a total of 136 samples (Supplements, Table 1). The number of samples exceeds the number of sites because some sites are multicomponent and because in some cases multiple samples were obtained from a site using different recovery methods (e.g., flotation versus dry screening on 6.4 mm mesh) and the data from the different samples have been reported separately. It is likely that there are many more analyses fitting our criteria buried in compliance archaeology reports, theses, and dissertations. These were not intentionally excluded, but for this project, we have made no effort to obtain them. Of the final total of 136 samples, zooarchaeological analysis was carried out in 104 cases by contract analysts, 20 by academics, 5 by advanced students, 2 by a combination of students and CRM contractors, and 5 by analysts of indeterminate background.

The majority ($n = 95$) of the samples were recovered during cultural resource management (CRM) projects carried out ahead of development, in compliance with Ontario heritage legislation first enacted in 1975. The remaining samples include 36 recovered by research projects or field schools and 5 that have an unknown project context. Most of the zooarchaeological material was obtained using the 6.4 mm mesh aperture that is the current minimum standard for recovery (see Ministry of Tourism and Culture, 2011). In 25 cases, samples were recovered using both fine screening methods (here defined as ≤ 3.2 mm,

including flotation) and 6.4 mm dry screening, and in at least 12 cases, the fractions were reported separately. Of the 10 sites with complete data separated by fraction for which we had access to all the data fields examined, we compared the proportion of fish in the total fish, bird, and mammal component of the faunal assemblages between the samples recovered through coarse screening and those recovered through fine screening. The difference between these is significant, with the average proportion of fish being higher for the samples collected on fine mesh.⁴ We know from previous research (Hawkins et al., 2015) that 6.4 mm mesh recovery produces bias within the fish assemblage as well. For comparability purposes, for our examination of the proportion of fish in assemblages, we relied on samples coming from coarse (i.e. 6.4 mm mesh) screening. However, we did include these fine screening samples in our analysis of the presence of different fish taxa across southern Ontario Woodland sites. Table 1 outlines the different recovery methods and how samples were used in this analysis.

There is reasonable data quality on the estimated age and cultural affiliation of sites, although the labels used to describe cultural affiliation are quite variable, with some reports using archaeological cultural historical labels (e.g., Princess Point, Middleport) and others using ethno-linguistic groupings (e.g., Odawa, Iroquoian, Wendat). For the purposes of this paper, we have assigned a century of occupation based on information found in the reports and elsewhere. In Late Woodland southern Ontario, most village sites were occupied for a period of 10–30 years before abandonment (Warrick, 2008), so we argue that binning sites by century of occupation should not be problematic.⁵ Fig. 1 shows the distribution of samples examined and their ages.

The information on the nature of sites is less good, because in many cases, while we had access to the faunal reports, we did not have or did not seek access to the full site reports. Most of the samples included come from habitation sites of different sizes (village = 69, camp = 16, village/camp = 1, hamlet = 2, cabin = 1). A single site is designated as special purpose, but the purpose is not stated. Some of the sites that have been designated as “camp” may have been oriented around particular tasks. We did not include any zooarchaeological samples that come from burial contexts.

Sample sizes range considerably (Table 2, Fig. 1), arising from differences in the extent of excavations, the recovery methods used, the size of sites, and preservation conditions, as well as a myriad of other factors. To account for this variability, we examined the contribution of fish as a percentage of the combined total of fish, bird, and mammal specimens recovered. Because the numbers for Mollusca (mostly bivalve shell), Amphibia, and Reptilia (mostly turtle carapace and plastron) are highly variable and usually form only a minor component of the total NISP, and because some of these items may be intrusive to the archaeological deposits, we used the combined fish, bird, and mammal sample (that is, including identifications to the taxonomic level of class) as a baseline. We examined the contributions of different fish taxa (Salmonidae vs. *Sander* spp.) as proportions of the fish remains identified below the taxonomic level of class. Fig. 1 demonstrates that most of the samples have > 500 specimens in the fish, bird, and mammal group and only 7 samples have fewer than 100 specimens. We argue that, while these 7 samples may not be representative, in the context of a meta-data analysis such as this, a few small samples do not significantly change the general spatial and temporal patterns observed.

The final set of faunal taxonomic abundance data for 136 samples

⁴ One-way ANOVA, p -value = 0.0242.

⁵ A recent publication by Manning et al. (2018) suggests that the accepted ages for contact-period Iroquoian sites on the north shore of Lake Ontario may be too old. However, as that publication deals with only one river drainage, and as the ages of sites in other drainages have not yet been re-evaluated, for the purposes of this analysis, we have elected to use the traditional age assignment for all sites on the north shore of Lake Ontario.

Table 1

Recovery method(s) for samples included in analysis and explanation of how samples were used in different aspects of the analysis. Fine screening is here defined as screening on ≤ 3.2 mm mesh, including flotation.

Sample recovery method(s)	Number of samples (number of sites in parentheses)	Comparison of proportion of fish in overall assemblage	Examination of specific fish taxa	Examination of element types
Hand collecting	12 (10)	Included	Included	Included
Hand collecting + 6.4 mm mesh screening	37 (37)	Included	Included	Included
6.4 mm mesh screening + fine screening, subsamples separated in reporting	23 (14)	Not included	Combined with data from 6.4 mm mesh screening	Combined with data from 6.4 mm mesh screening
Hand collecting + 6.4 mm mesh screening, subsamples combined in reporting	29 (27)	Included	Included	Included
Fine screening	16 (14)	Included	Included	Included
Recovery indeterminate	17 (14)	Included	Included	Included

Table 2

Range in size of samples included. Data available varied, explaining why the number of samples is not equal for the different measures.

	Number of specimens in sample from all zoological classes	Number of fish, bird, mammal specimens in sample	Number of fish, bird, mammal specimens identified below class in sample
Minimum	23	23	18
Maximum	69,544	68,217	17,405
Average	6204	5456	1581
Standard deviation	12,210	11,001	2908
Number of samples	100	125	96

from 106 sites was entered into ArcGIS, a Geographic Information System (GIS), along with data on the locations and age assignments of the sites under consideration. The results discussed below were obtained by utilizing the ability of the GIS to include a spatial dimension in the examination of different variables of the zooarchaeological assemblages. For the purposes of this study, the display properties of the GIS are sufficient to demonstrate the points we elaborate, and we have not undertaken spatial statistical analysis.

4. Results and discussion

The compiled faunal data from southern Ontario, when considered with respect to geographic and temporal trends and previously published human and faunal isotope data, provide results relevant to the three related research questions identified above. We address each of these questions in turn.

4.1. Variation in the proportion of fish in the diet: faunal samples and human stable isotope data

To examine potential change in fish consumption by Wendat ancestors over time, we plotted the percent of fish specimens of the total fish, bird, and mammal specimens on a series of maps. Pfeiffer et al. (2016) suggest that stable isotope analysis of human bone indicates a higher contribution of fish to human diet in the 14th and 17th centuries compared with the 15th and 16th centuries. We therefore separated sites by century, and focussed on the region of Ontario where the samples for the Pfeiffer study originated (Fig. 3). Note that we do not (yet) have good faunal coverage for some of the areas that the human ancestors come from and that the reverse is also true. The most noteworthy aspect of these maps is that for the more recent periods the stable isotope data and the faunal data show remarkable concordance. In the 17th century, when the Wendat ancestors tested lived in the Penetang peninsula, at the south end of Georgian Bay, human $\delta^{15}\text{N}$ values are relatively high, leading Pfeiffer et al. (2016) to suggest that fish consumption was elevated at this time. The faunal data compiled here support this argument, with fish making up a very large proportion of the combined fish, bird, and mammal specimens from all 17th century sites in that area. We see that, in the 16th century, when some Wendat ancestors still lived on the north shore of Lake Ontario, the faunal samples are remarkably low in fish remains along the north shore. These findings echo evidence from coeval human $\delta^{15}\text{N}$ values, interpreted as evidence for low

consumption of fish, which are on average also the lowest for the four centuries presented by Pfeiffer et al. (2016:525). While there are archaeological sites in the Penetang peninsula with high proportions of fish remains in the 16th century, none of the human samples analysed by Pfeiffer et al. come from this location. In the 15th century, the sites on the north shore have higher proportions of fish compared with the 16th century, but of the sites close to the locations sampled for stable isotope analysis, most are relatively low in fish (21–40%). By contrast, in the 14th century, the sites close to those sampled for stable isotope analysis have higher values (41–80%).

Overall, the maps show two important patterns that bear consideration in terms of other cultural changes occurring in southern Ontario. First, through the 14th and 15th centuries, fish appear to make some contribution to the diet of people living on the north shore of Lake Ontario, but by the 16th century this contribution has been essentially eliminated and mammalian taxa comprise the vast majority of faunal specimens from these sites. The stable isotope data, particularly from the 16th century, support the idea that this is not simply a matter of changes in disposal patterns, wherein fish were still consumed but prepared and disposed of off-site. Rather, this does appear to reflect a change in diet, and therefore in landscape use.

Why did this occur, and what impact did it have on the species present in the region? While our data do not speak directly to causality, we can offer some preliminary hypotheses in the context of other, related archaeological research in the area. As indicated previously, the Late Woodland period in southern Ontario is characterized by a settlement pattern wherein village sites were typically occupied for 10 to 30 years before abandonment (Warrick, 2008). On the north shore of Lake Ontario, during the 14th through 16th centuries, this resulted in occupation sequences that generally saw progressive movement of populations up drainage systems, farther and farther from the shore of the lake (Birch and Williamson, 2013; Williamson, 2014). Concurrent with these changing settlement patterns was the coalescence of smaller villages into larger villages (Birch, 2012; Williamson, 2014). While there is, as yet, no direct evidence for a connection between this broader societal change and subsistence practices, it may be that progressive movement away from the shore of Lake Ontario would have limited access to the productive fisheries of the lake. The coalescence of the populations of different villages into increasingly larger communities may have also meant that local fish resources could no longer support a significant portion of the subsistence needs of these larger villages.

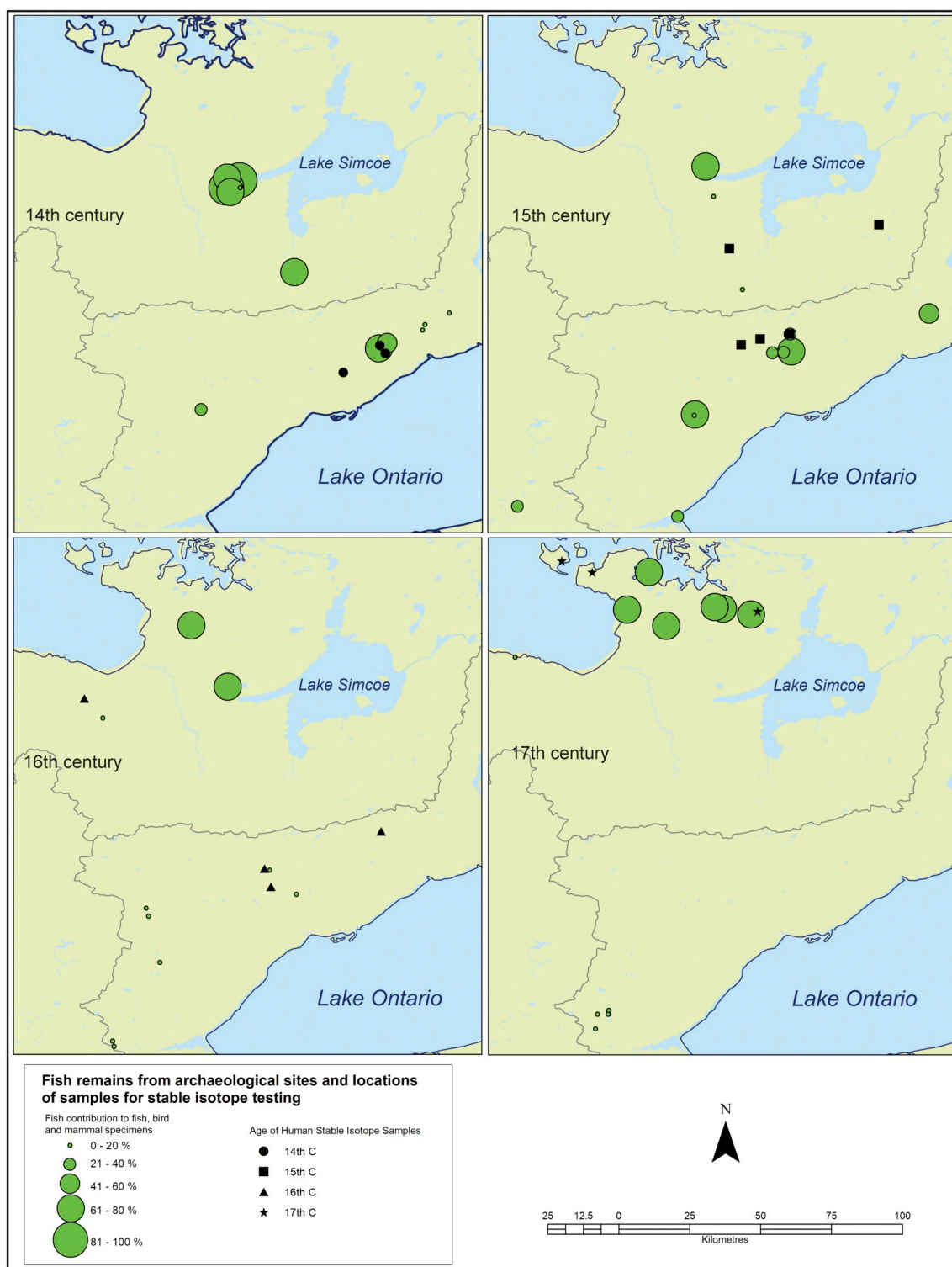


Fig. 3. Comparison over time of the proportion of fish of the total fish, bird, and mammal specimens in zooarchaeological samples, with the location of human samples of different ages analysed for stable isotopes also indicated. Map data from ESRI, Government of Canada, and Government of Ontario; stable isotope sample locations and dates from Pfeiffer et al. (2016). Grey lines demarcate drainage basins of the different Great Lakes.

Needs-Howarth and Williamson (2010) compiled class-level faunal data from all seven Iroquoian sites in the Duffins Creek drainage that have faunal data available and found that the contribution of mammal⁶ (as a

proportion of the combined fish, bird, and mammal counts) increases abruptly at Draper and Jean-Baptiste Lainé⁷ compared with the five sites that pre-date them. They also noted that at Jean-Baptiste Lainé, the inhabitants seemed to be focussing on mass capture of fish that

⁶ We acknowledge that the mammal counts in particular can encompass a lot of variation in body size and hence adhering meat.

⁷ In earlier published literature, this site is known as the Mantle site.

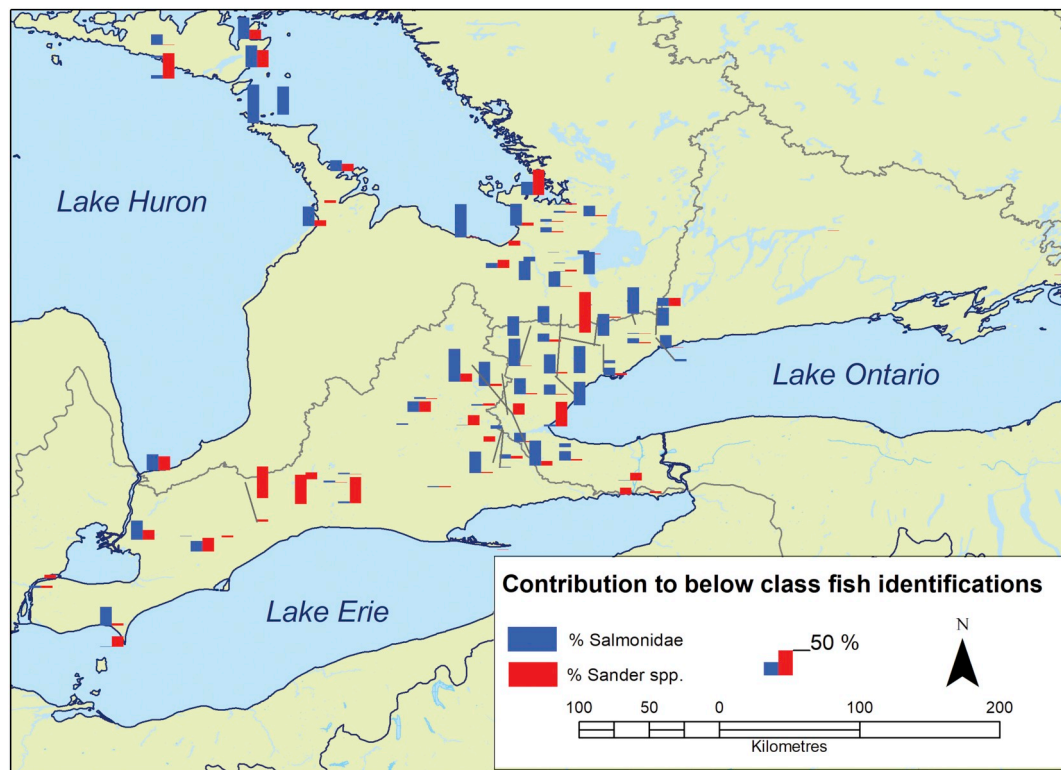


Fig. 4. Proportion of Salmonidae and *Sander* spp. of the below-class fish identifications from sites dating to before the 14th century CE to the 18th century. Map data from ESRI, Government of Canada, and Government of Ontario. Grey lines demarcate drainage basins of the different Great Lakes.

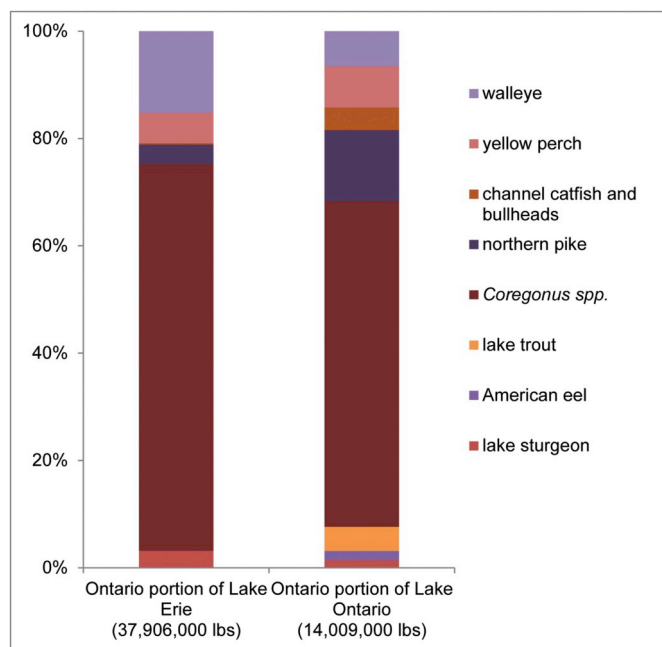


Fig. 5. Comparison of commercial fishery catch data from the Ontario portions of Lake Ontario and Lake Erie, 1895–1899. Data from Baldwin et al. (2009).

could be smoked and stored for winter, namely, salmonids. The fish data for Draper are incomplete, so we cannot assess whether the same thing was happening there. Clarification of these issues will require further research.

The second important pattern evident in the maps in Fig. 3 involves the consistent abundance of fish in sites in the Penetang peninsula and western Lake Simcoe areas in all of the periods examined. This matches

well with Pfeiffer et al.'s (2016) argument that fish consumption was again high in the 17th century, particularly given that all of their 17th century samples come from this region. It is problematic to make conclusive interpretations from these patterns given that we do not have complete spatial coverage for either zooarchaeological data or human isotopic data. However, archaeologists argue that Huron-Wendat ancestors living on the north shore of Lake Ontario moved to join other Huron-Wendat already resident in the Penetang peninsula during this period (Williamson, 2014), following the 14th to 16th century settlement patterns on the north shore of Lake Ontario outlined above. Both the faunal data and the stable isotope data indicate the importance of fish in the diet of people living in the Penetang peninsula during the 17th century. New immigrants to the area, then, appear to have shifted not only in terms of geography, but also in terms of subsistence, moving from a region where fish had come to play a relatively minor role to an area where fish were again dominant among faunal resources exploited. This suggests that social and technological changes must have accompanied the move from the north shore.

4.2. Geographic distribution and proportions of high trophic level fish

As outlined above, walleye and sauger (*Sander* spp.) have different life cycles and preferred habitats relative to lake trout, Atlantic salmon, and whitefishes. This has implications for the timing and method of fishing that would have been used to obtain these different species. We therefore began our examination of the different contribution of high trophic level fish by examining whether there is variation in the representation of these taxa across the study area. As shown in Fig. 4, there is clear spatial variation in the relative contribution of *Sander* spp. versus salmonids. With a few exceptions, the high trophic level fish in assemblages from the north shore of Lake Ontario are salmonids. The same is generally true for sites around Georgian Bay and on the Bruce Peninsula (which juts out between Georgian Bay and Lake Huron). The high trophic level fish in assemblages from sites close to Lake Erie and

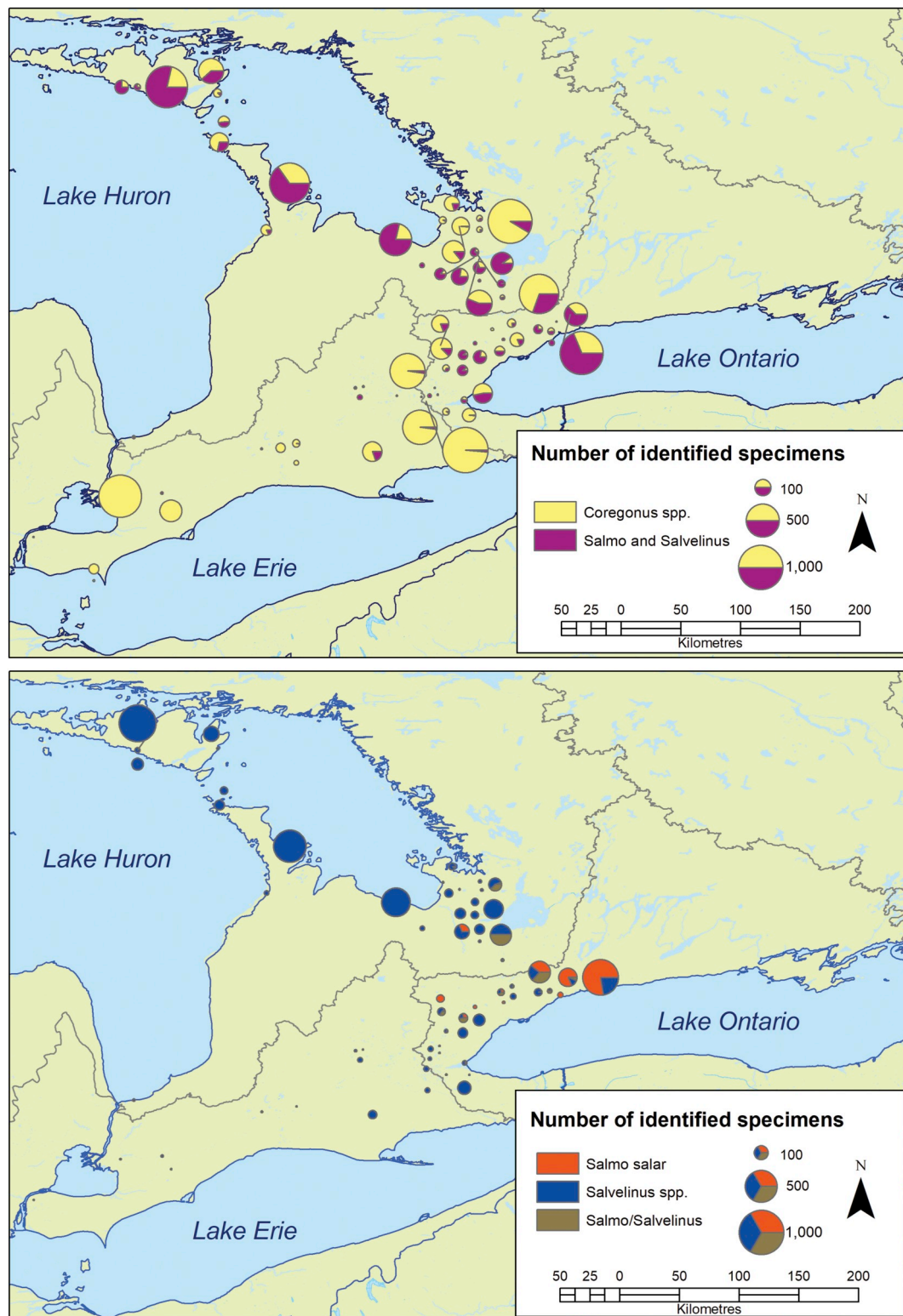


Fig. 6. Number of identified specimens of (a) *Coregonus* spp. and other salmonid taxa and (b) *Salvelinus* spp., *Salmo salar*, and undistinguished *Salmo salar* and *Salvelinus* spp. from sites dating to before the 14th century CE to the 18th century. Map data from ESRI, Government of Canada, and Government of Ontario. Grey lines demarcate drainage basins of the different Great Lakes.

its watershed, in contrast, are predominately *Sander* spp. We note, however, that our sample of sites from that region is smaller, and we reiterate that our geographical coverage may not be representative.

We suggest, based on the patterning evident in our maps, that the higher human $\delta^{15}\text{N}$ observed by Pfeiffer et al. (2016) reflects

consumption of Salmonidae rather than *Sander*. Because Salmonidae (offshore; lower $\delta^{13}\text{C}$) and *Sander* (near shore; higher $\delta^{13}\text{C}$) prefer habitats on different parts of the offshore–near shore continuum, this distinction should also be detectable through stable carbon isotope analyses. Future studies could test this hypothesis by comparing human



Fig. 7. Historically known Atlantic salmon spawning creeks on Lake Ontario and the location of, and number of identified Atlantic salmon specimens from, Ontario Woodland period sites with Atlantic salmon bones. Map data from ESRI and Government of Ontario; spawning creek data from the [Atlantic Salmon Federation \(2017\)](#).

$\delta^{13}\text{C}$ between the Lake Erie, Lake Ontario, and Lake Huron drainages.

The *Sander* results fit well with data from commercial harvests from the late 19th century (Baldwin et al., 2009),⁸ although we acknowledge that this may be a result of equifinality. While the commercial harvest from both lakes is dominated by whitefishes, there is a considerably higher walleye catch from Lake Erie than from Lake Ontario (Fig. 5).⁹ A focus on *Sander* rather than salmonids during the Late Woodland period may relate to the availability of the different species across southern Ontario, so it cannot be considered strictly related to different cultural preferences. However, at the same time it is important to recognize that exploitation of these two taxa would have required different scheduling and technologies.

In order to refine our understanding of which salmonids were of particular importance across the region, we grouped the salmonids into three categories: Atlantic salmon (*Salmo salar*), trout (*Salvelinus* spp., which, as noted, are likely mostly lake trout), and whitefishes (*Coregonus* spp.). It should be noted that whitefishes feed at a slightly lower trophic level than the other salmonids and that this is reflected in their $\delta^{15}\text{N}$ values (Guiry et al., 2016; Pfeiffer et al., 2016).

Fig. 6(a) shows the distribution of salmonid finds across southern Ontario. The variation in the number of salmonid finds is related, in part, to the variation in sample size across the province. This graphic demonstrates that the lower trophic level whitefishes are frequently more numerically important contributors to the salmonid portion of the fish assemblage than are *Salvelinus* and *Salmo*. The average NISP for *Coregonus* is higher ($\bar{x} = 83$) than that for *Salvelinus* and *Salmo salar* combined ($\bar{x} = 42$). Further, when we look at sites individually, we see that more sites have a higher *Coregonus* NISP ($n = 44$) than have a higher *Salmo* and *Salvelinus* NISP ($n = 34$). When considering these fish in terms of contribution to $\delta^{15}\text{N}$ values, it is worth noting that they vary in average maximum body size, with *Coregonus* being the smallest and *Salmo salar* being the largest.

Fig. 6(b) focuses on the highest trophic level salmonids, *Salvelinus* and *Salmo salar*. In some cases, analysts did not distinguish between these genera, and such higher level taxonomic identifications (i.e.,

Salmo/Salvelinus) are included to demonstrate the overall contribution of these two taxonomic groups. A few things are of note here. First, there are almost no non-*Coregonus* salmonid bones in the faunal assemblages from the Lake Erie drainage basin. Once again, the commercial fishery data is informative (Baldwin et al., 2009): lake trout, while present in Lake Erie (Scott and Crossman, 1973:221), did not form part of the commercial fishery there until after 1979, and then in only incidentally and in small amounts (Baldwin et al., 2009). Fig. 6(b) also shows that the distribution of *Salmo salar* is limited to the north shore of Lake Ontario, which matches what we know of its biogeography.

A closer examination of the distribution of Atlantic salmon remains shows that they only occur along a restricted section of Lake Ontario (Fig. 7). This is possibly explained by the location of historically known Atlantic salmon spawning creeks. Research conducted prior to recent re-introduction efforts has shown that in the 19th century, Atlantic salmon did not use any of the creeks flowing into the southwestern portion of the lake (Atlantic Salmon Federation, 2017), between Twelve Mile Creek and Grindstone Creek, or any of the creeks on the north shore east of the Salmon River. The spatial distribution of our collated data suggests that for this species it is probable that fishing was occurring in spawning creeks, rather than lake waters. This is not surprising: Spawning creeks would have been more predictable, more convenient, and less dangerous locations to fish.¹⁰ Note, however, that our coverage of the Niagara peninsula, which was occupied by Attawandaron people in the 16th and 17th centuries, is poor and that the issue of Atlantic salmon spatial distribution definitely warrants more investigation.

4.3. Preservation and identification of salmonid remains

The final question that we considered in this study was whether we could make any general observations relating to the preservation, recovery, and identification of Salmonid remains that might help others interpret their results. We know from research on a limited number of sites that the MNI from Salmonidae vertebrae can exceed that of cranial bones (Needs-Howarth and Hawkins, 2014). The poor preservation of salmonid remains, particularly cranial bones, has been observed by other researchers (Butler and Chatters, 1994; Lubinski, 1996; Thomas,

⁸ By the late 19th century, both lakes had seen decades of commercial fishing, and the composition of the fish fauna in Lake Ontario had changed following the establishment of alewife (*Alosa pseudoharengus*) earlier in the 19th century. In addition, neither the zooarchaeological assemblages nor the fish catches need necessarily reflect biomass abundance directly. Furthermore, commercial fishers had the ability, because of their watercraft and their gear, to target certain species in response to market demand.

⁹ The year 1895 is the earliest for which the records appear to show a wide range of taxa harvested instead of a select few taxa. We therefore suspect that the records are more complete starting in 1895. We chose a narrow time slice to capture the composition as early in time as was feasible. We assume that “herring” means lake herring/cisco (*Coregonus artedii*) and have included it under *Coregonus*.

¹⁰ According to Lizars (1913:126), a report to parliament from 1869 describes men using clubs and pitchforks to catch them, and “women seined them with flannel petticoats.” Likewise, Bogue (2000: 20–21) notes that “...on both the northern and southern shores of Lake Ontario, spawners swarmed up rivers and creeks in such numbers that settlers could catch them without fishing gear. The Superintendent of Fisheries for Upper Canada stated in a report written in 1859: ‘I have seen them from 1812 to 1815, swarming the rivers so thickly, that they were thrown out with a shovel, and even with the hand.’”

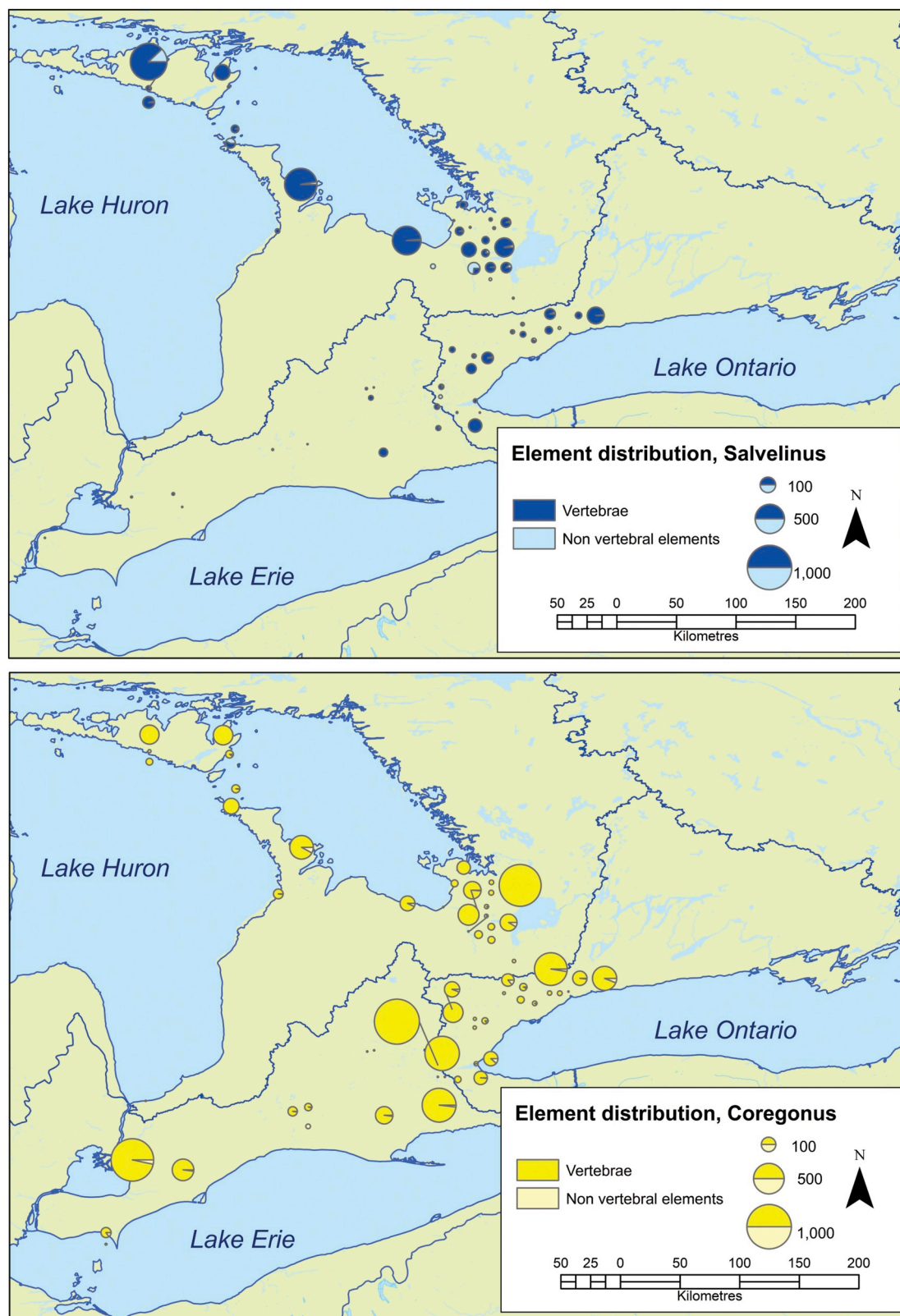


Fig. 8. Number of vertebral and non-vertebral elements identified of (a) *Salvelinus* spp. and (b) *Coregonus* spp. Map data from ESRI, Government of Canada, and Government of Ontario. Grey lines demarcate drainage basins of the different Great Lakes.

1996).¹¹ In this research, we wanted to determine a) if the NISP of vertebral elements outnumbers non-vertebral elements, as we had observed in previous research and b) if there were differences between salmonid taxa in such representation.

In our samples, it appears that for both of the salmonid taxa with widespread distribution across the province (*Salvelinus* and *Coregonus*), vertebral identifications far outnumber non-vertebral identifications (Fig. 8). The two taxonomic groups appear to be affected similarly by factors that contribute to the non-identification of cranial elements, including, perhaps, poor preservation, different disposal trajectories, and/or recovery methods. Slightly > 17% of sites with *Salvelinus* remains (i.e., 11 of 63 sites) had no cranial elements recovered; similarly, approximately 19% of sites with *Coregonus* remains (i.e. 13 of 67 sites) were also represented only by vertebrae. While there is variation, it is sobering to note that sites with hundreds of salmonid vertebrae identifications may have no identifications of cranial elements. In other words, the tendency to not identify vertebral elements of fish would have had a significant impact on our ability to determine even the presence or absence of these fish taxa. Importantly, others have also noted the effects of differential analytical treatment of fish vertebrae on meta-analysis results in other contexts (Orton et al., 2014). The relative contributions of differential preservation, disposal patterns, and recovery to the different presence of vertebrae versus non-vertebral elements remains unexplored at this time. Future big-data projects that focus on different site functions may be able to clarify this; however, at this time, the most significant take-away is the necessity of including fish vertebrae in standard identifications.

5. Conclusions

This project focussed on a few aspects of a subset of a much larger and as-yet untapped data source. This paper demonstrates the potential for data from cultural resource management (CRM) projects to contribute to the examination of large-scale research questions. Considering the three research questions posed at the beginning of this paper, we can respond that meta-analysis of zooarchaeological remains clearly has the potential to complement information from stable isotope analysis of human tissue. As we have demonstrated here, archaeological data support the finding from previous human isotopic analysis that Wendat ancestors consumed more fish in the 17th century and less in the 15th and, especially, 16th centuries.

We are also, through zooarchaeology, able to answer our second question and specify the taxa of high trophic level fishes that contributed to higher $\delta^{15}\text{N}$ values in humans. With respect to Wendat ancestors living near Lake Ontario, this was likely mainly salmonid taxa. We have also observed that some of the variation that is noted in zooarchaeological assemblages likely arose because of different availability of fish. This suggests that, for the most part, fishing was something that occurred close to settlements, with relatively little long-distance transport in the taxa we considered in this study. Technologies and scheduling for fishing would have varied accordingly.

Finally, we observe that analysis of zooarchaeological data at this scale is useful for analysts who may be faced with making decisions about analytical methodologies. The exclusion of fish vertebrae from identifications would have a significant impact on the visibility of Salmonidae, and likely other fish taxa, in the archaeological record across the study area.

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jasrep.2019.03.007>.

¹¹ An additional source of variability is that *Coregonus* vertebrae taper markedly towards the posterior end of the vertebral column, to the point where some of the caudal vertebrae would pass through 6.4 mm mesh, while the same is not true for *Salvelinus* and *Salmo*.

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