Journal of Archaeological Science: Reports 8 (2016) 470–485

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Meta-analysis in zooarchaeology expands perspectives on Indigenous fisheries of the Northwest Coast of North America

Iain McKechnie [a,b,*], Madonna L. Moss [a,c]

[a] Department of Anthropology, 1218 University of Oregon, Eugene, OR 97403, USA
[b] Hakai Institute, Department of Archaeology, Simon Fraser University, Burnaby, BC V5A 1S6, Canada
[c] Museum of Natural and Cultural History, 1218 University of Oregon, Eugene, OR 97403, USA

ARTICLE INFO

Article history:
Received 4 September 2015
Received in revised form 22 March 2016
Accepted 14 April 2016
Available online 21 May 2016

Keywords:
Archaeozoology
Fisheries
Historical ecology
Zooarchaeology
Northwest Coast
Meta-analysis
Ichthyoarchaeology

ABSTRACT

Fisheries are of fundamental importance to Indigenous peoples of the Pacific Northwest of North America today and in the past but few archaeological analyses have documented geographic patterning in fisheries across the entire region. This paper adopts meta-analysis methods and GIS-based spatial visualizations to survey the single largest compilation of fine-screened zooarchaeological fisheries data reported to date, including 513,605 fish remains identified at 222 sites from Oregon to southeast Alaska. These systematically collected zooarchaeological data indicate the most ubiquitous and proportionally abundant fish taxa over the late Holocene and reveal previously undocumented spatial patterning, indicating where certain fish taxa are consistently found in high relative proportions. Rather than seeking to evaluate chronological and/or evolutionary change, this study explores the environmental and cultural basis for assessing variability in Indigenous fisheries over millennial time scales. Specifically, we observe Pacific herring and the Pacific salmons to be the two most ubiquitous and proportionally abundant fish taxa across the Northwest Coast followed by flatfishes, sculpins, rockfishes, greenlings, dogfish, and a host of other poorly known taxa that represent consistent fishing effort. We document geographic patterning in the abundance and ubiquity of a range of fish including greater abundance of salmons in northern portions of the study area and outline trends that could represent biogeographic ranges for northern anchovy, Pacific hake, and pollock, among others. We conclude that examining patterning in the ubiquity and rank-order abundance represented by archaeological fisheries data offers significant potential for linking regionally distinct cultural practices noted in the 18th and 19th centuries to much longer human and ecological histories over the Holocene.

1. Introduction

Fishing is fundamental to the social and economic lives of Indigenous and non-Indigenous peoples on the Northwest Coast of North America. As documented in hundreds of ethnographic and ethnohistorical accounts, fisheries helped sustain communities for millennia and continue to anchor the cultural identities of many Northwest Coast peoples. While fishing has been an economic mainstay since the earliest documented records of animal utilization on the coast dating to the early Holocene, 10,700 years ago (Fedje et al., 2005; Moss and Cannon, 2011a), community-based fisheries have significantly declined in the 20th century due to poor health of fish stocks, consolidation of commercial fisheries, and a myriad of other factors. Zooarchaeological research in the region, traditionally focused on the antiquity of coastal adaptations, is increasingly recognized as providing key information about the former abundance and distribution of fish populations prior to industrial-scale commercial fisheries. In this paper, we examine the archaeology of Indigenous fishing from Oregon to Alaska to explore the cultural and ecological dimensions of ancient fisheries. Rather than a conventional site-based study, our analysis focuses on the most frequently occurring taxa in archaeological sites across the coast (ubiquity) and uses GIS based visualizations to examine spatial patterning and variability between geographically associated sites. We observe that in the past a much wider range of species were utilized as food fish than is the case today and as commonly portrayed in archaeological literature. While there remain considerable gaps in knowledge, an increasingly rich archaeological dataset offers new perspectives on variability and geographic patterning.

1.1. Archaeology of fisheries in the 'Salmon Area'

Anthropologists have classically referred to the Northwest Coast of North America as the "Pacific Salmon Area" (Hewes, 1973; Kroeber,

* Corresponding author at: Department of Anthropology, University of Victoria, PO Box 1700 STN CSC, Victoria, BC V8W 2Y2, Canada.
E-mail address: iim@uvic.ca (I. McKechnie).

http://dx.doi.org/10.1016/j.jasrep.2016.04.006

1923; Wissler, 1914) in reference to the seven species of anadromous Pacific salmon and trout (*Oncorhynchus* spp.) widely utilized by Indigenous peoples. Salmon[1] have an iconic status as a result of their cultural importance to Indigenous peoples as well as the rapid growth of Pacific salmon fishing and canning industries during the 19th and 20th centuries. Despite significant reductions in many wild populations, salmon remain the most widely recognized and regularly consumed food fish in the region today. Accordingly, archaeologists and anthropologists have long focused on the cultural and economic importance of salmon, and particularly its role in the emergence and development of distinctive Northwest Coast cultures (Cannon, 2001; Moss, 2012a; Moss and Cannon, 2011a). In a key paper published three decades ago, however, Gregory Monks (1987: 119) coined the term "salmonopia" to describe "the inability to see all the food resources because of salmon." Monks argued that archaeologists needed to temper speculation concerning the central importance of salmon and consider how other fish (and other animals) may have contributed to long term economic and cultural practices on the Northwest Coast. Monks emphasized the role of Pacific herring (*Clupea pallasii*) and other researchers have since demonstrated a plethora of fish species utilized (Butler and Campbell, 2004; Croes and Hackenberger, 1988; Moss and Cannon, 2011a). Despite this, salmon continue to play a key role in considerations of Northwest Coast economies (Coupland et al., 2010; Grier et al., 2013; Monks and Orchard, 2011).

A methodological factor that has historically constrained analyses of archaeological fisheries data is the limited use of fine mesh screens (≤3.2–2 mm) which are required for recovery of the overwhelming majority of fish bones (McKechnie, 2005; Moss and Cannon, 2011b: 7–8; Stewart and Wigen, 2003). In the absence of such recovery techniques, larger fish such as the salmons will be over-represented relative to smaller fish. Even though such sampling techniques have long been recognized as critical (Casteel, 1976), they have not been widely used until the last 15 years. Finally, an adequate number of assemblages have been analyzed enabling us to evaluate comparable data at a regional scale.

Previous syntheses of zooarchaeological abundance data have been hindered by differences in quantification and recovery methods, concerns over the reliability of morphological identification, and the adequacy of sample size (Driver, 1993). Those who have attempted to overcome these challenges have done so with a limited number of sampled datasets which seek to comprehensively estimate the numbers of individuals as well as relative meat weight contributions (e.g., Croes and Hackenberger, 1988; Moss, 1989). These concerns, combined with the relative lack of published zooarchaeological datasets for many areas of western North America, have created conditions where analyses of multiple sites are limited in scope and often fraught with perceived methodological limitations. For instance, Diane Hanson (1991) observed that although there were many zooarchaeological datasets in the Salish Sea region of southern British Columbia, very few were sampled adequately or reported consistently and thus very few could be comprehensively compared. More recently, Butler and Campbell (2004) evaluated a large dataset that treated classes of fauna separately (e.g., mammals, fish, birds) further reducing analytical incongruencies between taxonomic classes but included both fine and conventionally screened assemblages. Others have followed a multi-dimensional scaling approach (Orchard and Clark, 2005; Orchard and Clark, 2014) which examined temporal and spatial trends in the proportional abundance of birds, mammals and fish across sites but did not specifically focus on fish.

In this paper, we present and explore a database of fine screened archaeological fisheries data from throughout this large coastal region which demonstrates persistent use of a wide variety of species over the Holocene. This is the largest database of fine screened faunal data compiled from the Northwest Coast to date. By way of comparison, the recent analyses conducted by Orchard and Clark (2014) were restricted to 63 assemblages from 39 'large' shell midden sites while Butler and Campbell's (2004) important study examined 13 Early Holocene assemblages (from both the Northwest Coast and the Columbia Plateau) and 42 later Holocene faunal assemblages from 19 sites.

2. Materials and methods

2.1. Assembling a foundation for Northwest Coast ichthyoarchaeology

To assemble the database of 513,605 NISP from 222 archaeological sites used in this paper, we built upon existing databases that we compiled to analyze herring distribution and abundance (McKechnie et al., 2014; Moss et al., 2011). We compiled data from well-sampled sites with adequately recovered and identified fish bone assemblages located within 500 horizontal meters of the current marine shoreline in southeast Alaska, British Columbia, and Washington. The original herring database and the expanded database used to inform this paper required an extensive literature review of published and grey literature zooarchaeological analyses completed over the past 40 years. These data only include sites subjected to conventional excavation and fine screen recovery and quantification of fish remains. This reflects archaeological effort and necessarily excludes the vast majority of known site locations as well as unrecorded sites that occur both above and below current shorelines. Given the small size of herring, eulachon, and other culturally important forage fish bones (i.e., with vertebral centra 4 mm or less in diameter), we only included sites where the zooarchaeological remains were systematically recovered using a fine-screen mesh (equal to or smaller than 3.2 mm [1/8 in.]). All zooarchaeological remains were identified by established analysts or students working under the analysts' direct supervision using one or more of several comparative osteological collections. This earlier effort resulted in a database of 435,777 NISP from 171 sites (McKechnie et al., 2014). We have since expanded the database using newly available literature and extended the geographic coverage to include Oregon and numerous additional sites elsewhere in the study area. Only sites containing a minimum of 50 fish bone specimens identified to at least family level were included, forcing us to drop 35 site assemblages from consideration. Over 90% of the 222 sites have >100 fish bones. This is a reasonable threshold for assessing the ubiquity and relative abundance of the most common taxa.

To explore patterning in this larger dataset, we employ three measures of taxonomic abundance: ubiquity, rank order, and relative abundance data. We also use GIS visualizations to document geographical patterning for groups of ubiquitous taxa using relative abundance.

2.2. Ubiquity as a measure of regularity

Ubiquity is a measure of abundance based on the presence and absence of certain items in a number of discrete contexts. Calculated as the percentage of contexts in which a certain specimen type is found, ubiquity indicates the 'frequency of occurrence' or how consistently a certain item is encountered in an archaeological deposit. While this measure of abundance is regularly used in paleoethnobotanical research (Lepofsky and Lyons, 2003; Pearsall, 2000), it is infrequently applied in zooarchaeological research (Lyman, 2008; VanDerwarker, 2010). As a measure of consistency of use, ubiquity[2] is well suited to assessing the frequency of occurrence of animal bones in food refuse contexts as this relates to how often animals are consumed and/or discarded. Ubiquity is less subject to variations in the numbers of bones between

[1] In describing our results, for taxa represented by a single species (e.g., herring or dogfish) we treat the noun as singular. For taxa represented by multiple species (e.g., salmons, sculpins, flatfishes) we use the plural forms. When we discuss Northwest Coast literature more generally we refer to "salmon" in the singular form, following more traditional usage.

[2] Sometimes also known as 'percentage presence analysis'.

species which can affect measures of proportional abundance derived from numbers of identified bone specimens (i.e., %NISP). Ubiquity can provide additional perspective on relative abundance data and can be examined across sites or site contexts provided there are sufficient numbers of observations. A given taxon can be considered 'ubiquitous' if it occurs in the majority of the examined archaeological contexts, whether that be in sites across the Northwest Coast, within regions of the coast, or the discrete depositional settings within individual archaeological sites (e.g., stratigraphic layers, column sample levels, matrix samples). The measure is used here to assess the regularity of fish use across multiple shell midden sites (cf. Butler and Campbell, 2004:361). Because it evaluates presence or absence, it provides a measure of abundance that is not dependent on the proportion of other species at the site, although presence is, of course, partly a function of sample size (Grayson, 1984; Lyman and Ames, 2004). Ubiquity calculations are well-suited for application to small volume column sample assemblages where variation in the area excavated is low and variation in sample and number of taxa identified is moderate. This is because ubiquity values would be expected to reach 100% in comprehensively sampled sites whereas the presence of taxa in small volume samples is likely to reflect the most broadly distributed taxa.

Like all other zooarchaeological quantification measures, ubiquity, as a presence/absence proxy for the regularity of animal use can be influenced by sample size. To explore the magnitude of such sampling bias, we compared the average number of taxa from the smallest 20% and the largest 20% of assemblages based on the number of identified specimens. Predictably, the smallest 20% of assemblages has a significantly lower average number of taxa (mean = 6.1) than the average assemblage size (mean = 10.1). Similarly, the largest 20% of assemblages has a significantly higher than average number of taxa (mean = 15.1). This latter result indicates the potential for over-representation of the ubiquity of taxa relative to other sites while the former indicates that lower values document a smaller range of taxa relative to larger assemblages. Fortunately, both small and large assemblages are evenly represented throughout the different regions examined (e.g., Salish Sea, Haida Gwaii) and the smallest 20% of assemblages do not constitute >30% of sites in any one region. We suggest therefore, that both higher and lower than average assemblage sizes may counter-balance each other with regard to ubiquity estimates. Because ubiquity estimates the most regularly occurring species across this large area, it is expected that the most frequently occurring taxa are likely to be common even with small sample sizes. This is why we opted to focus on the top 15 taxa, recognizing that rare taxa need additional testing and analysis before their importance to Indigenous fisheries can be adequately assessed. This analysis is a first attempt at considering fisheries across sites and regions and should additional data from each site become available, this will improve the representation of various taxa.

2.3. Using GIS to assess spatial patterning in relative abundance

Zooarchaeologists have long drawn upon spatial analysis to identify archaeological patterning but most research seems to occur at the scale of an excavated surface or structural feature (e.g., Enloe, 2003; Marín-Arroyo, 2009). Geographic information systems (GIS) are well suited to contending with the complexity of integrating multiple datasets and forms of data including spatial analyses. As disciplinary knowledge and the number of studies have increased, researchers are increasingly comparing data across multiple studies to address large scale questions using the cumulative observations of the archaeozoological record (e.g., Arbuckle et al., 2014; Conolly et al., 2011; Orton et al., 2014). For instance, researchers have drawn on the hundreds of grey literature reports from the city of London to conduct meta-analyses of fish use at a centennial scale (Orton et al., 2014). Such research has been enabled by decades of sustained zooarchaeological effort that have reached a sufficient breadth in coverage and methodological standardization to address large-scale archaeological phenomena.

2.4. Visualization and interpolation methods

To evaluate spatial patterning in the abundance of fish remains across the coast, we utilize inverse distance weighting (IDW) to visualize relative abundance of identified specimens (%NISP) among spatially associated sites. This method interpolates between known points and overlays a predictive value expected for a given area based on the values from locations nearby (e.g., Barrientos et al., 2014; Sartori et al., 2014). Since the quality of observations depends on the spatial coverage, predictive solutions attenuate and have less relevance across greater distances. Herein, we constrain the extent of our interpolations to areas where individual sites are within 50 km of each other. We also lay the terrestrial landscape over our spatial interpolations to ensure they apply to the marine waters where fish are obtained rather than the land. The purpose of this analysis is not to correctly or precisely predict values in specific areas or microenvironments lacking data, but rather to explore potential spatial variability or lack thereof in the proportion of certain fish taxa. Where there are sufficient data points the observations are more robust. This method also offers a way to highlight regions that currently lack data and represent targets for future research. This method can graphically communicate spatial patterning effectively, especially to non-archaeologists, whether they are descendant communities, fisheries scientists, or the general public (e.g., Hanotte et al., 2002; Sartori et al., 2014).

An obvious drawback to the inverse distance weighting method is that it collapses assemblages of varying time depth into a single surface, masking potential temporal variability in an archaeological sequence. Such variability could be due to a variety of factors including environmental change over various time scales (e.g., El Niño, Pacific Decadal Oscillation, Little Ice Age), cultural practices, and a myriad of taphonomic factors. Yet most Northwest Coast sites with zooarchaeological fisheries data lack consistent and or fine temporal resolution and individually dated components often encompass timespans which could be as much as 500 or even 1000s of years (McKechnie et al., 2014). The benefit of the IDW method is that it provides for and incorporates the cumulative human experience of harvesting certain animals in certain places, a traditional strength of archaeological observation. Such visual patterning helps identify consistency in human practices across time periods and coastal environments, regional differences based on latitude and coastal position, and also reveals areas with disjunctures in abundance values between nearby sites. This latter feature is represented visually by a mottled or 'spotty' colour distribution rather than a single dark or light shade. We additionally use rank order abundance to evaluate geographic patterning for particularly abundant and ubiquitous fish taxa such as herring and the salmons. These ordinal scale measures provide a separate but complementary perspective across numerous contexts and are less susceptible to variations in abundance measures than can occur using proportion of NISP (cf. Wolverton et al., 2014).

3. Results

Our dataset represents 222 archaeological sites excavated over the past 40 years and analyzed by >40 different analysts working out of at least 14 separate labs in Canada and the United States. The total number of identified specimens (NISP) in this compilation of fine screened assemblages (2–3.2 mm mesh) is 513,605 with a mean per site of 2313 and a median of 634. The majority (72%) of these assemblages are derived from what are conventionally considered 'grey literature' sources (43% consulting reports, 28% unpublished theses or dissertations). In contrast, proportionally fewer data come from academic books, book chapters and peer-reviewed journal articles (28%). The number of analyzed sites has increased rapidly over the past 15 years. In fact, >70% of the total number of sites have been analyzed since the year 2000 (Supplementary online material). This dramatic increase provides a much improved basis for assessing regional and temporal patterning in

Indigenous fisheries. In the results presented below, we define three groups or 'tiers' of taxa that appear to loosely cluster in ubiquity, rank order, and abundance with a focus on the top 15 taxa. We recognize that many more species than those discussed here are present in these archaeological sites but for the purposes of this paper, we focus on the most common species across this large and diverse coastal area.

3.1. The first tier: herring and the salmons

Our dataset contains at least 100 unique fish taxa including several genera and family level taxonomic designations that contain a large range of species but are difficult to resolve from morphological identification alone. The two most ubiquitous fish in archaeological sites on the Northwest Coast are Pacific herring and the salmons (Fig. 1). Pacific herring, a species level designation, is the single-most common (98%) taxon in fine screened assemblages whereas the salmons, representing seven potential species, are a close second (95%). Both are present in the vast majority of sites that have sufficiently identified and quantified assemblages indicating that both taxa were the most widely utilized fish by Indigenous peoples across the Northwest Coast.

These observations affirm recent analyses demonstrating the importance of herring in Indigenous fisheries on the Northwest Coast (McKechnie et al., 2014; Moss et al., 2016). Herring bones are consistently more abundant than salmon bones for sites across the coast as indicated by rank order abundance and ubiquity. Assemblages composed predominantly of herring (over 60%) are found in all regions with available data (e.g., central British Columbia Coast, southeast Alaska, Haida Gwaii, western Vancouver Island, Salish Sea) and are present and consistently abundant in many places where they are not regularly observed today. Herring exhibit a hyper-abundance in the Salish Sea region and on the west coast of Vancouver Island. Moreover, herring occur consistently over time as indicated by their presence in 569 individual levels from 50 sites, where herring occur in 99% of examined contexts (McKechnie et al., 2014). Despite geographic gaps, sites located near one another (ca. 5–50 km) have generally similar abundance values, indicating that sites in close proximity share environmental characteristics and cultural preferences which sustained herring

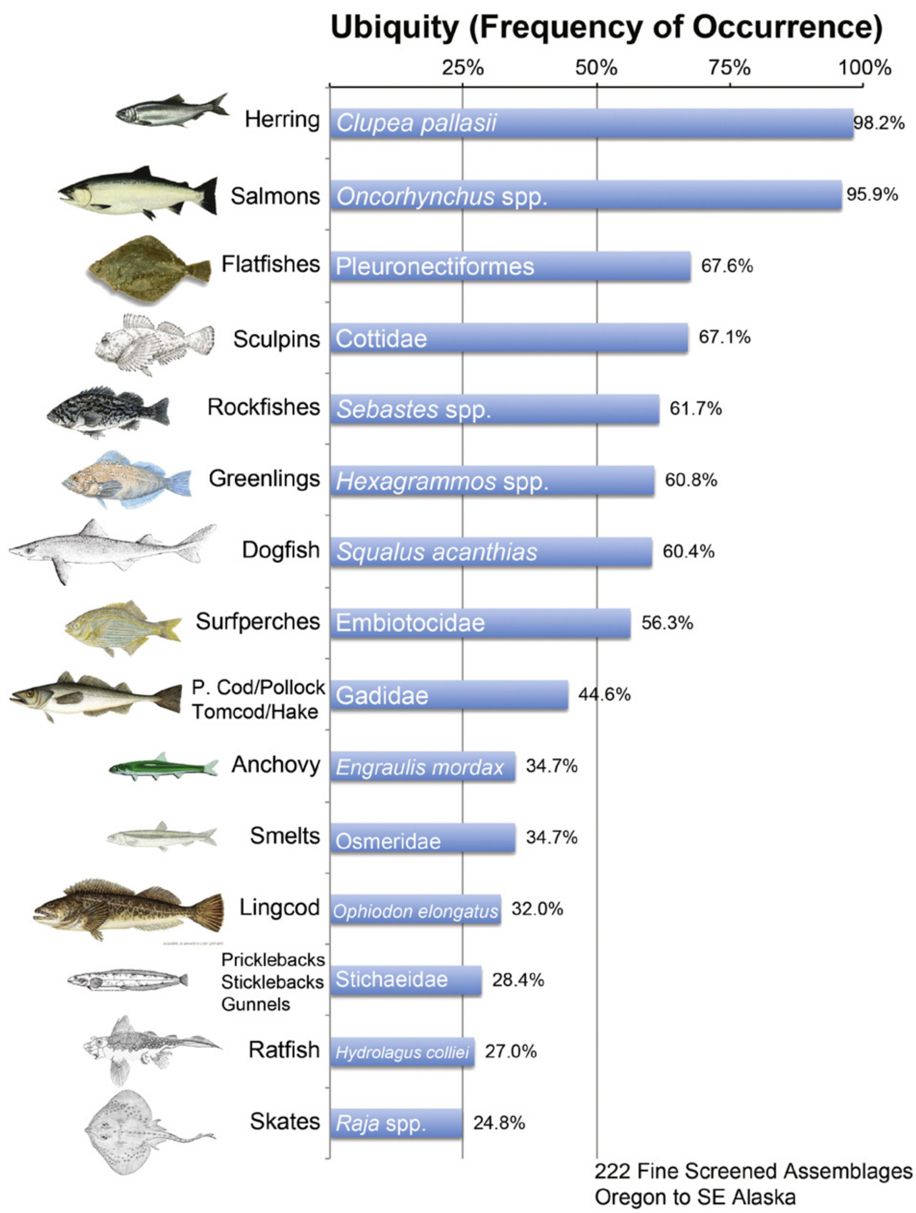


Fig. 1. Ubiquity values for the top 15 fish taxa in sites subjected to fine-screen vertebrate recovery and identification throughout the Northwest Coast.

harvesting. This indicates that enduring habitat characteristics and cultural practices specific to herring occurred at those localities and that regions with abundant herring appear to have supported very productive herring massing and spawning areas that withstood millennia of human use and ecological variability.

That the salmons are the second-most common fish in Northwest Coast sites demonstrates that this iconic genus indeed plays a significant role in Indigenous fisheries as has long been recognized (Drucker, 1965; Fladmark, 1975; Hewes, 1973). These ubiquity values represent frequency of occurrence in individual sites, not proportional abundance. To further explore these observations, we examined the rank order abundance of both herring and salmons by region and note higher rank order and ubiquity values for the salmons in the northern portion of the study area and correspondingly, higher ubiquity and rank order abundance for herring in the Salish Sea and west coast of Vancouver Island regions (Fig. 2). This pattern lends support to previous observations of a greater reliance on salmon fisheries in northerly regions but should not detract from the richness of Indigenous fisheries beyond these two taxa as will be discussed in later sections.

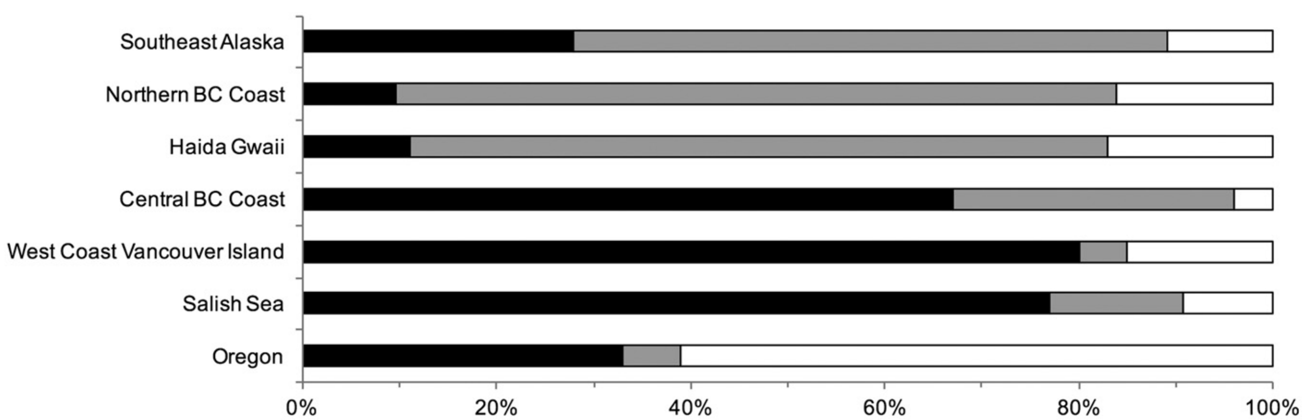
Given significant differences in body size between herring and the salmons, many researchers will likely interpret a similarly high ubiquity value between herring and salmons to indicate that salmons represent an even greater contribution to diet than herring or any other fish. While this is possible, demonstrating such will require quantitative modelling that takes into account variations in salmon species, body size, minimum number of individual calculations, seasonality, and other factors which are beyond the scope of this paper. It is also possible that salmon may be identified more frequently in archaeological assemblages partly because relative to other fish, their vertebrae are identifiable even when fragmentary (Cannon, 2000a; Orchard, 2007; Wigen and Stucki, 1988). Recall that there are seven species of salmon, although they are typically identified only to genus (Cannon et al., 2011). Thus, while factors such as individual fish size may exaggerate the archaeological abundance based on bone counts, ubiquity values still relate to how regularly certain fish were utilized — a meaningful proxy of their role in Indigenous fisheries as inferred from archaeological data. We note that both herring and the salmons were taken in mass capture devices ethnographically; a variety of weirs and traps were designed to catch each type of fish (e.g., Caldwell, 2011; Langdon, 2006; Menzies, 2012; Monks, 1987; Moss, 2012b). The salmons were also taken in gill, seine, and reef nets, while herring were taken in basketry traps and nets (Swan, 1857: 27). Herring were also raked into canoes (Drucker, 1951: 23; Suttles, 1974: 126). Salmons were also harpooned, speared, taken with leisters and caught on hook and line (Croes, 1997; Stewart, 1996; Suttles, 1974: 141; Turner et al., 1983). When and where these various technologies evolved, of course, is a topic beyond the scope of this paper.

3.2. The second tier: so common they are taken for granted

3.2.1. Flatfishes and sculpins

The third and fourth most widely occurring fish taxa are flatfishes (Pleuronectiformes) and sculpins (Cottidae), which occur in 67.6% and 67.1% of the assemblages across the Northwest Coast, respectively. These taxonomic designations represent large groups of species that, like the salmons, often share morphological characteristics that make it challenging to identify to species based on morphology. Both sculpins and flatfishes are ecologically associated with the sea floor and do not exhibit concentrated schooling behaviour. Sculpins lack swim bladders, so they cannot ‘float’ in the water column and primarily rest on the bottom. Similarly, flatfishes have an early life history stage where larvae drift in current but settle on the bottom as juveniles and only venture off the sea floor when actively swimming.

A large variety of flatfish species are represented in the assemblage, with halibut (*Hippoglossus stenolepis*), the largest flatfish, having the most common species occurrence (19%) followed by starry flounder (*Platichthys stellatus*), arrowtooth flounder (*Atheresthes stomias*), and a variety of soles. Aside from halibut (Orchard and Wigen, 2008; Smith, 2008), comparatively little zooarchaeological attention has been paid to these numerous flatfishes which represent small to medium sized fish that could be readily harpooned in shallow water or caught by trolling along the generally low relief sediment-dominated sea floor. Visualization of the geographic patterning shows a coast-wide hotspot for flatfishes along the Fraser Lowlands and in Puget Sound, which has not been previously identified at this scale (Fig. 4). Many of the flatfish in Puget Sound are starry flounder (*P. stellatus*), noted for its tolerance of low salinity (Hart, 1973: 632). Unsurprisingly, other areas of concentrated archaeological abundance of flatfish are along the west side of Dall Island in southeast Alaska and along the southern reaches of Haida Gwaii (Fig. 3), where halibut are strongly emphasized in ethnographic accounts (de Laguna, 1972; Langdon, 1979). It is worth noting that areas with low relative abundance values do not necessarily



	Oregon	Salish Sea	West Coast Vancouver Island	Central BC Coast	Haida Gwaii	Northern BC Coast	Southeast Alaska
■% of sites Herring as rank order #1	33%	77%	80%	67%	11%	9.7%	28%
■% of sites Salmon as rank order #1	6%	14%	5%	29%	72%	74%	61%
□% of sites other as rank order #1	61%	9%	15%	4%	17%	16%	11%

Fig. 2. Rank order abundance of herring, salmons, and all other fish by sub-region arranged north to south. Note the higher rank order for salmons in the northern regions and herring in the southern regions with the exception of coastal Oregon.

indicate a lack of considerable harvesting effort, only that taxa are proportionally less abundant than other harvested fish.

As is the case for flatfishes, most assemblages do not identify individual sculpin specimens to genus or species but of those, Irish lords (*Hemilepidotus* spp.) are the most ubiquitous (present in 27% of sites throughout the coast), followed by staghorn sculpin (*Leptocottus armatus*, 20.7%), cabezon (*Scorpaenichthys marmoratus*, 16.2%), and buffalo sculpin (*Enophrys bison*, 13.5%), as well as several other species present in fewer than 10% of sites. Considering their overall ubiquity, sculpins have a remarkably low profile in the archaeological reporting of Northwest Coast fisheries. This may be because beachgoers (including archaeologists) typically experience sculpins as tiny inhabitants of tidepools, not as food fish served on dinner plates. Notably, tidepool sculpins (*Oligocottus maculosus*) are very small and are rarely observed archaeologically (but see Moss (2015) for an exception where cultural and mustelid deposits alternate). In the authors' experience, sculpins (as well as rockfishes, *Sebastes* spp.) are frequently caught by sport fishers while jigging for halibut, but are often considered by non-Indigenous fishers to be "too bony" to be eaten. The most regularly occurring sculpins in archaeological assemblages are medium to large sized fish including red and yellow Irish Lords as well as staghorn, great, and buffalo sculpins, and cabezon, the largest sculpin in the region, which can be up to a meter long and weigh over 10 kg (Eschmeyer et al., 1983). These medium to large fish represent considerable food value. Despite their ubiquity, sculpins are not commonly the singlemost numerous fish in sites across the coast but do have considerable proportional abundance along the central Oregon Coast, at a site in Masset in northern Haida Gwaii (Christensen et al., 2010), and

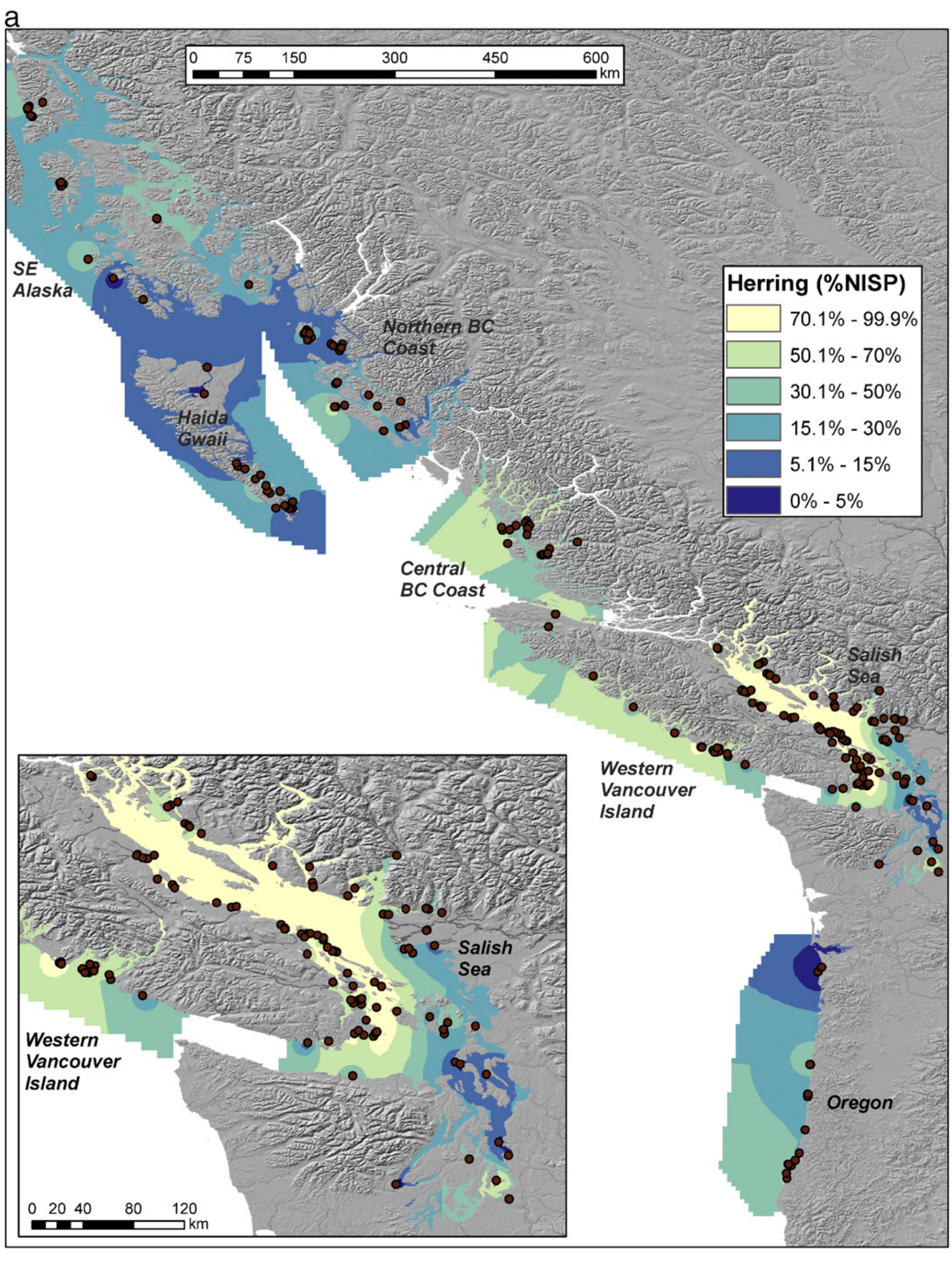


Fig. 3. a–b. Visual representation of geographic patterning of relative abundance of herring (a) and salmon (b) versus all other identified fish as interpolated by inverse distance weighting from archaeological sites with available data (dots).

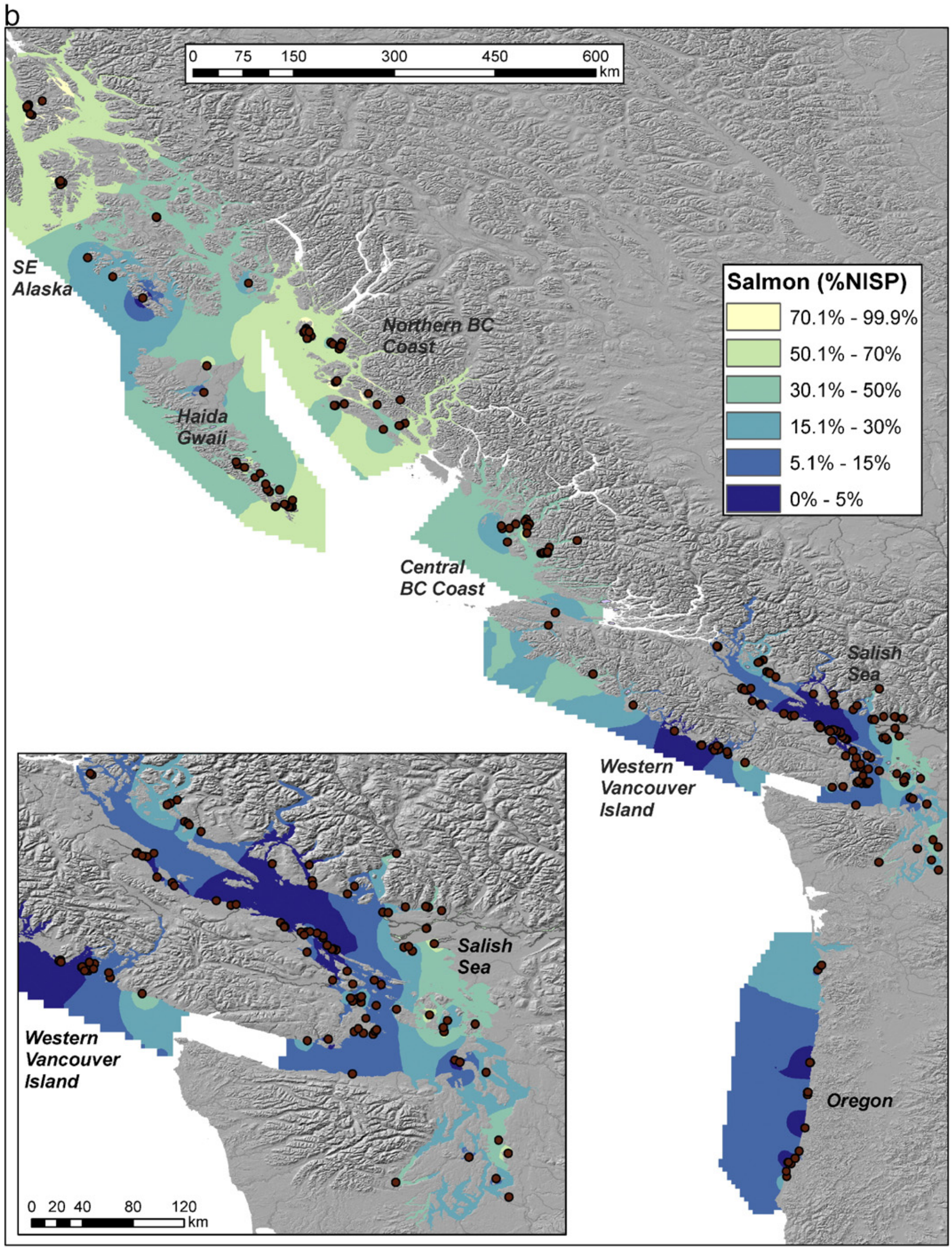


Fig. 3 (*continued*).

at the Cama Beach site in Puget Sound (Trost et al., 2011). The Oregon coast has the highest sculpin ubiquity whereas the lowest sculpin ubiquity is found along the mainland coasts of northern and central BC (see Tables 1 and 2).

The ubiquity of both flatfishes and sculpins indicates a widespread use of 'groundfish' across the coast. Many sculpin and flatfish species were likely caught with hook and line, and it is well-known that larger halibut and other large fish inhabit deep waters during portions of their life cycles and were likely caught with long lines. The proclivity of some flatfishes to mass in shallow water, such as starry and other flounders, led to their capture in nets, tidal weirs, or by harpooning from canoes in shallow water (Byram, 2002; Ham, 1982; Suttles, 1974: 47). Further examination of the co-occurrence of multiple species associated with local habitats is needed. Although the under-representation of halibut remains a taphonomic concern (Orchard and Wigen, 2008; Smith, 2008), it is the singlemost commonly identified flatfish species in fine screened assemblages across the coast. This may be because of its large size, the distinctive fibrous texture of its bones relative to other flatfishes, its prominence in ethnographic accounts, its perceived economic importance, or some combination of these factors. While further attention to the taphonomy of halibut is welcome, particularly how cooking in soups, stews, and chowders (as documented ethnographically, e.g., Blackman, 1990; de Laguna, 1972: 392–400) may have affected bone preservation, our study suggests that other flatfish and sculpin species are equally worthy of consideration in terms of their contribution to Indigenous fisheries.

3.2.2. Rockfishes

Rockfishes (*Sebastes* spp.) represent another genus that occurs in the majority (61.7%) of fine screened assemblages across the Northwest Coast. This genus represents >36 species in British Columbia alone (Hart, 1973; Love et al., 2002) and it is unclear which species are most commonly targeted across the many regions in the study area. A minimum of 10 rockfish species have been identified based on a preliminary analysis of ancient DNA from archaeological samples from western Vancouver Island (Rodrigues et al., 2014). Rockfishes appear to have been harvested in relatively close proximity to residential sites as observed via stable isotope data from southern Haida Gwaii (Szpak et al., 2013).

Rockfish habitat is most productive along rocky, exposed coasts with strong currents. Rockfishes occur in lower numbers and are slower growing when occupying protected inlets (Dick et al., 2014; Markel, 2011). They can be readily procured through hook and line fishing from shore or canoe during all seasons of the year (Love et al., 2002; White, 2003). While there is ecological variation among species, rockfishes are generally long-lived, relatively slow growing, and non-migratory, and thus can be readily affected by overharvesting (Berkeley et al., 2004; McKechnie, 2007). Many commercially important species of this genus (*Sebastes alutus*, *Sebastes caurinus*, *Sebastes maliger*, *Sebastes nebulosus*, *Sebastes paucipinis*, *Sebastes ruberrimus*) have been severely over-exploited during the last 50 years (Levin et al., 2006), making the archaeological record that much more valuable for historical ecological studies of rockfishes (Braje et al., 2012; McKechnie, 2007).

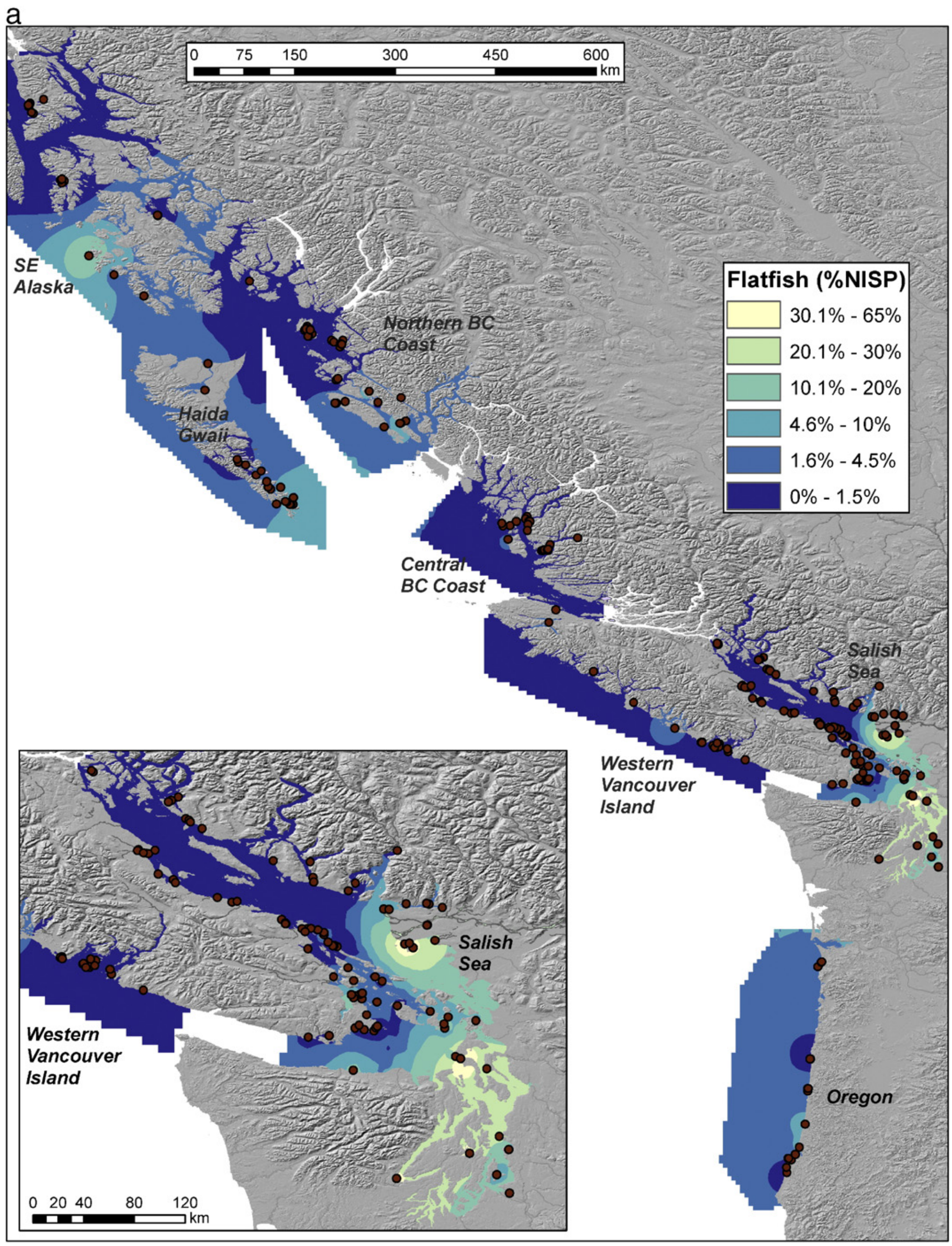


Fig. 4. a–b. Visual representation of geographic patterning of relative abundance of flatfish (a) and sculpin (b) versus all other identified fish as interpolated by inverse distance weighting from archaeological sites with available data (dots).

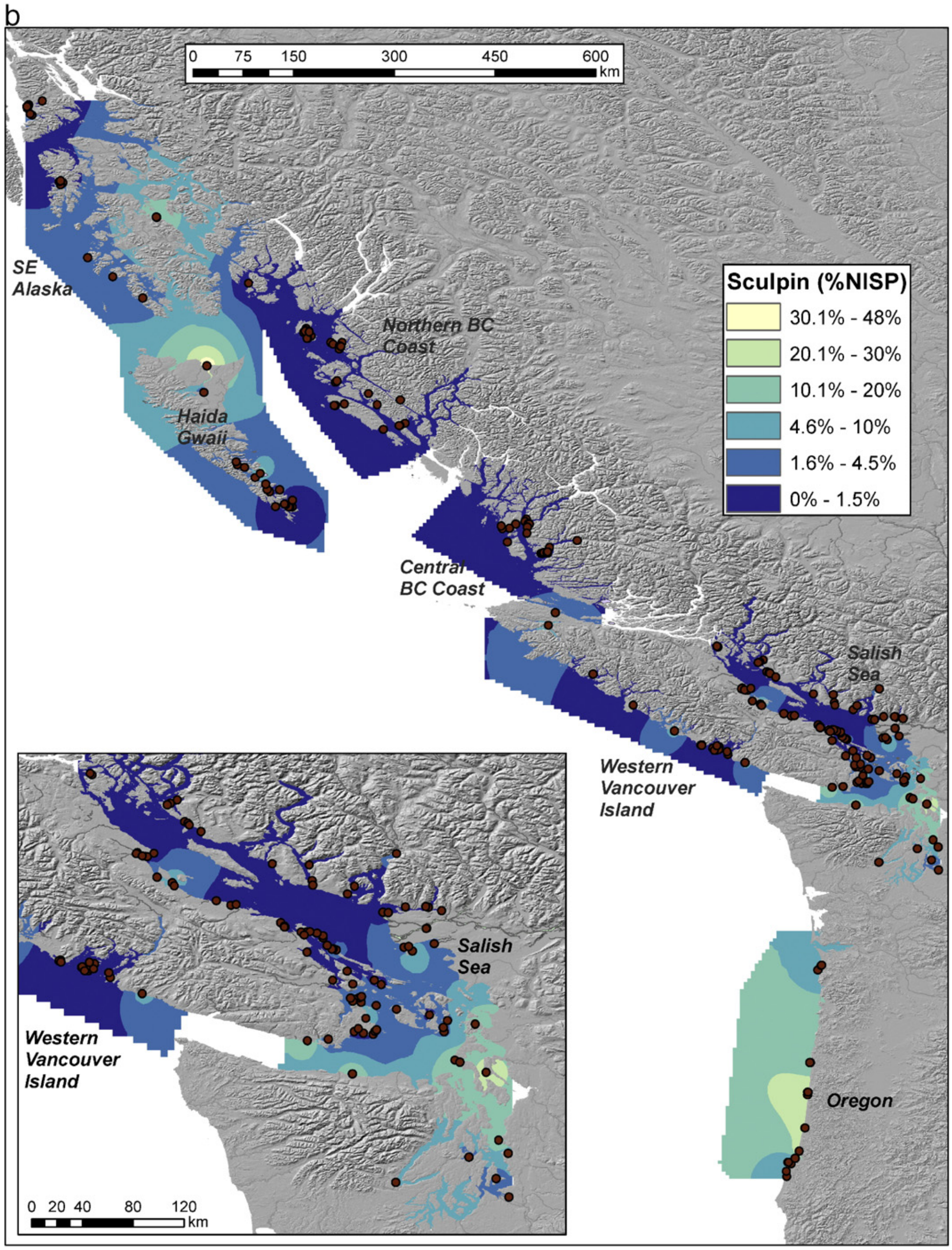


Fig. 4 (*continued*).

Archaeological assemblages indicate that rockfishes are most ubiquitous in Haida Gwaii, along western Vancouver Island and in coastal Oregon and they are least ubiquitous along the northern British Columbia coast where only 32% of sites contain this genus (Table 1). The widespread use of rockfishes relative to other fish suggests they have an under-appreciated role in Indigenous fisheries across the coast.

3.2.3. Greenlings

Greenlings (*Hexagrammos* spp.) comprise a genus of medium-sized rocky reef and kelp-associated bottom dwelling fish which occur in a majority of archaeological sites on the coast (60.8%) and consist of four main species: kelp, rock, masked, and painted greenlings (Love, 1991). Greenlings are particularly common along the west coast of Vancouver Island and Oregon (Table 1). Similar to other archaeologically ubiquitous taxa such as sculpins and lingcod (see below), greenlings are ambush predators that lack swim bladders and rest on the bottom when not actively moving and occupy similar rocky kelp-associated habitats where rockfish regularly occur. For the few sites where measurements have been taken, greenlings appear to be most commonly 20–30 cm in size (McKechnie, 2005, 2013; Orchard, 2007). Ethnographically described fishing methods include jigging by hook and line, creating buoyant lures, or capturing fish in submerged or intertidal basket traps (Stewart, 1977; Turner, 1982). Greenlings are prominent constituents in fish assemblages at several sites and their consistent occurrence in sites throughout the coast reveals a very significant role in Indigenous fisheries.

Table 1
Ubiquity values for fish identified from regions of the Northwest Coast. Colours are shaded according to frequency of occurrence in archaeological assemblages (darker shades indicate higher ubiquity values). Number of assemblages per region indicated in top row.

Fish taxa	All sites n = 222	SE Alaska n = 18	N BC coast n = 31	Haida Gwaii n = 18	Central BC coast n = 24	WC V. Island n = 20	Salish Sea n = 94	Oregon n = 17
Herring	98%	94%	97%	89%	100%	100%	100%	100%
Salmons	96%	100%	100%	100%	100%	95%	93%	94%
Flatfishes	68%	72%	48%	94%	33%	75%	70%	94%
Sculpins	67%	67%	32%	83%	29%	90%	74%	100%
Rockfishes	62%	56%	32%	89%	54%	95%	60%	76%
Greenlings	61%	50%	39%	61%	75%	100%	53%	88%
Dogfish	60%	28%	23%	89%	46%	75%	83%	12%
Surf-perches	56%	Absent	16%	22%	25%	90%	81%	94%
Gadids & hake	45%	83%	19%	56%	8%	55%	45%	76%
Anchovy	35%	Absent	13%	Absent	79%	85%	37%	12%
Smelts	35%	6%	55%	44%	42%	40%	31%	24%
Lingcod	32%	39%	6%	33%	8%	95%	23%	76%
Prickle-stickle-gunnel	28%	28%	16%	72%	21%	35%	26%	24%
Ratfish	27%	6%	10%	50%	21%	45%	32%	18%
Skates	25%	11%	16%	28%	8%	30%	32%	29%

3.2.4. Dogfish

Dogfish (*Squalus acanthias*) also exhibits high ubiquity; it occurs in >60% of archaeological sites on the coast. The high ubiquity of dogfish is surprising given that sharks are predominantly cartilaginous, lacking many of the ossified skeletal elements present in other fishes,[3] diminishing their potential abundance relative to other fish (Rick et al., 2002). Dogfish do have visually distinctive vertebrae which are particularly numerous (ca. 100–110) in comparison with many other fish (Last et al., 2007), and this may help offset an otherwise sparse anatomical representation. While dogfish are not widely considered a food source today, they were consumed in the past (see Drucker, 1951: 108; Hart, 1973: 46; Jewitt, 1807), and their high oil content is notable for potential use during lean periods or to supplement a protein-rich diet (Cannon, 2000b). Dogfish are generalist predators who have a keen sense of smell (Hart, 1973: 45) and sport and commercial fishers in the 20th century widely report catching dogfish while targeting other species with bait (White, 2003: 102). This may have been the case in the past but the high rank order and ubiquity of dogfish cannot simply be dismissed as by-catch. Dogfish have rough skin, which was used as an abrasive in a variety of woodworking tasks (Eells, 1887: 620; Stewart, 1977) and the oil was also used in the curing process for preparing kelp fishing line (Turner et al., 1983:36). In the historic era, dogfish oil was targeted for fuel for lamps used in mining and early industrial logging (Gedosch, 1968; Ketchen, 1986). Dogfish can live to be over 100 years old (Campana et al., 2006) and their archaeological ubiquity as well as oil content indicates their occurrence deserves further scrutiny.

[3] Dogfish elements represented archaeologically are primarily vertebrae, dorsal spines, and occasionally teeth.

3.2.5. Surfperches

Surfperches are a family (Embiotocidae) of 22 species, 11 of which occur along some portion of the study area (Eschmeyer et al., 1983). Often simply referred to as 'perch,' this taxon occurs in >56% of sites across the Northwest Coast. Surfperches are mid-water schooling fish (Hart, 1973). Archaeological attention to the role of surfperches in Indigenous fisheries is limited on the Northwest Coast, but this family of fish is recognized as widely used in Native California (e.g., Gobalet et al., 2004). While there is a tendency to consider surfperches as small 'bait-sized' fish (Drucker, 1951: 19; Stewart, 2001), many of the surfperches archaeologically identified to species are not just small shiner perch (*Cymatogaster aggregata*) but rather medium sized species (pile perch [*Rhacochilus vacca*], striped sea perch [*Embiotoca lateralis*], kelp surfperch [*Brachyistius frenatus*], red-tail surfperch [*Amphistichus rhodoterus*]) which can be readily encountered in a wide range of nearshore habitats and caught by hook and line or by dip net (Department of Fisheries and Oceans Canada, 2011; Robinson et al., 2007). These dinner plate-sized fish could also be caught in baited basket traps as

Table 2
Mean rank order of the 15 most ubiquitous fish taxa from all study sites as well as within regions of the study area. Rank order for 'all sites combined' shown in the left column and further indicated by colours gradients that are variously represented in the regional columns to the right (shades of red represent ranks 1–5, green 6–10, and blue 11–15 respectively). Colour gradients aim to indicate differences and similarities between the all sites combined rank order and rank order between regions.

Rank Order[a]	All sites combined n = 222	SE Alaska n = 18	Haida Gwaii n = 18	N BC coast n = 31	Central BC coast n = 24	WC Van. island n = 20	Salish sea n = 94	Oregon n = 17
1	Herring	Salmons	Salmons	Salmons	Herring	Herring	Herring	Sculpins
2	Salmons	Herring	Herring	Herring	Salmons	Anchovy	Salmons	Herring
3	Anchovy[b]	Gadids/Hake	Rockfishes	Smelts	Anchovy	Salmons	Flatfishes	Gadids/ Hake
4	Sculpins	Rockfishes	Dogfish	Greenlings	Greenlings	Greenlings	Surf-perches	Salmons
5	Flatfishes	Prickle/Stickle /Gunnel	Flatfishes	Flatfishes	Rockfishes	Rockfishes	Sculpins	Anchovy
6	Rockfishes	Sculpins	Prickle/Stic kle/Gunnel	Rockfishes	Sculpins	Dogfish	Dogfish	Rockfishes
7	Dogfish	Greenlings	Sculpins	Sculpins	Smelts	Surf-perches	Anchovy	Greenlings
8	Surf-perches	Flatfishes	Smelts	Dogfish	Dogfish	Sculpins	Smelts	Surf-perches
9	Greenlings	Ratfish	Surf-perches	Anchovy	Surf-perches	Lingcod	Rockfishes	Skates
10	Smelts	Lingcod	Greenlings	Prickle/Stic kle/Gunnel	Prickle/Stickl e/Gunnel	Flatfishes	Gadids/ Hake	Lingcod
11	Gadids/ Hake	Dogfish	Ratfish	Gadids/ Hake	Flatfishes	Gadids/ Hake	Greenlings	Flatfishes
12	Prickle/Stic kle/Gunnel	Skates	Gadids/ Hake	Surf-perches	Ratfish	Prickle/Stic kle/Gunnel	Prickle/Stickle /Gunnel	Smelts
13	Lingcod	Smelts	Skates	Skates	Gadids/Hake	Smelts	Ratfish	Ratfish
14	Ratfish	Anchovy – ABSENT	Lingcod	Ratfish	Lingcod	Ratfish	Lingcod	Prickle/Stic kle/Gunnel
15	Skates	Surf-Perches – ABSENT	Anchovy – ABSENT	Lingcod	Skates	Skates	Skates	Dogfish

[a] rank order is based on the mean rank order of identified specimens (NISP) from many sites in each region. Mean values per taxa were then arranged by rank and excluded absences (i.e., zero values).

[b]mean rank order of northern anchovy appears higher in rank order for 'all sites combined' but it is not highly ubiquitous (see Table 1 for contrast).

[a]Rank order is based on the mean rank order of identified specimens (NISP) from many sites in each region. Mean values per taxa were then arranged by rank and excluded absences (i.e., zero values).
[b]Mean rank order of northern anchovy appears higher in rank order for 'all sites combined' but it is not highly ubiquitous (see Table 1 for contrast).

ethnographically described for the Nuu-chah-nulth on western Vancouver Island (Drucker, 1951: 16).

3.3. The third tier: worthy contributors

3.3.1. Gadids

The gadid family is made up of large to medium-sized predatory fishes including Pacific cod (*Gadus macrocephalus*), Pacific hake (*Merluccius productus*), and walleye pollock (*Gadus chalcogrammus*), that is represented in 45% of sites across the study area. Despite differences among species, these fish serve similar ecological roles in marine foodwebs as semi-pelagic schooling predators (Ressler et al., 2010). Hake is associated with the California Current upwelling system which predominantly occurs in the southern portion of the region including Oregon and western Vancouver Island whereas Pacific cod and walleye pollock are more commonly associated with the northerly Gulf of Alaska Current. While the use of Pacific cod is relatively well established in archaeological research in Alaska (Moss, 2011; Partlow and Kopperl, 2011), other gadids are not as well-known. Hake have their highest ubiquity value in coastal Oregon (71%) with lower values along western Vancouver Island (41%) and yet are entirely absent from assemblages in the northern half of the study area including Haida Gwaii, the central and northern BC coast, as well as southeast Alaska. Conversely, Pacific cod, and to a lesser extent walleye pollock, have the opposite pattern where their highest ubiquity values are in southeast Alaska (50% and 22% respectively) with lower ubiquity values further south; e.g., they are absent in Oregon (Table 1). Such geographic distribution likely has implications for biogeography and culturally specific fishing practices. For example, drawing from ethnographic evidence, Moss (Bowers and Moss, 2001; Moss, 2011) argued that Tlingit fishers took Pacific cod in late winter–early spring when these fish move into shallow waters where they are more accessible to hook and line. In contrast, non-resident Pacific hake populations seasonally migrate northwards during summer and during warmer climatic periods (King et al., 2012; McFarlane et al., 2000). Thus, the occurrence of abundant hake in archaeological deposits may indicate warmer conditions in the marine environment, perhaps associated with El Niño events or even more extended multi-decadal warm periods in the North Pacific such as observed at a site on southwest Vancouver Island (McKechnie, 2012: 179; cf. Anderson et al., 2005).

3.3.2. Northern anchovy

Northern anchovy (*Engraulis mordax*) is a schooling forage fish that occurs in over 35% of sites in the study area indicating a significant role in Northwest Coast fisheries. While commonly considered a southerly species associated with California, northern anchovy has a broader latitudinal distribution than is generally recognized and numerous resident populations in British Columbia (Therriault et al., 2002). Paleoecological information from a sediment core from Effingham Inlet on the west coast of Vancouver Island indicates that anchovy were slightly more numerous than herring in that inlet environment (Wright et al., 2005).

Archaeological data demonstrate that anchovy regularly occur as far north as Grenville Channel south of Prince Rupert (Smethurst, 2014), but are absent from Haida Gwaii and southeast Alaska to the north (Table 1). Anchovy is most ubiquitous along the west coast of Vancouver Island (85%) and on the central B.C. coast (79%) and also regularly occurs in protected inlets around metropolitan Vancouver and Puget Sound (37%), but is curiously uncommon in coastal Oregon (12%). This latter point may relate to the exclusive use of 3.2 mm screens for fine screening in this region in contrast to other areas where use of 2 mm screens is more common. Moss is currently analyzing an assemblage from southern Oregon (Moss et al., n.d.), and has identified northern anchovy, but only in the 1 mm mesh screen material. It therefore seems possible that this small fish (and similarly sized species) may not be detected in archaeological analyses conducted with 3.2 mm mesh. Unlike eulachon and other smelts (see below) the ethnographic record of anchovy fishing and processing is comparatively non-existent.

3.3.3. Smelts

Smelts (Osmeridae) are a family of oil-rich schooling forage fish that occur in 35% of sites across the study area. Those species most commonly identified, surf smelt (*Hypomesus pretiosus*), capelin (*Mallotus villosus*), and eulachon (*Thaleichthys pacificus*), are often difficult to distinguish based on osteology. Smelts were harvested by dip nets either from boats or from shore and then smoked and dried, or processed for grease, as in the historic eulachon trade (Moody and Pitcher, 2010). Archaeologically, smelts are found in the greatest ubiquity on the northern B.C. coast (Table 1) which is historically associated with the eulachon grease trade along the lower Nass and Skeena rivers (Mitchell and Donald, 2001). Haida Gwaii, western Vancouver Island, and the central British Columbia coast are other localities where smelts commonly occur, but they have only been reported from one site in southeast Alaska. As mentioned above, due to the small size of smelt skeletal elements, it is likely that smelt are underrepresented given conventional fine mesh screens (3.2–2 mm) although smelt have been identified in coastal Oregon using 3.2 mm screens (Table 1). Some smelt remains are quite small; Moss is also finding surf smelt in the 1 mm fraction from the southern Oregon site mentioned above (Moss et al., n.d.). While eulachon fishing and processing are relatively well-documented for the northern BC coast (Brewster and Martindale, 2011; Crockford, 2014), and surf smelt fishing and processing are well known from northwestern California (Drucker, 1937; Gould, 1978; Tushingham et al., 2013), the role of smelt in the intervening areas is less clear. Even finer resolution sampling and analysis are needed to better understand the fishing and processing of various smelt species across the Northwest Coast.

3.3.4. Lingcod

Lingcod is a large predatory bottom fish that occurs in 32% of sites along the Northwest Coast. Lingcod can grow to over 1.5 m, particularly older female fish who inhabit deeper waters than males but come to shalllower waters to spawn in late winter (Hart, 1973; Martell et al., 2000). Ecologists and environmental historians have noted that modern lingcod populations are a fraction of their former abundance, particularly in the Salish Sea (Frid et al., 2012; Glavin, 2000; Martell and Wallace, 1998). Given the propensity of lingcod to pursue prey throughout the water column, an ethnographically documented fishing method involved the use of buoyant lures that were thrust into the water with a pole and released, bringing the fish to the surface where they could be harpooned or gaffed (Suttles, 1966; Swan, 1870). Archaeologically, the greatest ubiquity values for lingcod are along the west coast of Vancouver Island and Oregon while lingcod are rare along the relatively less exposed inlets of the central and northern BC coast (Table 1). Because 50% of female lingcod can reproduce by age four and generally do not live >20 years, lingcod have the potential to rebound when fishing is closed or marine protected areas are established in productive habitat (Martell et al., 2000). For instance, in 1997, the lingcod stock in Oregon was estimated at 10% of its historic abundance, but contemporary fishers are noting a potential recovery (Freeman, 2015). Such resiliency might be detectable archaeologically when considered in relation to much slower growing, later maturing, and longer-lived rockfishes and given a sufficiently resolved chronological record.

3.3.5. Pricklebacks, sticklebacks, and gunnels

Sticklebacks (Gasterosteidae) are small schooling fish often found in protected low energy coastal areas such as eelgrass beds and even in freshwater (Robinson et al., 2007). Pricklebacks (Stichaeidae) and gunnels (Pholidae) are eel-like fish found in rocky nearshore and intertidal environments (Hart, 1973; Robinson et al., 2007). Consisting of several species that can be difficult to distinguish osteologically, these taxa are present in 28% of archaeological sites in the study area with their highest ubiquity in Haida Gwaii, where over 80% of sites contain at least one of these three taxa. In contrast, lower ubiquity values (15–35%) occur across all other regions of the coast and additionally exhibit lower relative abundance values. The relatively small size and predictable occurrence in specific nearshore and even intertidal settings appear to indicate consistent use of these environments perhaps during periods of rough weather on exposed coasts. This latter observation is consistent with the highest ubiquity values for these taxa in Haida Gwaii suggesting a higher ecological abundance and/or more targeted use of these species in that setting (Table 1).

3.3.6. Ratfish

As noted by Cannon (1995), ratfish (*Hydrolagus colliei*) is commonly encountered in archaeological sites on the Northwest Coast but is likely under-represented because this cartilaginous species has only six teeth and a spine which are regularly recovered in archaeological contexts. The frequent occurrence of ratfish in sites across the study area (27%) indicates that the extent of ratfish use is not reflected in bone counts (NISP). Given the oil content of ratfish livers, representing up to 18% of the body weight, Cannon (1995) suggested that ratfish oil may have been used to supplement diets of lean protein made up predominantly of deer and shellfish. An additional possibility, is that the persistent use of ratfish may have been because, like dogfish, their oil could be burned in clamshell or stone lamps for illumination, such as during night-time low tide clam harvesting (cf. de Laguna, 1972: 305; Drucker, 1951: 108).

3.3.7. Skates

Remains identified to the skate family (Rajidae) have relatively high ubiquity in archaeological assemblages (25%) and are also present in the earliest dated fish assemblage on the coast (Fedje et al., 2005: 195) indicating these bottom dwelling fish are underappreciated in the pantheon of Northwest Coast fish. Similar to other cartilaginous fishes, skates are represented by few skeletal elements relative to other fish taxa and the proportional abundance is therefore likely to be underrepresented relative to bony fish when based on NISP alone (cf. Cannon, 1995; Rick et al., 2002). Big skates (*Raja binoculata*) can grow to over 2 m in length and over 80 kg while longnose skates (*Raja rhina*) regularly reach over 1 m and live as long as 26 years (Hart, 1973; McFarlane and King, 2006). Skates and rays are ethnographically described as desired food items in the Salish Sea region (Curtis, 1913; Eells, 1887; Suttles, 1974), along the outer Washington Coast (Swan, 1870: 24), and in southeast Alaska (de Laguna, 1972: 53), but very little archaeological attention has been devoted to these fish (Hanson, 1991; Moss and Cannon, 2011b). Harvesting methods included spearing and harpooning while in shallow water (Smith, 1940 [1969:268]; Swan, 1870: 24).

4. Discussion

Through measures of ubiquity and relative abundance, the archaeological fisheries data examined in this paper reveal a long-standing and consistent use of a wide variety of fish from a broad range of sites across the Northwest Coast. Certain fish were regularly utilized throughout the study area despite the widely recognized cultural and environmental variability within this region (e.g., Suttles, 1962). Such commonality in use, over dozens of human generations spanning millennia and a broad geographic area, has considerable archaeological relevance. Fishing, fish processing, and fish eating were part of daily life, and stored fish provided sustenance throughout the year and valuable commodities for trade. A wide range of fish-associated practices played crucial historical roles in individual Indigenous communities, and also in the emergence of regional cultural identities and political relationships. This study documents geographically patterned variation in the ubiquity and relative abundance of fish taxa at multiple spatial scales. Sites that are close together tend to have similar species represented and similar proportional abundances of those species. On a coast-wide scale, the salmons have a higher ubiquity and relative abundance in the northern portion of the study area compared to the southern portion. At a smaller scale, herring abundance is highest in the Salish Sea region, especially at certain sites as indicated in Fig. 3a. This suggests that the taxonomic composition of assemblages is strongly associated with place and appear less subject to variations over time, a circumstance that has been difficult to discern in many archaeological accounts of Northwest Coast fisheries (Cannon et al., 2011; Moss, 2012a). These geographically patterned uses reflect ecological characteristics of site locations overlain by cultural practices and preferences that emerge and can intensify at those places over long periods of time (e.g., McKechnie and Wigen, 2011). These interactions can lead to a taxonomically concentrated fishery detectable archaeologically at a variety of spatial and temporal scales (Moss, 2012a).

That the two most commonly encountered taxa are Pacific herring and the salmons is noteworthy. The salmons have long been recognized as significant (e.g., Butler and Chatters, 1994; Carlson, 2003; Fladmark, 1975; Matson, 1992), but the role of herring has only arisen over the last fifteen years (Caldwell, 2011; Kopperl, 2001; McKechnie et al., 2014; Moss et al., 2011; Speller et al., 2012). The overwhelming importance of both species is affirmed.

Like the many other ubiquitous fish identified in this study, future research on herring could focus on adding ethnographic and archaeological details to what we know about harvest methods, seasonality, nutritional qualities, size and weight estimation methods, as well as processing and storage. It is indeed remarkable that herring has such numerical prominence in archaeological assemblages for all regions, suggesting that herring had at least as historically important a role in the regional economy as Atlantic herring (*Clupea harengus*) did, for instance, to peoples in northern Europe (e.g., Barrett et al., 2004; Poulsen, 2008). Widespread use of salmon is demonstrated, although variation in which species were relied upon where will await more studies that incorporate results from analysis of ancient DNA (e.g., Cannon et al., 2011; Grier et al., 2013; Moss et al., 2014) or other methods to determine salmon species (e.g., Huber et al., 2011; Orchard and Szpak, 2011).

A particularly striking result is the widespread archaeological occurrence of fish that are rarely discussed in archaeological and anthropological literature for the region yet which clearly played vital roles in Northwest Coast fisheries (Fig. 1). Most notable are the many species of sculpins, flatfishes, rockfishes, and surfperches, as well as dogfish and greenlings, whose occurrence in over half of all archaeological sites on the coast is disproportionate to their role in conventional archaeological discourse about the development of semi-sedentary storage-based economies. Although gadids, greenlings, and ratfish have garnered some attention (e.g., Cannon, 1995; Croes and Hackenberger, 1988; Moss, 2011; Smith et al., 2011), anchovy, smelts, lingcod, pricklebacks, and skates have rarely been discussed in zooarchaeological and archaeological syntheses. Hopefully, this study will stimulate research into the use of these 'worthy contributors' to Northwest Coast economies.

This study has built on a dramatically increased quantity of fine screened archaeological fisheries data in recent years, particularly from grey literature datasets. Large scale comparisons allow us to move beyond, as Aubrey Cannon (2001: 180) has written, "general models of Northwest Coast subsistence" based on very few sites. Thus, it is no longer the case that "patterns evident at one or two sites" can be used to "characterize trends for the entire region" (Cannon, 2001: 180). The data compiled herein broaden our interpretations beyond a limited number of sites and handful of well-known species. As one of us has stated previously "while a master narrative of long-term subsistence change under-writing cultural complexity might be appealing, the diversity of human-environment interactions over 10,000 years of Northwest Coast history is more variable and complicated" (Moss, 2012a: 2). More detailed research questions can be asked of species associations, storage and harvest technologies, nutritional qualities, seasonal fluctuations in the availability of fish, biogeographic ranges, and a host of other dimensions. Additionally, examination of fish taxa that are not among the top 15 most abundant and ubiquitous is warranted as frequency of use can be spatially restricted to particular regions, sample types and/or time periods that are scale dependent. For example, Bluefin tuna (*Thunnus orientalis*) are recovered during large scale excavations on western Vancouver Island (e.g., Crockford, 1997) but are not present in small volume fine screened column samples. Similarly, Pacific mackerel (*Scomber japonicus*) were identified at a single archaeological site on Haida Gwaii (Christensen and Stafford, 2005: 255); they likely indicate anomalously warm waters, perhaps associated with El Niño like conditions. Further attention is needed to retrospectively scrutinize such anomalies, test the reliability of taxonomic identifications with ancient DNA and other means, as well as refine species identifications within osteologically indistinguishable genera using ancient DNA and geochemical data as appropriate (e.g., Jones and Gabe, 2015; Rodrigues et al., 2014; Wolverton, 2013).

Rather than evaluating the role of one particular taxon and/or time period, one of the benefits of the analysis of ubiquity presented here is that it can be used to examine a range of species across multiple locations and time scales. Ubiquity offers a different perspective on relative abundance data and can be examined to explore whether taxa that have high relative abundance or rank order are also found consistently within a site deposit or series of sites. A disjuncture between these abundance measures may indicate sample biases such as numerous fish occurring from one particular context in a site (an individual layer with a hyper-abundance of remains) or it may reflect seasonal differences in site use or restricted availability of certain taxa. Alternatively, a high ubiquity value may indicate extended use of stored fish consumed regularly over the course of a year, perhaps indicated by the ubiquity and abundance of salmons and herring in this analysis.

A considerable body of research has concentrated on evaluating temporal change in Northwest Coast subsistence practices, particularly identifying periods of punctuated and prolonged environmental change (e.g., Butler and Campbell 2004; Matson, 1992; Monks, 2006; Orchard and Clark, 2005). Less research has focused on how place and the ecological qualities of microenvironments structure patterning in regions and at specific sites (Moss, 2012a). The insights generated from this analysis are based on a significantly greater amount of information than any previous study, including data from a wide variety of habitats and coastal settings collectively representing millennia of fishing across a roughly 2000 km north–south distance from southern Oregon to southeast Alaska. Such a large scale perspective relies on concerted archaeological research effort and recognition that fine screen recovery and quantification efforts are vital to documenting and interpreting archaeological fisheries information on the Northwest Coast. Future research will aim to further assess sampling effort, including measures of excavated volume, temporal variability, as well as refine efforts to derive biomass estimates from such data.

5. Conclusion

This study identifies a broad range of frequently utilized fish species as measured by ubiquity and relative abundance from fine screened archaeological deposits across the Northwest Coast. While this analysis of fish remains cannot fully encompass the richness, dynamism, and complexity of Indigenous fishery practices spanning millennia of cultural and environmental history, these data form a significantly expanded basis for assessing archaeological fisheries data and surpass previous observations. This study additionally reveals that Indigenous fishers possessed detailed knowledge of the habitats and behaviours of dozens of fish species found in the region's waters and developed cultural preferences for targeting certain taxa. These preferences reveal spatial patterning within geographically and culturally distinct regions. Such observations highlight the importance of both cultural and ecological factors that combine to influence and guide fishery harvest choices by Indigenous peoples at multiple spatial and temporal scales (Moss, 2012a; Orchard and Szpak, 2015). Indeed, the development of fishing tenure systems, Indigenous governance practices, as well as the construction and maintenance of harvesting infrastructure all contributed to amplifying cultural patterns of certain food harvesting, storage, and consumption practices. This study has added taxonomic detail to the history of fishing over a broad area and a vast extent of human history. Future research will aim to further explore and refine the broad chronological and spatial patterning identified here and develop more specific quantitative metrics for interpreting archaeological abundance observations into more anthropologically and ecologically meaningful estimates. Such work will also benefit from investigating temporal trends and species composition at the scale of individual sites and incorporating more detailed ethnographic accounts of traditional fishing and fish processing, and the cultural and spiritual values that inform these practices. Fish and fishing were clearly central to life everywhere on the Northwest Coast.

Acknowledgements

Many thanks to Mike Blake, Virginia Butler, Aubrey Cannon, Susan Crockford, Gay Frederick, Dana Lepofsky, Quentin Mackie, Charles Menzies, Trevor Orchard, Rudy Reimer, Kisha Supernant, and Becky Wigen for sharing data and perspective over many years. We are additionally grateful to the session organizers and special issue editors Dr. Atilio Francisco J. Zangrando and Philippe Béarez for their invitation to submit this paper and the 2014 International Council for Archaeozoology conference organizing committee in San Rafael, Argentina for hosting the symposium in which this paper was initially presented. McKechnie acknowledges the support of a postdoctoral fellowship from the Social Sciences and Humanities Council of Canada supported by the University of Oregon and the Hakai Institute at Simon Fraser University (Grant # 756-2013-0836-A28). Moss expresses special thanks to Virginia Butler (Portland State University), Tom Thornton (Oxford), and J. Tait Elder (ICF International) whose work with her on the *Herring Synthesis* project helped inspire this effort.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jasrep.2016.04.006.

References

Anderson, L., Abbott, M.B., Finney, B.P., Burns, S.J., 2005. Regional atmospheric circulation change in the North Pacific during the Holocene inferred from lacustrine carbonate oxygen isotopes, Yukon Territory, Canada. Quat. Res. 64 (1), 21–35.

Arbuckle, B.S., Kansa, S.W., Kansa, E., Orton, D., Çakırlar, C., Gourichon, L., Atici, L., Galik, A., Marciniak, A., Mulville, J., Buitenhuis, H., Carruthers, D., Cupere, B.D., Demirergi, A., Frame, S., Helmer, D., Martin, L., Peters, J., Pöllath, N., Pawłowska, K., Russell, N., Twiss, K., Würtenberger, D., 2014. Data sharing reveals complexity in the westward spread of domestic animals across neolithic Turkey. PLoS One 9 (6), e99845.

Barrett, J.H., Locker, A.M., Roberts, C.M., 2004. Dark age economics revisited: the English fish bone evidence AD 600–1600. Antiquity 78 (301), 618–636.

Barrientos, G., Catella, L., Oliva, F., 2015. The spatial structure of lithic landscapes: the late Holocene record of east-central Argentina as a case study. J. Archaeol. Method Theory 22 (4), 1151–1192.

Berkeley, S.A., Chapman, C., Sogard, S.M., 2004. Maternal age as a determinant of larval growth and survival in a marine fish, *Sebastes melanops*. Ecology 85 (5), 1258–1264.

Blackman, M.B., 1990. Haida: traditional culture. In: Suttles, W.P. (Ed.), Northwest Coast. Smithsonian Institution, Washington D.C., pp. 240–260.

Bowers, P.M., Moss, M.L., 2001. The North Point wet site and the subsistence importance of Pacific cod on the northern Northwest Coast. In: Gerlarch, C., Murrary, M.S. (Eds.), People and Culture in Northern north American: Essays in Honor of R. Dale Guthrie. BAR International Series, Oxford, pp. 159–177.

Braje, T.J., Rick, T., Erlandson, J.M., 2012. Rockfish in the long view: applied zooarchaeology and conservation of Pacific red snapper (genus *Sebastes*) in southern California. In: Wolverton, S., Lyman, R.L. (Eds.), Conservation Biology and Applied Zooarchaeology. University of Arizona Press, Tucson, pp. 157–178.

Brewster, N., Martindale, A., 2011. An archaeological history of Holocene fish use in the Dundas Island Group, British Columbia. In: Moss, M.L., Cannon, A. (Eds.), The Archaeology of North Pacific Fisheries. University of Alaska Press, Fairbanks, pp. 247–264.

Butler, V.L., Campbell, S.K., 2004. Resource intensification and resource depression in the Pacific northwest of North America: a zooarchaeological review. J. World Prehistory 18 (4), 327–405.

Butler, V.L., Chatters, J.C., 1994. The role of bone density in structuring prehistoric salmon bone assemblages. J. Archaeol. Sci. 21 (3), 413–424.

Byram, R.S., 2002. Brush Fences and Basket Traps: The Archaeology and Ethnohistory of Tidewater Weir Fishing on the Oregon Coast (PhD Dissertation) Department of Anthropology, University of Oregon.

Caldwell, M., 2011. Fish traps and shell middens at Comox Harbour, British Columbia. In: Moss, M.L., Cannon, A. (Eds.), The Archaeology of North Pacific Fisheries. University of Alaska Press, Fairbanks, pp. 235–245.

Campana, S.E., Jones, C., McFarlane, G.A., Myklevoll, S., 2006. Bomb dating and age validation using the spines of spiny dogfish (*Squalus acanthias*). Environ. Biol. Fish 77, 327–336.

Cannon, A., 1995. The ratfish and marine resource deficiencies on the Northwest Coast. Can. J. Archaeol. 19, 49–60.

Cannon, A., 2000a. Assessing variability in Northwest Coast salmon and herring fisheries: bucket-auger sampling of shell midden sites on the central coast of British Columbia. J. Archaeol. Sci. 27 (8), 725–737.

Cannon, A., 2000b. Faunal remains as economic indicators on the Pacific Northwest Coast. In: Rowly-Conwy, P. (Ed.), Animal Bones, Human Societies. Oxbow Books, Oxford, pp. 49–57.

Cannon, A., 2001. Was salmon important in Northwest Coast prehistory? In: Gerlach, S.C., Murray, M.S. (Eds.), People and Wildlife in Northern North America: Essays in Honor of R. Dale Guthrie. British Archaeological Reports, Oxford, UK, pp. 178–187

Cannon, A., Yang, D.Y., Speller, C.F., 2011. Site-specific salmon fisheries on the central coast of British Columbia. In: Moss, M.L., Cannon, A. (Eds.), The Archaeology of North Pacific Fisheries. University of Alaska Press, Fairbanks, pp. 117–148.

Carlson, R.L., 2003. Human response to environmental change on the coast of British Columbia. Paper presented at the Fifth World Archaeological Congress, Theme: Past Human Environments in Modern Contexts, Washington D.C.

Casteel, R.W., 1976. Comparison of column and whole unit samples for recovering fish remains. World Archaeol. 8 (2), 192–196.

Christensen, T., Stafford, J., 2005. Raised beach archaeology in Northern Haida Gwaii: Preliminary results from the Cohoe Creek Site. In: Fedje, D.W., Mathewes, R.W. (Eds.), Haida Gwaii: Human History and Environment from the Time of Loon to the Time of the Iron People. UBC Press, Vancouver, pp. 245–273.

Christensen, T., Stafford, J., McKechnie, I., 2010. Masset health centre site GaUa-18, Haida Gwaii: excavation and monitoring report, permit 2005-408. Coast Interior Archaeology report submitted to the Council of the Haida Nation and the BC Archaeology Branch, Victoria.

Conolly, J., Colledge, S., Dobney, K., Vigne, J.-D., Peters, J., Stopp, B., Manning, K., Shennan, S., 2011. Meta-analysis of zooarchaeological data from SW Asia and SE Europe provides insight into the origins and spread of animal husbandry. J. Archaeol. Sci. 38 (3), 538–545.

Coupland, G., Stewart, K.M., Patton, K., 2010. Do you never get tired of salmon? Evidence for extreme salmon specialization at Prince Rupert Harbour, British Columbia. J. Anthropol. Archaeol. 29 (2), 189–207.

Crockford, S.J., 1997. Archaeological evidence of large northern bluefin tuna, *Thunnus thynnus*, in coastal waters of British Columbia and northern Washington. Fish. Bull. 95 (1), 11–24.

Crockford, S.J., 2014. Analysis of the vertebrate fauna from neighbouring Prince Rupert Harbour sites GbTo 54 and GbTo 13: prehistoric mountain goat capital of North America. In: Eldridge, M., Parker, A., Mueller, C., Crockford, S.J. (Eds.), Archaeological Investigations at Ya asqalu'i/Kaien Siding, Prince Rupert Harbour, Millennia Research Limited Report Prepared for CN Rail and Submitted to CN Environmental

Assessment, Lax Kw'alaams First Nation, Metlakatla First Nation, Victoria, BC (pp. A3-1–A3-313).
Croes, D.R., 1997. The north-central cultural dichotomy on the Northwest Coast of North America: its evolution as suggested by wet-site basketry and wooden fish-hooks. Antiquity 71, 594–615.
Croes, D.R., Hackenberger, S., 1988. Hoko River archaeological complex: modeling prehistoric Northwest Coast economic evolution. In: Issac, B.L. (Ed.), Prehistoric Economies of the Pacific Northwest Coast. JAI Press, Greenwich, pp. 19–85.
Curtis, E.S., 1913. The North American Indian, Volume 9: Salishan Tribes of the Coast. Johnson Reprint Co., New York.
Department of Fisheries & Oceans Canada, 2011. Surfperch Integrated Fisheries Management Plan. Pacific Region Integrated Fisheries Management Plan: Surf and Pile Perch, September 1 to December 31, 2011 Fisheries and Oceans Canada Pacific Region, Nanaimo.
Dick, S.J., Shurin, J.B., Taylor, E.B., 2014. Replicate divergence between and within sounds in a marine fish: the copper rockfish (*Sebastes caurinus*). Mol. Ecol. 23, 575–590.
Driver, J.C., 1993. Zooarchaeology in British Columbia. BC Stud. (99), 77–104.
Drucker, P., 1937. The Tolowa and their southwest Oregon kin. University of California Publications in American Archaeology and Ethnology 36(4), pp. 221–300.
Drucker, P., 1951. The Northern and Central Nootkan Tribes. Smithsonian Institution, Washington D.C.
Drucker, P., 1965. Cultures of the North Pacific Coast. Chandler Publishing Company, Scranton.
Eells, M., 1887. The Twana, Chemakum, and Klallam Indians of Washington Territory. Smithsonian Annual Report. Smithsonian Institution, Washington DC, pp. 605–681.
Enloe, J.G., 2003. Food sharing past and present: archaeological evidence for economic and social interactions. Before Farming 1 (1), 1–23.
Eschmeyer, W.N., Herald, E.S., Hammann, H., 1983. A Field Guide to Pacific Coast Fishes of North America: From the Gulf of Alaska to Baja. Houghton Mifflin, Boston, California.
Fedje, D.W., Mackie, A.P., Wigen, R.J., Mackie, Q., Lake, C., 2005. Kilgii Gwaay: an early maritime site in the south of Haida Gwaii. In: Fedje, D.W., Mathewes, R.W. (Eds.), Haida Gwaii: Human History and Environment from the Time of Loon to the Time of the Iron People. UBC Press, Vancouver, pp. 187–203.
Fladmark, K.R., 1975. A Paleoecological Model for Northwest Coast Prehistory. National Museums of Canada, Ottawa.
Freeman, M., 2015. Brookings becomes a Lingcod Haven. The Medford Mail Tribune (July 28).
Frid, A., Marliave, J., Heithaus, M.R., 2012. Interspecific variation in life history relates to antipredator decisions by marine mesopredators on temperate reefs. PLoS One 7 (6), e40083.
Gedosch, T.F., 1968. A note on the dogfish oil industry of Washington Territory. Pac. Northwest Q. 59 (2), 100–102.
Glavin, T., 2000. The Last Great Sea: A Voyage Through the Human and Natural History of the North Pacific Ocean. Greystone Books, Vancouver.
Gobalet, K.W., Schulz, P.D., Wake, T.A., Siefkin, N., 2004. Archaeological perspectives on Native American fisheries of California, with emphasis on steelhead and salmon. Trans. Am. Fish. Soc. 133, 801–833.
Gould, R.A., 1978. Ecology and adaptive response among the Tolowa Indians of Northwestern California. J. Calif. Anthropol. 2 (2), 148–170.
Grayson, D.K., 1984. Quantitative Zooarchaeology: Topics in the Analysis of Archaeological Faunas. Academic Press, New York.
Grier, C., Flanigan, K., Winters, M., Jordan, L.G., Lukowski, S., Kemp, B.M., 2013. Using ancient DNA identification and osteometric measures of archaeological Pacific salmon vertebrae for reconstructing salmon fisheries and site seasonality at Dionisio Point, British Columbia. J. Archaeol. Sci. 40 (1), 544–555.
Ham, L.C., 1982. Seasonality, Shell Midden Layers, and Coast Salish Subsistence Activities at the Crescent Beach Site, DgRr-1 (PhD. Dissertation) Department of Anthropology and Sociology, University of British Columbia.
Hanotte, O., Bradley, D.G., Ochieng, J.W., Verjee, Y., Hill, E.W., Rege, J.E.O., 2002. African pastoralism: genetic imprints of origins and migrations. Science 296 (5566), 336–339.
Hanson, D.K., 1991. Late Prehistoric Subsistence in the Strait of Georgia Region of the Northwest Coast (PhD Dissertation) Department of Archaeology, Simon Fraser University.
Hart, J.L., 1973. Pacific Fishes of Canada. Fisheries Research Board of Canada, Ottawa.
Hewes, G.W., 1973. Indian fisheries productivity in precontact time in the Pacific salmon area. Northwest Anthropol. Res. Notes 7 (2), 133–155.
Huber, H.R., Jorgensen, J.C., Butler, V.L., Baker, G., Stevens, R., 2011. Can salmonids (*Oncorhynchus* spp.) be identified to species using vertebral morphometrics? J. Archaeol. Sci. 38 (1), 136–146.
Jewitt, J.R., 1807. A journal kept at Nootka Sound. Printed for the Author, Boston. Digital Copy of Original Obtained from Canadiana.org October 16, 2003.
Jones, E.L., Gabe, C., 2015. The promise and peril of older collections: meta-analyses and the zooarchaeology of late prehistoric/early historic New Mexico. Open Quaternary 1 (6), 1–13.
Ketchen, K.S., 1986. The Spiny Dogfish (*Squalus acanthias*) in the Northeast Pacific and a History of Its Utilization. Department of Fisheries and Oceans, Canada, Ottawa.
King, J.R., McFarlane, G.A., Jones, S.R.M., Gilmore, S.R., Abbott, C.L., 2012. Stock delineation of migratory and resident Pacific hake in Canadian waters. Fish. Res. 111 (2), 19–30.
Kopperl, R.E., 2001. Herring use in southern Puget Sound: analysis of fish remains at 45-KI-437. Northwest Anthropol. Res. Notes 35 (1), 1–20.
Kroeber, A.L., 1923. American culture and the Northwest Coast. Am. Anthropol. 25 (1), 1–20.
de Laguna, F., 1972. Under Mount Saint Elias: The History and Culture of the Yakutat Tlingit: Part One. Smithsonian Institution, Washington D.C.
Langdon, S.J., 1979. Comparative Tlingit and Haida adaptation to the west coast of the Prince of Wales Archipelago. Ethnology 18 (2), 101–119.
Langdon, S.J., 2006. Tidal pulse fishing: selective traditional Tlingit salmon fishing techniques on the west coast of the Prince of Wales archipelago. In: Menzies, C.R. (Ed.), Traditional Ecological Knowledge and Natural Resource Management. University of Nebraska Press, Lincoln, pp. 21–46.
Last, P.R., White, W.I.T., Pogonoski, J.J., 2007. Descriptions of New Dogfishes of the Genus '*Squalus*' (Squaloidea: Squalidae), CSIRO Marine and Atmospheric Research. Hobart, Tasmania.
Lepofsky, D., Lyons, N., 2003. Modeling ancient plant use on the Northwest Coast: towards an understanding of mobility and sedentism. J. Archaeol. Sci. 30 (11), 1357–1371.
Levin, P.S., Holmes, E.E., Piner, K.R., Harvey, C.J., 2006. Shifts in a Pacific Ocean fish assemblage: the potential influence of exploitation. Conserv. Biol. 20 (4), 1181–1190.
Love, M.S., 1991. Probably More Than You Want to Know About the Fishes of the Pacific Coast. Really Big Press, Santa Barbara.
Love, M.S., Yoklavich, M., Thorsteinson, L.K., 2002. The Rockfishes of the Northeast Pacific. University of California Press, Berkeley.
Lyman, R.L., 2008. Quantitative Paleozoology. Cambridge University Press, Cambridge.
Lyman, R.L., Ames, K.M., 2004. Sampling to redundancy in zooarchaeology: lessons from the Portland Basin, northwestern Oregon and southwestern Washington. J. Ethnobiol. 24 (2), 329–346.
Marín-Arroyo, A.B., 2009. Assessing what lies beneath the spatial distribution of a zooarchaeological record: the use of GIS and spatial correlations at El Mirón Cave (Spain). Archaeometry 51 (3), 506–524.
Markel, R.W., 2011. Rockfish Recruitment and Trophic Dynamics on the West Coast of Vancouver Island: Fishing, Ocean Climate, and Sea Otters (PhD Dissertation) Department of Zoology, University of British Columbia.
Martell, S., Wallace, S.S., 1998. Estimating historical lingcod biomass in the Strait of Georgia. In: Pauly, D., Pitcher, T.J., Preikshot, D. (Eds.), Back to the Future: Reconstructing the Strait of Georgia Ecosystem., No. 5, UBC Fisheries Centre. University of British Columbia, pp. 45–48.
Martell, S., Walters, C.J., Wallace, S.S., 2000. The use of marine protected areas for conservation of lingcod (*Ophiodon elongatus*). Bull. Mar. Sci. 66 (3), 729–743.
Matson, R.G., 1992. The evolution of Northwest Coast subsistence. In: Croes, D.R., Hawkins, R., Issac, B.L. (Eds.), Research in Economic Anthropology. JAI Press Inc., Greenwich, CT, pp. 367–428.
McFarlane, G.A., King, J.R., 2006. Age and growth of big skate (*Raja binoculata*) and longnose skate (*Raja rhina*) in British Columbia waters. Fish. Res. 78 (2–3), 169–178.
McFarlane, G.A., King, J.R., Beamish, R.J., 2000. Have there been recent changes in climate? Ask the fish. Prog. Oceanogr. 47, 147–169.
McKechnie, I., 2005. Column sampling and the archaeology of small fish at Ts'ishaa. In: McMillan, A.D., St. Claire, D.E. (Ed.), Ts'ishaa: Archaeology and Ethnography of a Nuu-chah-nulth Origin Site in Barkley Sound. Archaeology Press, Simon Fraser University, Burnaby, BC, pp. 206–223.
McKechnie, I., 2007. Investigating the complexities of sustainable fishing at a prehistoric village on western Vancouver Island, British Columbia, Canada. J. Nat. Conserv. 15 (3), 208–222.
McKechnie, I., 2012. Zooarchaeological analysis of the indigenous fishery at the Huu7ii Big House and Back Terrace, Huu-ay-aht Territory, Southwestern Vancouver Island. In: McMillan, A.D., St. Claire, D.E. (Eds.), Huu7ii: Household Archaeology at a Nuu-chah-nulth Village Site in Barkley Sound. Archaeology Press, Simon Fraser University, Burnaby, BC, pp. 154–186.
McKechnie, I., Wigen, R.J., 2011. Toward a Historical Ecology of Pinniped and Sea Otter Hunting Traditions on the Coast of Southern British Columbia. In: Braje, T.J., Rick, T.C. (Eds.), Human Impacts on Seals, Sea Lions, and Sea Otters: Integrating Archaeology and Ecology in the Northeast Pacific. University of California Press, Berkeley, pp. 129–166.
McKechnie, I., 2013. An Archaeology of Food and Settlement on the Northwest Coast (PhD Dissertation) Department of Anthropology, University of British Columbia.
McKechnie, I., Lepofsky, D., Moss, M.L., Butler, V.L., Orchard, T.J., Coupland, G., Foster, F., Caldwell, M., Lertzman, K., 2014. Archaeological data provide alternative hypotheses on Pacific herring (*Clupea pallasii*) distribution, abundance, and variability. Proc. Natl. Acad. Sci. U.S.A. 111 (9), E807–E816.
Menzies, C.R., 2012. The disturbed environment: the indigenous cultivation of salmon. In: Colmnbi, B.J., Brooks, J.E. (Eds.), Keystone Nations: Indigenous Peoples and Salmon Across the North Pacific. School for Advanced Research, Santa Fe, pp. 162–182.
Mitchell, D.H., Donald, L., 2001. Sharing resources on the Pacific Northwest Coast of North America: the case of the eulachon fishery. Anthropologica 43 (1), 19–35.
Monks, G.G., 1987. Prey as bait: the Deep Bay example. Can. J. Archaeol. 11 (1), 119–142.
Monks, G.G., 2006. The fauna from Ma'acoah (DfSi-5), Vancouver Island, British Columbia: an interpretive summary. Can. J. Archaeol. 30 (2), 215–244.
Monks, G.G., Orchard, T.J., 2011. Comment on Cannon and Yang: early storage and sedentism on the Pacific Northwest Coast. Am. Antiq. 76 (3), 573–584.
Moody, M., Pitcher, T.J., 2010. Eulachon (*Thaleichthys pacificus*): past and present. Fisheries Centre Research Reports Vol 18(2). Vancouver, UBC Fisheries Centre.
Moss, M.L., 1989. Archaeology and Cultural Ecology of the Prehistoric Angoon Tlingit (PhD Dissertation) Department of Anthropology, University of California, Santa Barbara.
Moss, M.L., 2011. Pacific cod in southeast Alaska: the "cousin" of the fish that changed the world. In: Moss, M.L., Cannon, A. (Eds.), The Archaeology of North Pacific Fisheries. University of Alaska Press, Fairbanks, pp. 149–169.
Moss, M.L., 2012a. Understanding variability in Northwest Coast faunal assemblages: beyond economic intensification and cultural complexity. J. Island Coastal Archaeol. 7 (1), 1–22.
Moss, M.L., 2012b. Fishing traps and weirs on the Northwest Coast of North America: new approaches and new insights. In: Menotti, F., O'Sullivan, A. (Eds.), The Oxford Handbook of Wetland Archaeology. Oxford University Press, Oxford, pp. 323–337.
Moss, M.L., 2015. An ethnozooarchaeological study of land otters and people at Kit'n'Kaboodle (49-DIX-46), Dall Island, Alaska. BC Stud. (187), 21–50.

Moss, M.L., Butler, V.L., Elder, J.T., 2011. Herring bones in southeast Alaska archaeological sites. In: Moss, M.L., Cannon, A. (Eds.), The Archaeology of North Pacific Fisheries. University of Alaska Press, Fairbanks, pp. 281–291.

Moss, M.L., Cannon, A., 2011a. The Archaeology of North Pacific Fisheries. University of Alaska Press, Fairbanks.

Moss, M.L., Cannon, A., 2011b. The archaeology of North Pacific fisheries: an introduction. In: Moss, M.L., Cannon, A. (Eds.), The Archaeology of North Pacific Fisheries. University of Alaska Press, Fairbanks, pp. 1–15.

Moss, M.L., Judd, K.G., Kemp, B.M., 2014. Can salmonids (*Oncorhynchus* spp.) be identified to species using vertebral morphometrics? A test using ancient DNA from Coffman Cove, Alaska. J. Archaeol. Sci. 41 (1), 879–889.

Moss, M.L., Rodrigues, A., Speller, C.F., Yang, D.Y., 2016. The historical ecology of Pacific herring: tracing Alaska native use of a forage fish. J. Archaeol. Sci. Reports 8, 502–510.

Moss, M.L., Minor, R., Page-Botelho, K., n.d. Where have all the little fish gone? Studying anchovies and surf smelt on the Oregon Coast: a view from Tcetxo.

Orchard, T.J., 2007. Otters and Urchins: Continuity and Change in Haida Economy during the Late Holocene and Maritime Fur Trade Periods (PhD. Dissertation) Department of Anthropology, University of Toronto.

Orchard, T.J., Szpak, P., 2015. Zooarchaeological and isotopic insights into locally variable subsistence patterns: a case study from Late Holocene Southern Haida Gwaii, British Columbia. BC Stud. 187, 129–153.

Orchard, T.J., Clark, T.N., 2005. Multidimensional scaling of Northwest Coast faunal assemblages: a case study from southern Haida Gwaii, British Columbia. Can. J. Archaeol. 29 (2), 88–112.

Orchard, T.J., Clark, T.N., 2014. Shell middens, vertebrate fauna, and Northwest Coast subsistence intensification and generalization of prehistoric Northwest Coast economies. In: Roksandic, M., de Souza, S.M., Eggers, S., Burchell, M., Klokler, D.M. (Eds.), The Cultural Dynamics of Shell-Matrix Sites. University of New Mexico Press, Albuquerque, pp. 199–212.

Orchard, T.J., Szpak, P., 2011. Identification of salmon species from archaeological remains on the Northwest Coast. In: Moss, M.L., Cannon, A. (Eds.), The Archaeology of North Pacific Fisheries. University of Alaska Press, Fairbanks, pp. 17–29.

Orchard, T.J., Wigen, R.J., 2008. Halibut use on the Northwest Coast: reconciling ethnographic, ethnohistoric, and archaeological data. Paper presented at the 61st Annual Northwest Anthropological Conference, Victoria, BC.

Orton, D.C., Morris, J., Locker, A., Barrett, J.H., 2014. Fish for the city: meta-analysis of archaeological cod remains and the growth of London's northern trade. Antiquity 88 (340), 516–530.

Partlow, M.A., Kopperl, R.E., 2011. Processing the patterns: elusive archaeofaunal signatures of cod storage on the North Pacific coast. In: Moss, M.L., Cannon, A. (Eds.), The Archaeology of North Pacific Fisheries. University of Alaska Press, Fairbanks, pp. 195–218.

Pearsall, D., 2000. Paleoethnobotany: A Handbook of Procedures. second ed. Academic Press, New York.

Poulsen, B., 2008. Dutch Herring: An Environmental History, C. 1600–1860. Amsterdam University Press, Amsterdam.

Ressler, P.H., Holmes, J.A., Fleischer, G.W., Thomas, R.E., Cooke, K.C., 2010. Pacific hake, *Merluccius productus*, autecology: a timely review. Mar. Fish. Rev.

Rick, T.C., Erlandson, J.M., Glassow, M.A., Moss, M.L., 2002. Evaluating the economic significance of sharks, skates, and rays (Elasmobranchs) in prehistoric economies. J. Archaeol. Sci. 29, 111–122.

Robinson, C.K.L., Martel, G., Yakimishyn, J., 2007. A Guide to Fishes and Invertebrates Found in Eelgrass Meadows (*Zostera marina*) in National Park Reserves on the Pacific Coast of Canada. Parks Canada, Ottawa.

Rodrigues, A., McKechnie, I., Zimmerman, K., Yang, D.Y., 2014. Species identification of archaeological rockfish (*Sebastes* spp.) in the Northeast Pacific: new insights from ancient DNA. Poster presented at the 67th Northwest Anthropological Conference. Western Washington University, Bellingham, WA.

Sartori, J., Colasurdo, M.B., Santiago, F., 2014. Zooarchaeology in the Paraná River flood plain: GIS implementation at a regional scale. J. Anthropol. Archaeol. 2 (2), 77–106.

Smethurst, N.H., 2014. Inscribed on the Landscape: Stories of Stone Traps and Fishing in Laxyuup Gitxaała (MA Thesis) Department of Anthropology, University of British Columbia.

Smith, M.W., 1940 [1969]. The Puyallup-Nisqually. AMS ed. Columbia University Press, New York.

Smith, R.E., 2008. Structural Bone Density of Pacific Cod and Halibut: Taphonomic and Archaeological Implications (MA Thesis) Department of Anthropology, Portland State University.

Smith, R.E., Butler, V.L., Orwoll, S., Wilson-Skogen, C., 2011. Pacific cod and salmon structural bone density: implications for interpreting butchering patterns in North Pacific archaeofaunas. In: Moss, M.L., Cannon, A. (Eds.), The Archaeology of North Pacific Fisheries. University of Alaska Press, Fairbanks, pp. 45–56.

Speller, C.F., Hauser, L., Lepofsky, D., Peterson, D., Moore, J., Rodrigues, A., Moss, M.L., McKechnie, I., Yang, D.Y., 2012. High potential for using DNA from ancient herring bones to inform modern fisheries management and conservation. PLoS One 7 (11), e51122.

Stewart, H., 1977. Indian Fishing: Early Methods on the Northwest Coast. Douglas & McIntyre, Vancouver.

Stewart, H., 1996. Stone, Bone, Antler & Shell: Artifacts of the Northwest Coast. 2nd rev. Douglas & McIntyre, Vancouver.

Stewart, K.M., 2001. Fauna from Prince Rupert Harbour sites, British Columbia: preliminary findings. Canadian Zooarchaeology 19, 12–15.

Stewart, K.M., Wigen, R.J., 2003. Screen size and the need for reinterpretation: a case study from the Northwest Coast. Florida Museum of Natural History Bulletin 44(1), pp. 27–34.

Suttles, W.P., 1962. Variation in habitat and culture on the Northwest Coast. Internationalen Amerikanistenkongresses Wien 1960. Verlag Ferdinand Berger, Vienna, pp. 522–537.

Suttles, W.P., 1966. The Subsistence Base on the Northwest Coast. Manuscript on File with the Audrey and Harry Hawthorne Reading Room and Lab of Archaeology Reading Room. University of British Columbia, Musuem of Anthropology.

Suttles, W.P., 1974. The Economic Life of the Coast Salish of Haro and Rosario Straits. Garland Pub Inc., New York.

Swan, J.G., 1857. The Northwest Coast, or Three Years' Residence in Washington Territory. Harper & Brothers, New York.

Swan, J.G., 1870. The Indians of Cape Flattery. Smithsonian, Washington D.C.

Szpak, P., Orchard, T.J., Salomon, A.K., Gröcke, D.R., 2013. Regional ecological variability and impact of the maritime fur trade on nearshore ecosystems in southern Haida Gwaii (British Columbia, Canada): evidence from stable isotope analysis of rockfish (*Sebastes* spp.) bone collagen. Archaeol. Anthropol. Sci. 5 (2), 159–182.

Therriault, T.W., McDiarmid, A.N., Wulff, W., Hay, D.E., 2002. Review of northern anchovy (*Engraulis mordax*) biology and fisheries, with suggested management options for British Columbia. DFO Pacific Scientific Advice Review Committee Working Paper P2002-11, Ottawa.

Trost, T., Schalk, R.F., Wolverton, M., Nelson, M.A., 2011. Patterns of fish usage at a late prehistoric Northern Puget Sound shell midden. In: Moss, M.L., Cannon, A. (Eds.), The Archaeology of North Pacific Fisheries. University of Alaska Press, Fairbanks, pp. 265–280.

Turner, N.J., 1982. Traditional use of devil's-club (*Oplopanax horridus*; Araliaceae) by native peoples in western North America. J. Ethnobiol. 2 (1), 17–38.

Turner, N.J., Thomas, J., Carlson, B.F., Ogilvie, R., 1983. Ethnobotany of the Nitinaht Indians of Vancouver Island, Royal BC Museum, Victoria.

Tushingham, S., Spurling, A.M., Carpenter, T.R., 2013. The Sweetwater site: archaeological recognition of surf fishing and temporary smelt camps on the north coast of California. J. California and Great Basin Anthropology 33 (1), 25–37.

VanDerwarker, A., 2010. Simple measures for integrating plant and animal remains. In: VanDerwarker, A., Peres, T.M. (Eds.), Integrating Zooarchaeology and Paleoethnobotany: A Consideration of Issues, Methods, and Cases. Springer, New York, pp. 65–74.

White, C., 2003. How to Catch Bottomfish. Heritage House, Surrey.

Wigen, R.J., Stucki, B.R., 1988. Taphonomy and stratigraphy in the interpretation of economic patterns at Hoko River rockshelter. In: Isaac, B.L. (Ed.), Research in Economic Anthropology, Supplement 3: Prehistoric Economies of the Pacific Northwest Coast. JAI Press, Greenwich, pp. 87–146.

Wissler, C., 1914. Material cultures of the North American Indians. Am. Anthropol. 16 (3), 447–505.

Wolverton, S., 2013. Data quality in zooarchaeological faunal identification. J. Archaeol. Method Theory 20 (3), 381–396.

Wolverton, S.J., Dombrosky, J., Lyman, R.L., 2014. Practical significance: ordinal scale data and effect size in zooarchaeology. Int. J. Osteoarchaeol. 26 (2), 255–265.

Wright, C.A., Dallimore, A., Thomson, R.E., Patterson, R.T., Ware, D.M., 2005. Late Holocene paleofish populations in Effingham Inlet, British Columbia, Canada. Palaeogeogr. Palaeoclimatol. Palaeoecol. 224 (4), 367–384.