Fisheries at a new scale: The contributions of archaeological fish scales in understanding Indigenous fisheries in Wuikinuxv First Nation territory and beyond

by

Alyssa Megan Ball
B.A. (Distinction), Simon Fraser University, 2017

A Thesis Submitted in Partial Fulfillment
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We acknowledge with respect the Lekwungen peoples on whose traditional territory the university stands and the Songhees, Esquimalt, and W̱SÁNEĆ peoples whose historical relationships with the land continue to this day.

Supervisory Committee

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Abstract

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Archaeological fisheries information represented in fish scales provides relative abundance and age-at-harvest data that can assist in understanding a range of culturally vital Indigenous fisheries. In this thesis, I undertake fish scale analysis (squamatology) to explore fish scale preservation in twelve coastal archaeological sites from two First Nations' territories in coastal British Columbia (Wuikinuxv and Tseshaht). These data demonstrate that fish scales are more readily preserved in coastal archaeological deposits than is currently appreciated and can refine species-level identification of culturally significant Indigenous fisheries including forage fish and salmon. Fish scales can additionally generate baseline data on age-at-harvest in Pacific herring and when considered alongside other fisheries records provide relative abundance records for forage fisheries in Wuikinuxv territory that span the last 3000 years. This study additionally temporally anchors eulachon fishing along the Wannock River by at least 3000 years ago extending upon previous archaeological assessments by over 2000 years. I apply the concept of two-eyed seeing, as envisaged by Mi'kmaw elder Dr. Albert Marshall, to recognize the strengths of Indigenous and Western perspectives in developing decolonial practices for sharing archaeological fisheries data with community-based fisheries managers. Two-eyed seeing highlights the strength of archaeological data as deep time records of Indigenous fisheries that can be anchored by Indigenous knowledge including cultural stewardship and fishing practices. In this case study, I provide baseline fisheries data co-derived from archaeological and Indigenous knowledges including deep time accounts of relative abundance and traditional harvest methods that community-based managers may wish to use on their terms to pursue future activities of restoration, renewal, and affirmation of traditional fishing practices.

Table of Contents

List of Tables

List of Figures

Acknowledgments

In recognition of the contributions of my collaborators, ‘we’ is used as the subject in Chapters 2 and 3. In line with academic requirements, ‘I’ is used as a subject throughout the Introduction and Conclusion of this document. However, in reality, this ‘I’ represents an entire team of people who have supported both this research and myself directly. This is to say that the completion of this thesis is largely a testament to the efforts of the communities, landscapes, and relationships that supported this work from its inception. Your people, lands, and wildlife have been the source of inspiration and context throughout this thesis.

I am grateful for the leadership of the Wuikinuxv Stewardship Department whose foresight and concern for their eulachon fishery was the original impetus for this work. A special thank you to Jennifer Walkus, Danielle Shaw whose support and mentorship has been invaluable in completing this milestone. Also, a huge thank you to Ted Walkus for your enthusiasm and willingness to chat about all things fish, fishing and history. Without all of your ideas and support this research would not have been possible! I have learned so much from you all! *Gila'kasla*

Many thanks to my committee, Iain McKechnie and Quentin Mackie. You have been exceptionally generous in sharing your ideas, mentorship, and expertise. To Iain, in particular, thank you for being up for field stint on the Central Coast in February 2020 (brrrrr). Thanks for your faith and trust in this work since our first conversation about your “wild” idea about fish scales. Thanks to my external Natalie Ban for her feedback, comments, and insight that helped this project together. Thanks to Dr. Aubrey Cannon for sharing reports, data, samples, and lab space.

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All mistakes are mine alone.
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Dedication

I dedicate this thesis to all those enthralled by fish, fishing and the marine environment and to Wuikinuxv and other Indigenous fishers who continue to fight for access, control, and renewal of their fisheries.

I also dedicate this to my late grandfather Valentine (Wally) Ball and our shared love of fishing.

Preface

Chapter 2 is written as a co-authored manuscript intended for publication with significant data, knowledge contributions and editing from Iain McKechnie.

Chapter 3 is written as a multi-authored manuscript intended for publication with significant knowledge contributions, fieldwork, and input from Iain McKechnie, Jennifer Walkus (Wuikinuxv First Nation), and hereditary chief Ted Walkus (Wuikinuxv First Nation).

Due to this structure there is a minor amount of redundancy between chapters and changes in first person singular vs. first person plural (I/we phrasing) reflecting.

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Chapter 1: Introduction

Introduction

Fish and fishing have shaped the lives of coastal Indigenous peoples living along the Northwest Coast for over 10,000 years (Moss 2011). Testament to this rich history, hundreds of ethnographic, ethnohistorical, and contemporary accounts document how fisheries have helped sustain communities for millennia and continue to be vital in the lives of many Northwest Coast peoples. The tremendous depth to human-fish relationships on the Northwest Coast is also apparent in zooarchaeological records where fish bone represents up to 85-95% of all recovered vertebrate bones (Moss and Cannon 2011). These records include a particular emphasis on low trophic level fisheries 'forage fisheries' which, in many cases, were harvested by Northwest coast Indigenous peoples throughout the Holocene (Caldwell 2011; McKechnie and Moss 2016; McKechnie et al. 2014; Moss et al. 2017; Patton et al. 2019; Tushingham et al. 2013). However, despite evidence of fishing over millennia, many culturally vital fisheries are presently experiencing significant declines (e.g., Pinksy et al. 2011; Levin et al. 2016; Pikitch et al. 2012; Essington et al. 2015) that threaten community access to and complicate the management of these fisheries.

Zooarchaeological data provide a valuable but often underrecognized archive that can refine understandings of change in fisheries through time by providing pre-industrial and context-specific point(s) of comparison for contemporary declines in fisheries. Accordingly, this thesis explores and applies multiple lines of zooarchaeological data (fish scales and bones) to better understand ancient Indigenous forage fisheries in British Columbia and context-specific points of change over time in local fisheries in Wuikinuxv territory. This thesis focuses on fisheries data that span the late Holocene (~3000 cal. B.P.) to contact primarily from archaeological sites in Wuikinuxv First Nation territory on the Central Coast of British Columbia (Ball et al. 2020; Cannon 2013a,b) but also discusses zooarchaeological fish scale data from ancient village sites in Tseshaht First Nation territory in the Broken Group Islands on the West Coast of Vancouver Island (McKechnie 2014).

Using these data sets, I expand on conventional zooarchaeological analyses by overviewing an additional kind of archaeological fisheries data – fish scales. This project reintroduces the study of fish scales (squamatology) to zooarchaeological analyses on the Northwest Coast, a method archaeologist Richard Casteel first introduced to zooarchaeology in the 1970s, and that has been infrequently applied in this region (e.g., Casteel 1970; Troffe et al. 2017). This thesis builds on Casteel's work by attempting to demonstrate how squamatological analyses can complement and expand current understandings from fisheries zooarchaeology of ancient Indigenous fisheries on the Northwest Coast by providing age-at-harvest data and through refining species-level identifications. Using two geographically and culturally distinct datasets (i.e., Rivers Inlet and Barkley Sound), I describe zooarchaeological criteria for interpreting scale preservation and recovery in shell-bearing archaeological sites and explore how squamatological analyses might be applied to large samples of fish scale specimens from coastal archaeological sites on the Northwest Coast. I also review the kinds of analytical contributions fish scales can provide in service to fisheries management on the Northwest Coast.

This thesis aims to contribute data to a diverse and interdisciplinary audience of academics, fisheries managers, and Indigenous communities. Accordingly, localized and community-specific interests in Wuikinuxv territory of generating additional comparative fisheries data (particularly regarding eulachon) from archaeological deposits for uptake in their contemporary Stewardship and Fisheries management programs are central to my research. I provide and evaluate data from local archaeological deposits in Wuikinuxv territory related to relative abundance, species composition, and age-at-harvest in ancient Wuikinuxv fisheries using fish scale and bones. With guidance and knowledge sharing from community members, I additionally discuss an archaeological feature associated with traditional eulachon fishing technology.

I evaluate these data within the theoretical frameworks of marine historical ecology and two-eyed seeing. I use marine historical ecology to examine non-conventional records and evidence, in this case, archaeological fisheries data, of long-term and reciprocal interactions between humans and the marine environment (compare with Balée 2006: 213). I use two-eyed seeing, a Mi'kmaw concept envisaged by Mi'kmaw elder Dr. Albert Marshall, to pair perspectives from fisheries science and Indigenous knowledge. The purpose of this knowledge pairing in this thesis is to generate deliverables for fisheries management that benefit both Indigenous and non-Indigenous knowledge holders (cf. Reid et al. 2020; see also Bartlett et al. 2012:335). In the section that follows I outline my use of these theoretical frameworks in this thesis.

Two-eyed Seeing (*Etuaptmumk*)

Two-eyed seeing (*Etuaptmumk* in Mi'kmaw) is a concept developed within the context of natural resource management and fisheries science that seeks to pair

Indigenous and Western ways of knowing to improve management outcomes and access for Indigenous fisheries. Marine conservation planning is forward-looking—concerned with what management actions we can take today to ensure a species and ecosystem's future (Ban et al. 2014). Appropriately, two-eyed seeing brings the underlying Mi'kmaw concept of *netukulimk*, which calls for managers to consider their decisions with the next seven generations in mind to bear on conservation decisions (McMillan and Prosper 2016; Reid et al. 2020).

Two-eyed seeing approaches require that all involved are responsive to the knowledge shared and that knowledge holders make use of all available data (Reid et al. 2020; Denny and Finning 2016: Figure 3). In practice, two-eyed seeing Albert Marshall explains involves weaving back and forth between Indigenous and Western knowledges. As a result, according to Marshall, all involved can grow to recognize that for particular circumstances, one knowledge may have more applicable strengths than the other and vice versus (Bartlett et al. 2012). Accordingly, Reid et al. (2020) recently articulated that two-eyed seeing can, therefore, assist in developing more inclusive fisheries management policies.

The weaving of Indigenous and Western ways of knowing in two-eyed seeing parallels approaches in collaborative and community-based archaeology for imbricating and pairing Indigenous knowledge (specifically oral narratives) with archaeological accounts and also require engagement and willingness of all parties involved (Gauvreau and McLaren 2016; Martindale and Nicholas 2014; McKechnie 2015; Wylie 2015). The pairing of archaeological data with Indigenous knowledges generally aims to generate more robust understandings of histories and past phenomena and to guide archaeological hypotheses and predictions about the past (e.g., Gauvreau and McLaren 2016). Thus, while I do not discount that archaeological data certainly has contemporary consequences for Indigenous peoples and their assertions of rights under law (for further discussion, *see* Hogg and Welch 2020; Martindale 2014), our disciplinary tendency to look back and reconstruct pasts as archaeologists even when imbricating our data with Indigenous accounts separates existing frameworks for pairing archaeological accounts with Indigenous knowledge from two-eyed seeing (cf. Reid et al. 2020). Further, two-eyed seeing's positioning and use within fisheries management (see Giles et al. 2016; Raincoast Conservation 2020; Reid et al. 2020) set two-eyed seeing apart from existing frameworks for pairing archaeological data and Indigenous knowledges.

In Chapter 3, I extend Reid et al.'s (2020) discussion of two-eyed seeing to consider how archaeological fisheries data and knowledge can provide a valuable yet underappreciated complement to Indigenous fisheries knowledges. Pulling from Reid et al.'s 2020 stepwise framework for applying two-eyed seeing, I recognize several tenets that align with research design recommendations for community-based and Indigenous archaeological research. These include identifying mutual research interests, identifying required tools and responsibilities, research co-development, co-evaluation, and community validation (Atalay et al. 2012, Figure 3; Nicholas and Andrews 1997; Nicholas 2008). Using Wuikinuxv's forage fisheries as a case study, I assert that two-eyed seeing is a suitable but underrealized framework for pairing Western archaeological science with Indigenous knowledge. As I use it in this thesis, two-eyed seeing provides a basis for discussing archaeological fisheries data in service to Indigenous community-based fisheries management without overshadowing the contributions of community knowledge on local fisheries already held in Indigenous communities. I establish this research in relation to co-generated research questions and objectives that aim to generate archaeological data appropriate for informing community-based fisheries managers in Wuikinuxv territory. Chapter 3 also identifies that archaeological study of traditional harvesting technologies can further support community-based fisheries management by providing context-specific and pre-industrial points of comparison for Indigenous eulachon fisheries.

(Marine) Historical Ecology

Historical ecology is a broad multidisciplinary research framework capable of grappling with human engagements with the natural world through time and space (Armstrong et al. 2017; Balée 1998, 2006; Beller et al. 2017; Crumley 2003). Unlike theoretical approaches such as cultural ecology, which frame humans' relationships with the environment as reactionary (Steward 1955), historical ecology challenges evolutionary systems thinking and adaptationist models of human behaviour by emphasizing landscapes as cultural, historical, and political products with traceable human inputs and material manifestations (Balée 1998, 2006; Crumley 1996; Szabó 2015). Historical ecology further emphasizes that human interactions with natural environments are dynamic rather than the traditional view that humans are naturally conservators or destructive in their interactions and relationships with the natural world (Balée 1998:14; Balée 2013).

A related approach, marine historical ecology, has been developed explicitly within the context of species and ecosystem management. Marine historical ecology is uniquely positioned to address conservation and management questions by better identifying the consequences of recent human-environmental interaction and influence on contemporary fisheries (Pitcher 2001; Rick and Lockwood 2013). Marine historical ecology recognizes that human influence and pressures on marine ecosystems are observable (Lotze and McClenachan 2013). Accordingly, this framework seeks to provide perspective on changes in marine populations over time and to address data gaps (Engelhard et al. 2016; Jackson et al. 2001; Kittinger et al. 2015; Lotze and McClenachan 2013; McClenachan et al. 2012; Pitcher 2001; Thurstan et al. 2015). Marine historical ecology can also inform the previous distributions of species and their habitats and highlight management potential for areas not previously considered management targets (Ban et al. 2014). Marine historical ecology responds to "shifting baseline syndrome" in fisheries management, which describes successive generations of observers who become accustomed to increasingly degraded stocks and, in the process, lose perspective on changes in fish populations over time (Pauly 1995; also see Zeller and Pauly 2018). I employ marine historical ecology to investigate human-influenced biological landscapes over time, wherein regular harvesting effort, maintenance of spawning habitat, and social controls on harvesting fish may function to elevate abundance and resilience in targeted fish (cf. Balée 1998:13). Using a marine historical ecology framework, I employ interdisciplinary methods from fisheries science (e.g., squamatology) and zooarchaeology to explore human-fish interactions in Wuikinuxv and Tseshaht territories and beyond.

In Chapter 3, from the standpoint of marine historical ecology, I reconcile human-influenced fish landscapes in Wuikinuxv territory, in this case, biological landscapes related to fish population age characteristics. I discuss how these data may reflect the biological consequences of intentional practice, relationships, and change over time in local herring populations. I also examine rank abundance for herring, eulachon, and salmon from archaeological fish bone and scale assemblage data in Wuikinuxv territory with the intent to complement and expand on existing efforts towards establishing pre-industrial baseline data for these fisheries (cf. Cannon 2013a).

Personal Relation to the Work

Undertaking this thesis required an honest and ongoing exploration of my positionality in this work. As a person of Scandinavian descent, living and working on Wuikinuxv, Tseshaht, Lekwungen, and K'omoks unceded territories, I recognize the inherently violent historical legacy that enables my occupation and profession on Indigenous lands and waters. In establishing my heritage as a settler, I recognize my part in benefiting from the colonial regime that drastically and intentionally impacts First Nations peoples' connection to their lands and waters and dispossessed fisheries from local management. Engaging with Indigenous heritage, lands, and waters as an archaeologist, I acknowledge the disciplinary baggage archaeological research entails (e.g., Deloria 1969:7; Simpson 2011; Starn 2011). Additionally, as an ecologist, I bring an awareness of a deeply entrenched and widespread assumption of *terra nullius* and colonial control over conservation and management and the responsibility as ecologists to advocate for more diverse and pluralistic ecological research and resource management (e.g., Brondizio and Le Tourneau 2016; Mistry and Berardi 2016).

Throughout this work, I aim to grow in my propensity to forward a decolonizing archaeology (see Atalay 2012). I maintain that this research is inseparable from the political-ecological issues experienced by the communities whose history and fisheries I discuss (see Veteto and Lockyear 2015; also see Armstrong et al. 2017). However, given my positionality, in this thesis, I am not speaking for Wuikinuxv or Tseshaht peoples about their complex and deep histories with the marine environment. Instead, I aim to use my privilege to be critical of colonial tenets and discourses of discovery (e.g., Asch 2002; Harris 2004, 2009) and elevate community-engaged fisheries research through archaeology in the Indigenous communities on whose lands I live and do work.

Accordingly, this thesis is motivated by the following objectives:

- To apply zooarchaeological methods to investigate the long history of human-fish relationships on the Northwest Coast
- To further develop the capabilities of archaeological data to extend and complement contemporary fisheries concerns and community-directed research in tandem with local knowledge.
- To investigate squamatology as a method for obtaining zooarchaeological abundance and age data from coastal archaeological sites that hold contemporary relevance to Indigenous communities, their fisheries, and management programs.

Research Questions

My research is guided by three research questions (Table 1.0) developed in collaboration with the Wuikinuxv First Nation Stewardship office, which governs resource stewardship, fisheries, forestry and lands, and marine use planning in Wuikinuxv First Nation territory (Wuikinuxv 2020). Development of these questions included significant contributions from Wuikinuxv Stewardship members Jennifer Walkus and Danielle Shaw and research collaboration from Wuikinuxv Guardian watchmen and Chief and Council. The Tseshaht First Nation was not directly involved in formulating these research questions; however, the fish data I share in Chapter 2 was developed in long-term collaboration with the Tseshaht First Nation, Pacific Rim National Park Reserve, and archaeologists Denis St. Claire, Alan McMillan, and Iain McKechnie.

Table 1.0. Research questions, sources of data, and methods.

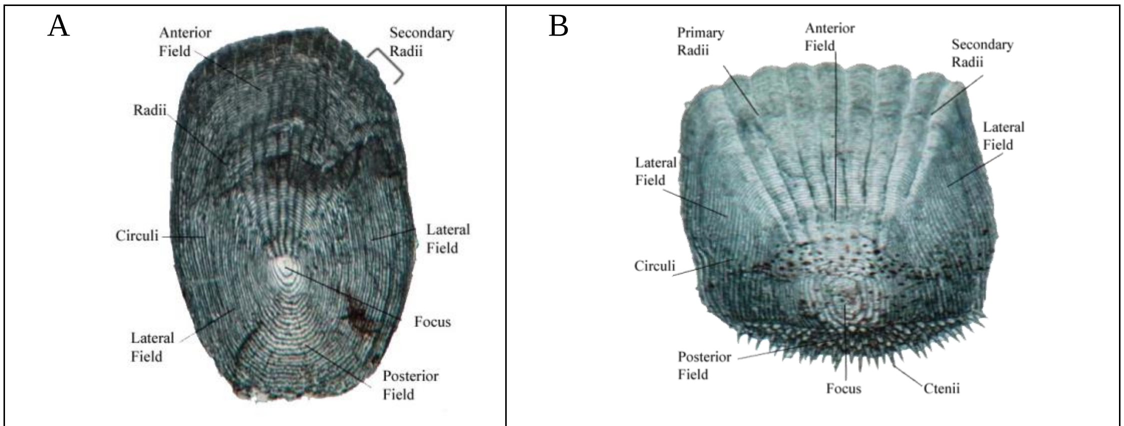
Research Questions	Specific questions	Related Sections	Data Sources	Methods
Are fish scales recoverable and identifiable to species from archaeological contexts on the Northwest Coast?	What factors affect the recovery of and the feasibility of squamatological study of fish scales from archaeological deposits in Wuikinuxv and Tseshaht territories?	Chapter 2 Chapter 4 Appendices A & B	Archaeological fish scales from auger sediment samples from archaeological village sites in Wuikinuxv and Tseshaht territories -Radiocarbon dates (cal. B.P.)	-Squamatological Identification -Fish scale degradation scale -Zooarchaeological quantification (NSP, NISP, NISP/L); ubiquity
Can archaeological fish scales provide age-at-harvest data?	What are the minimum age-at-harvest estimates for the species that can be identified? What other kinds of information do these minimum age estimates provide?	Chapter 3 Appendix A	Archaeological fish scales from auger sediment samples from village sites in Wuikinuxv territory	-Squamatological age analysis -Community-Based Participatory Research
How can archaeological fisheries data address the contemporary concerns of community-based fisheries?	How might archaeological data complement Indigenous knowledge on forage fisheries in Wuikinuxv territory? How might archaeological fisheries data inform community-based management of Indigenous fisheries in Wuikinuxv territory and beyond?	Chapter 3 Chapter 4 Appendix C	-Archaeological fish scales and sediment samples from village sites in Wuikinuxv territory -Archaeological fish bone data (Cannon 2013; Wigen 2020) -Aerial photos and multispectral imagery of a eulachon fishing feature -Radiocarbon dates	-Squamatological Ageing Analysis -Community-Based Participatory Research -Two-Eyed Seeing -GIS mapping of archaeological fish features -Rank Order, Abundance (NISP/L)

Question 1: Are fish scales recoverable and identifiable to species from archaeological contexts on the Northwest Coast?

Fish remains are superabundant in archaeological deposits on the Northwest Coast (Moss and Cannon 2011) and provide valuable information about targeted species and context-specific points of comparison about their past abundance to improve understandings of ancient Indigenous fisheries. However, zooarchaeologists often face challenges when identifying specific fish taxa to species from bone, given morphological similarities among particular taxa (e.g., *Oncorhynchus, Osmeridae, Hexagrammidae*). The consequence of this challenge is that zooarchaeological data may be more limited in providing species specific points of comparison between contemporary and ancient Indigenous fisheries. Another component of the fish remains record, fish scales, comparatively have more distinctive morphological differences between species and may be a more reliable means for identifying to species-level for many North Pacific fish taxa (Casteel 1974; Patterson et al. 2002). Using differences in the location, shape, and morphology of structures in fish scales such as the focus, radii, annuli, and scale shape, one can attribute family or even species-level designations from fish scales (Patterson 2001; see Figure 1.1. for an annotated summary of these structures).

Early research by Casteel advocated for closer attention to the potential contributions of fish scales to coastal zooarchaeology. According to Casteel (1976:17), fish scales can provide valuable information about fish identified from archaeological sites, including describing characteristics of past fish populations such as age, growth rate, and seasonality Early fisheries researchers identified fish scales as having utility in classifying the remains of archaeological shell midden (Lagler 1947:155; Lagler, Bardach, and Miller 1962:118). However, despite the significant recovery of fish scales from archaeological deposits (see Casteel 1974 and references therein) and suspicions of their superabundance in archaeological assemblages (Sutton and Arkush 2002: 234), there are only two published studies of archaeological fish scale analyses on the Northwest Coast. These studies report on the identification of a single salmon (Oncorhynchus sp.) fish scale (Troffe et al. 2017) and discuss the presence of fish scales in coastal shell-bearing archaeological deposits in California (Casteel 1970).

Fish scales have not historically been a research focus for zooarchaeologists in many areas. There is generally limited archaeological literature discussing archaeological recovery of fish scales in other regions, and potential for squamatological analyses of specimens from archaeological deposits remains uncertain. For example, some zooarchaeologists working in Oceania already tend to limit their identifications to only a select number of skeletal elements from fish, let alone fish scales (e.g., Leach and Anderson 1979; Masse 1986: 95; Nims et al. 2020). European zooarchaeologist Mortimer Wheeler additionally stressed caution for using fish to get at particular kinds of archaeological data. Wheeler (1978: 80) argued that ageing and seasonality estimates could be difficult to obtain from fish scales unless exceptional circumstances of preservation and recovery occur and the margins of fish scales are preserved, allowing annuli , which are aging features in fish scales to be discerned. Wheeler generally asserts that fish scales are too severely damaged to warrant study but that scales from small-scaled species may be more suited for archaeological study (Wheeler 1978:70). Prior to Wheeler's critique, Casteel's literature review from the 1920s through to the early 1970s indicates numerous studies were successful in identifying fish scales from archaeological sites (Casteel 1974:561-562); However, given the lacking studies addressing fish scales as a topic in zooarchaeological research, Wheeler's emphasis on the limitations of fish scales and a disciplinary preoccupation with obtaining seasonality data from fish scales stunted research efforts to better understand the preservation, recovery, and analytical potential of fish scales from archaeological deposits. As a result, there remain significant opportunities to refine squamatology regionally on the Northwest Coast of North America. Accordingly, my thesis demonstrates that archaeological fish scales preserve in several archaeological sites and that species-level identifications can be derived and refined from fish scales in archaeological contexts.



Circuli: elevated markings on the scale's surface, usually appearing as lines following the scale's outline of the scale. **Focus:** first portion of growth on a scale, often at the scale's centre. **Radii:** grooves that radiate from the focus to the scale margins. **Primary Radii**: radii that extend from the focus to margin.	**Secondary Radii:** are radii that begin outward from, not at, the focus. **Ctenii:** toothlike structures on the posterior portion of some scales. **Fields**: areas of the outer surface of the scale, either real as delimited by angulations of the circuli, or implied if the configuration of the circuli are otherwise.	**Anterior Field**: area bounded by imaginary lines connecting the anterolateral corners (dorsal and ventral) or their equivalent points on rounded scales. **Posterior Field**: area bounded by imaginary lines connecting the posterolateral corners (dorsal and ventral) with the focus.

Figure 1.0. Overview of key features in fish scales. A. Cycloid type scale. B. Ctenoid type scale. Modified from Patterson et al. 2002.

Question 2: Can archaeological fish scales provide age-at-harvest data?

Age determination in fish is fundamental for understanding life histories, growth, and population dynamics (Beddington and Kirkwood 2005) and for management of fish populations (Hilborn and Walters 1992). Fisheries management and conservation are critical to addressing diminishing fish populations globally; Age structure analysis can provide information on population health (e.g., recruitment, age-at-mortality, age-at-harvest, and age-at-spawning) that can assist management efforts by improving understandings of variability in the age of targeted fish. Various structures, including scales, fin rays, and otoliths, are available for ageing fish (Casselman 1990) that archaeologists may encounter in archaeological deposits (Casteel 1970, 1972; 1974; Wheeler and Jones 1989). Historically, fish scales are one of the most widely used ageing structures in North American fisheries management because of their non-lethal ease of collection (Al-Absy and Calander 1988), although age can also be estimated from otoliths and inferred from size. Age from scales is estimated by counting the number of annuli (rings), and by using the spacing between these rings to infer growth rate (Casteel 1974; NOAA 2018).

Estimating fish age from scales has not conventionally been focused on in zooarchaeological fisheries analyses, even though its potential has been previously discussed (see Casteel 1972; 1974). Contributing factors include critiques claiming the limited preservation of calcium-rich structures suitable for ageing fish from archaeological assemblages (e.g., Wheeler and Jones 1989) and preoccupation with disciplinary questions such as interpreting seasonality from archaeological records rather than the characterization of past fish populations targeted by ancient Indigenous fishers. However, there are some contemporary examples of reconstructions of seasonality, growth rate, and minimum age from ageing structures (i.e., fish scales and otoliths) where they preserve in archaeological sites (e.g., Van Neer et al.2002; Guilland et al. 2017).

Despite the clear contributions of age data in refining archaeological research questions about seasonality, age-at-harvest, and growth, it is still unclear how to integrate archaeologically derived age data from fish scales into discussions of contemporary fisheries management and what limitations these non-conventional data might have. Additionally, it remains unclear what the archaeological record can reveal about age-specific harvest and age-at-spawning in ancient Indigenous fisheries on the Northwest Coast. I investigate the potential to estimate age from archaeological specimens from Northwest Coast archaeological deposits. I also guided by co-produced research questions situate archaeological fish scale data within Wuikinuxv fisheries to establish local context for considering age-at-harvest data for use in comparisons of past and contemporary age composition that can address local management efforts.

Question 3: How can archaeological fisheries data address the contemporary concerns of community-based fisheries?

Multidisciplinary approaches to ecologically engaged research, especially work related to conservation and resource management, that incorporate social dimensions are proving to be increasingly effective approaches for considering the impacts of research for local communities (Adams et al. 2015; Berkes 2010; Douglass et al. 2018; Housty et al. 2014; Poe et al. 2014; Salomon et al. 2018; Trosper 2009). Fisheries are tightly coupled and complex social ecological systems that can be challenging to study and manage (van Poorten et al. 2011). Fisheries also tend to be data deficient with poorly defined historical baselines or at least those that lack considerable time depth (Pauly 1995). Recognizing underutilized and unconventional deep time data sources in fisheries management can, therefore, allow managers to address data gaps and to make more socially informed management decisions (e.g., Braje et al. 2017; Drew 2005; Eckhert et al. 2017; Haggan et al. 2006; Huntington 2000; Huntington et al. 2011; McKechnie 2014; Mellado et al. 2014).

Zooarchaeological data are particularly well suited to provide localized insight into fisheries baselines over the last several millennia. Using zooarchaeological data, archaeologists can extend existing baselines several millennia by providing relative minimum dates for the occurrence of particular taxa and using the associated context of these data to draw comparisons between pre-industrial and contemporary fisheries at local and regional scales. However, there is a need to further refine zooarchaeological fisheries data and research designs to be more representative of local contexts and to prioritize community needs to avoid enforcing conventional colonial fisheries management schemes that prioritize Western science or Eurocentric paradigms, often at the cost of excluding local managers from decision making. Consequently, to meet this challenge, archaeologists will need to gain a better understanding of how their fisheries data complement existing knowledge of ancient Indigenous and contemporary fisheries already held within communities.

Various approaches currently address the pairing of archaeological data with Indigenous knowledges (Gauvreau and McLaren 2016 and references therein). Approaches for pairing knowledge in archaeology emphasize collaborative practice and decolonizing our consideration of Indigenous heritage and knowledges by undertaking archaeological work with, for, and by Indigenous communities (e.g., Atalay 2012; Marshall 2002; Nicholas 2008). However, these approaches have primarily discussed how this pairing can improve insight into past phenomena rather than generate data that inform future management decisions. It may, then, be more appropriate when the aim is to use archaeological data as a tool for providing data in service to contemporary Indigenous community-based fisheries concerns to draw from attempts to pair knowledge developed specifically in the context of fisheries and ecosystem management. I bridge this gap by considering, two-eyed seeing , which in a recent discussion (see Reid et al. 2020) provide an effective means to pair Western fisheries data and Indigenous knowledge as an equally appropriate paradigm for pairing archaeological fisheries data and community-based fisheries knowledge.

Regional Fisheries Context

The Northwest Coast of North America is home to a diverse range of marine fish species, many of which are vitally important for Indigenous peoples and are the focus of large-scale commercial fisheries. Of the large variety of marine fish species which inhabit these areas, many would have been accessible within the vicinity of archaeological village sites discussed in this thesis. Within the Northwest Coast study area, I discuss archaeological fisheries data from coastal shell-bearing deposits from two areas in what is currently known as British Columbia. First, I discuss archaeological data specific to Rivers Inlet on the Central Coast of British Columbia (Chapters 2, 3, and 4; Figure 1) from eleven archaeological village sites total but with more significant discussion of fish scales from EjSw-1 (Cockmi), EjSv-1, EjSv-9, and EkSt-1 (Katit and Zawias two separate place names located with one archaeological site boundary) (see Figure 1.1). Second, I discuss fish scale data from eight archaeological sites in Barkley Sound on the western coast of Vancouver Island (see Figure 1.1; for further discussion, see McKechnie 2014).

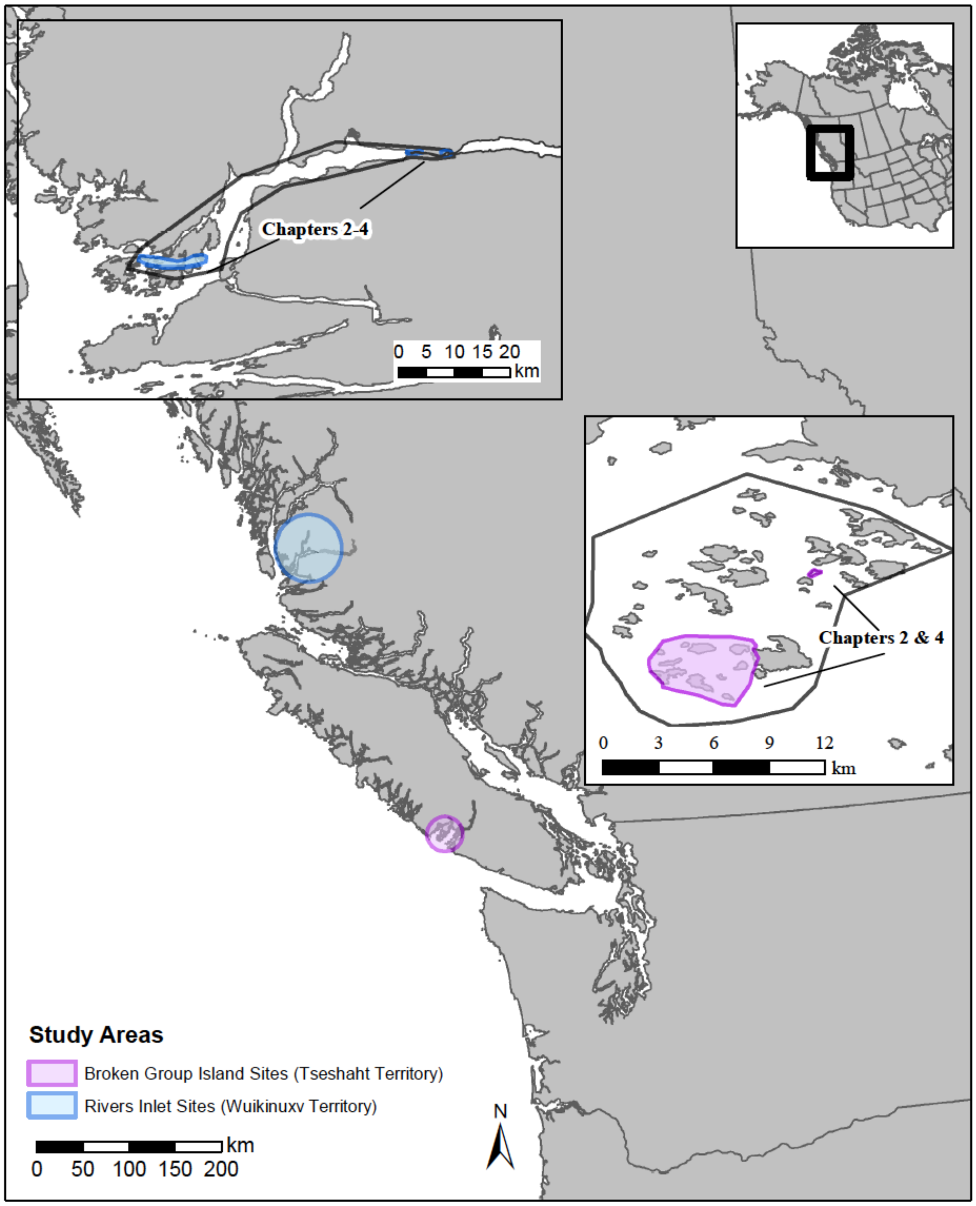


Figure 1.1. Map of the Northwest Coast showing the location of archaeological sites in the Broken Group Islands (bottom left insert) and Rivers Inlet (top right insert) discussed in this thesis.

Rivers Inlet

Several rivers and streams, where anadromous fish species spawn, run through Wuikinuxv territories (Olson 1954; Hilton and Rath 1982). The Wannock River, which is adjacent to the village site of Katit (EkSt-1), traditionally supported large runs of salmon (*Oncorhynchus spp.*), particularly sockeye (*Oncorhynchus nerka*) and chinook salmon (*Oncorhynchus tshawytscha*) and eulachon (*Thaleichthys pacificus*). However, eulachon also spawned traditionally in three other rivers in Wuikinuxv territory: the Chuckwalla, Kilbella, and Clyak (Moody 2008, Figure 2.18), and all five species of Pacific salmon are known to run throughout the Oweekeno Lake watershed. Numerous nearshore and intertidal regions on kelp, in eelgrass beds, and rocky shorelines in the territory from the mouth of Rivers Inlet to Koeye to Moses Inlet additionally would have supported herring, rockfishes, greenlings, and other nearshore pelagic fishes (Cannon 2013a,b; Duffield 2017; Hay and McCarter (1997) 2006 Walkus 2011).

Barkley Sound

Archaeological sites from Tseshaht territory discussed in this thesis are located in the Broken Group Islands on the west coast of Vancouver Island. This area is known for its high current and extensive nearshore kelp habitat. Accordingly, areas surrounding these islands would have provided habitat for a variety of marine species, including demersal fishes, mid-water schooling fish, and pelagic species. Broken Group Island sites discussed in this thesis are also within 2.5 km of known herring spawning areas (McKechnie 2014: Table 2.3) and have considerable access to rockfish, greenling, and schooling fish such as anchovy and herring (Hillis et al. 2020; McKechnie and Moss 2016; Rodrigues et al. 2018). The Nahmit, Sarita, and Somass rivers historically supported large runs of salmon (*Oncorhynchus sp.*) and all five species of salmon migrate and forage in nearshore areas surrounding the Broken Group Islands.

Archaeological Context

Previous Central Coast Archaeological Studies

Archaeological surveys and investigations on the Central Coast have occurred at several archaeological sites since the 1970s (Carlson 1976; Conover 1972; Drucker 1943; Luebbers 1971; Pomeroy 1972; Simonsen 1970). Early archaeological surveys in or adjacent to Wuikinuxv First Nation territory include assessments Simonsen (1970) and Hobler (1970). Researchers at both the University of Colorado and Simon Fraser University (SFU) also undertook extensive archaeological investigations on the Central Coast between the late 1960s to mid-1990s (Carlson 1996; Cannon 1991; Hester and Nelson 1978; Pomeroy 1980) in neighbouring Heiltsuk territories. This included excavations between 1968 and 1974 at Namu (ElSx-1), Kisameet Bay (ElSx-3), Roscoe Inlet (FaSx-61), and McNaughton Island (ElTb-20) (Conover 1972; Hester and Nelson 1978; Luebbers 1971;Carlson 1976; and Pomeroy 1972, respectively). In the late 1990s, on the Central Coast. Cannon (1997, 2000) also undertook a percussion core and bucket augering program to study the broader regional context of the history of resource use and occupation at Namu. Significant recent archaeological work has also been undertaken in neighboring Heiltsuk territory, but I do extensively discuss this research in my thesis (e.g., Duffield 2017; Dyck et al. 2020; Maxwell et al. 1997; McLaren 2018; McLaren et al. 2014; McLaren et al. 2015; White 2006, 2011).

Historically, much of the zooarchaeological research on the Central Coast has concerned itself with or revealed a focus on salmon (*Oncorhynchus spp.*), (Cannon 2001, 2002, 2003; Cannon et al. 2011; Cannon and Yang 2006; Crockford and Fredrick 2013; Rahemtulla 2014; Wigen 2011). However, there is also substantial archaeological data available on other ancient Indigenous forage fisheries (Cannon 2000, 2013a; Duffield 2017; Wigen 2011), and patterns in abundance by rank show that herring out ranks salmon overall in Central Coast assemblages with fine screening (McKechnie and Moss 2016). Additionally, overall in the region, in order of rank, herring, salmon, anchovy, greenling are the most highly ranked taxa (McKechnie and Moss 2016:Table 2).

Zooarchaeological Research in Wuikinuxv Territory

Zooarchaeological work in Wuikinuxv territories[1] documents a heavy reliance on fish. In general, fish taxa make up the majority of identified specimens (NISP) at several sites in the vicinity of Rivers Inlet and Calvert Island (e.g., EjTa-1, EjTa-13, EkSt-1) (*see* Cannon 2013a,b; Duffield 2017; Wigen 2011). Sites in this region occupy an environmental gradient from sheltered inner fjords with freshwater influence (e.g., EkSt-1) to outer coastal islands with various degrees of exposed coastline (e.g., EjTa-4). Accordingly, these sites contain a variety of fish species associated with riverine, nearshore, and open ocean habitats; However, as with previous research on the Central Coast (e.g., Namu) the two most frequently occurring taxa in nearly all sites are salmon (*Oncorhynch*us sp.) and herring, except in areas where fine screening is not employed (*see* Crockford and Fredrick 2013). In line with site history elsewhere on the Central Coast, some archaeological sites in the vicinity of Wuikinuxv territory have faunal records that track long term continuity and use of salmon and herring (e.g., EjTa-13, Duffield 2017) that extends back to ~5800 years ago (ibid).

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1 Several of the sites discussed in terms of fisheries zooarchaeology fall in areas where Wuikinuxv and neighbouring Heiltsuk territories overlap. e.g., EjTa-1, EjTa-4.

Cannon's 2004/2005 bucket augering program also reveal an emphasis on eulachon from archaeological investigations near eulachon spawning river (i.e., EkSt-1) along the Wannock River (NISP=282) and to a lesser extent at other sites in the region (e.g. EjSw-1 on Walbran Island (NISP=17) (Cannon 2013a,b). Eulachon are also recovered from archaeological sites located in the vicinity of outer coastal waters (i.e., EjTa-13), but account for only 2% of all identified fish species from ≥2 mm mesh (Duffield 2017). Northern anchovy is also similarly abundant in Cannon's auger recovery program in those sites adjacent to bays, islands, and outer coastal areas – west and in the vicinity of the southwest entrance of River Inlet (e.g., EjSw-1, NISP=220; EjSv-9, NISP=100; Cannon 2013a) compared to other studies where they account for a small proportion of observed identified specimens (e.g., EjTa-13 Duffield 2017). Other observed and top ranked species based on Number of Identified Specimens (NISP) include halibut, rockfish, flatfish, and greenling (Cannon 2013a,b; Duffield 2017; Crockford and Fredrick 2013; Rahemtulla 2014; Wigen 2011).

Structure of Thesis

This thesis first addresses the recovery, preservation, and identification of fish scales in archaeological deposits on the Northwest Coast. Second, I address how to incorporate fish scale data with other fish remains data to provide data for community-based fisheries management. Accordingly, two central chapters in this thesis (Chapter 2 and 3) are designed as self-contained manuscripts intended for publication in a peer-reviewed journal.

Chapter 2 is zooarchaeologically oriented and focuses on fish scale recovery from archaeological sites on the Northwest Coast using data from auger samples from coastal archaeological shell middens in Wuikinuxv and Tseshaht territories. This chapter describes how the factors relevant to processing, screening, the presence of fish bone, and the age of archaeological deposits might affect fish scale preservation in coastal shell-bearing deposits.

Chapter 3 addresses how zooarchaeological and squamatological evidence can be used in service to community-based fisheries on the Northwest Coast by providing baseline relative abundance and minimum age data on ancient Indigenous forage fisheries. As explained, this chapter operationalizes the Mi'kmaw principle of two-eyed seeing (*Etuaptmuk* in Mi'kmaw) (see Reid et al. 2020) to mobilize archaeological fisheries data alongside other kinds of community fisheries knowledge to improve understandings of ancient Indigenous fisheries.

Chapter 4 concludes with an overview of how to situate fish scale analyses within Central Coast zooarchaeology research and offers an outlook for squamatological analyses on the Northwest Coast with respect to my research questions and objectives. In three supplementary appendices, I include:

- A discussion of microscopic photography and ageing methods for archaeological fish scale specimens (Appendix A), including an online open-access digital catalogue for all identified fish scales discussed in this thesis[2].
- A table of radiocarbon dates associated with deposits containing identified fish at all four sites reported as 2 sigma cal. B.P.. dates, an approximation of site age with depth assuming linearity to relatively date deposits by depth, and maps showing the location of auger samples from Rivers Inlet (Appendix B).
- A letter of permission to do archaeological work in Wuikinuxv territory from Wuikinuxv Chief and Council (Appendix C)

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2 Open access digital catalogue for fish scales recovered from archaeological sites in Wuikinuxv territory
https://osf.io/vxz2f/?view_only=52172ebd23174a52ab7efde996c4db34

Chapter 2: Examining fish scale preservation and recovery in coastal archaeological sites on the Northwest Coast

> "A detailed study of fish scales is needed to aid the non-ichthyologist archaeologist" (Olsen 1969:4)

Introduction

Squamatology, or the study of fish scales, is an established method in fisheries management for identifying species, assessing age composition in fish populations (Campana 2001), and for evaluating past fisheries from palaeoceanographic sediment records (Holmgren and Baumgartner 1993; Patterson et al. 2005; Schwartzlose et al. 1999). Fish scales also occur in archaeological deposits (Casteel 1974; Lagler 1947:155; Lagler et al. 1962), and in certain cases, so much so that they clog mesh screens (Sutton and Arkush 2002: 234). Unlike many fish bones, fish scales often accurately reflect species-level taxonomic designations (Patterson et al. 2002) and can provide estimates of the age-at-death or age-at-harvest, and rates of growth in fish (Campana 2001; Casteel 1974). Analysis of fish scales has not been widely applied to archaeological contexts in western North America despite early advocates (e.g., Casteel 1970; 1972; 1974) who demonstrated and discussed their potential for contributing biologically meaningful data and in refining taxonomic identifications where skeletal morphologies make it difficult to distinguish beyond family or genus level. This early work also debated whether the state of preservation and degradation of fish scales in archaeological sites allows for accurate assessments of seasonality of harvest (Wheeler 1978; Casteel 1972, 1974).

A considerable focus for research in contemporary fisheries management over the past two decades has been on otoliths, which are mineralized ear-stone structures consisting of calcium carbonate regularly used for ageing fish and fishery analyses

(NOAA 2018). Prior to otoliths, fisheries researchers commonly used fish scales for ageing and management purposes, and a wide range of scientific fisheries literature was developed to interpret scales. While a variety of zooarchaeological research has been conducted on otoliths elsewhere in the Pacific (Disspain et al. 2016; Weisler 1993; West et al. 2012), otoliths have not been regularly recovered and reported in archaeological deposits on the Pacific Northwest Coast. Similarly, the potential for archaeological fish scales has not been a focus of concerted research in recent decades despite the potential for preservation and recovery in shell midden sediments. In contrast, palaeoceanographic research has been conducted on fish scales preserved in marine sediment records (e.g., Holmgren and Baumgartner 1993; Patterson et al. 2005) and methods for quantifying fish scale preservation in paleontological marine sediments (Salvatteci et al. 2012), and researchers developed a photographic atlas for North Pacific fish species (Patterson et al. 2002).

Recent inclusion of archaeological fisheries data in fisheries science and its engagement with Indigenous fisheries management (e.g., Braje 2013; McKechnie et al. 2014; Petrou et al. 2021; Salmen-Hartley 2018) indicate potential for considering fish scales beyond archaeological questions as a source for addressing interdisciplinary questions about the ecology of past and present fisheries. In this contribution, we examine fish scale preservation in archaeological deposits in two areas on the Pacific Northwest Coast. We examine fish scale data from coastal archaeological sites in Tseshaht First Nation territory in the Broken Group Islands on western Vancouver Island (n=1251) and Rivers Inlet in Wuikinuxv territory on the Central Coast of British Columbia (n=376). As part of our analysis, we provide a descriptive index of degradation for archaeological fish scales and examine four factors hypothesized to influence the recovery and/or condition of fish scales from coastal archaeological sites (Table 2.1): deposit age, screen size, degree of degradation, and fish bone presence on the number of recovered and identified scale specimens. To address Casteel's prediction that fish scales can refine archaeological identifications, in our case study we assess and discuss the feasibility of identifying fish scales from archaeological deposits including whether additional species-level identifications are possible. By evaluating the preservation and recovery of fish scales, we aim to assess their suitability for further kinds of squamatological analysis (e.g., species identifications, age, and size estimation) and consider the potential of applying this analysis to other coastal archaeological deposits on the Northwest Coast.

Background

The coastal archaeological deposits discussed in this chapter are shell-bearing cultural deposits, often called 'shell middens,' which occur at Indigenous settlement and resource harvesting sites throughout the Northwest Coast (Cannon 1991; Hopt and Grier 2018; McKechnie 2005). Shell middens sites tend to be particularly suitable for studying ancient Indigenous fisheries as they provide long temporal records and contain abundant marine resources, particularly fish remains. The presence of shell generally enhances the preservation of bone by altering the chemistry of the soil matrix to be more alkaline (Wheeler and Jones 1989: 63). However, there has been a lack of research examining the preservation of fish scales in shell-bearing deposits on the Northwest Coast. To address this gap, we share data on fish scales preservation that highlight that they are worthy of study in shell-bearing coastal archaeological deposits.

Zooarchaeology and Taphonomy of Fish Remains

An array of taphonomic agents including combustion and heating; biological activity (microbes, carnivores); water; mechanical and chemical weathering; and carnivores that affect bones during site formation determine the preservation of faunal assemblages in archaeological sites (Behrensmeyer 2000; Behrensmeyer & Hill 1980; Schiffer 1976, 1983). In fish, the structure of skeletal elements (Wigen and Stucki 1988), cultural butchery and preparation practices (Butler and Chatters 1994; Lubinski 1994; Wigen and Stucki 1988), and the possibility of increasing destruction or degradation of bones from older depositional periods (Wigen and Stucki 1988) are also identified as factors that influence observed patterns in fish remains in archaeological sites. Archaeologists have developed indices and criteria to describe and measure the effects of these agents on recovered faunal specimens (e.g., Behrensmeyer 2000).

However, the effects of taphonomic agents on some lesser studied components of zooarchaeological such as fish scales, remain unclear. To date, the only discussion of taphonomic agents concerning fish scales comes from O'Connell and Tunnicliffe (2001), who describe scales as preserving poorly in oxygenated marine sediments on the Northwest Coast. To approximate the effects of taphonomic agents on fish scales we compare the recovery and identification of fish scales between archaeological sediments dating before and within the last 1000 years.

Recovery Bias in Fisheries Zooarchaeology

Fish bone recovery and the resulting composition of identified species from archaeological sediments can be heavily influenced by recovery method (McKechnie 2005; Partlow 2006). The use of fine screening methods (3.2 mm mesh screens or finer) at Ts'ishaa, on western Vancouver Island, resulted in 7.4 times greater recovery of identified bone specimens (NISP/L) than the use of ¼-inch (6.35 mm) mesh, and recovery rate was 27.6 times greater using 1.5 mm mesh (McKechnie 2005: 214). Accordingly, faunal collections that use fine mesh document the presence of small-bodied fish taxa provide a more accurate representation of the proportional abundance of fish bones, and a higher taxonomic richness though the latter depends on sample size (McKechnie 2005; McKechnie and Moss 2016; Zohar and Bellmaker 2005). This is consistent with observations that the recovery of fish bone increases and there is improved documentation of particularly abundant and ubiquitous archaeological fish taxa (e.g., herring) where smaller mesh screen fractions are employed (McKechnie et al. 2014). As some researchers have argued, this may indicate that fine screening can provide a greater appreciation of the broad range of fish used by Indigenous peoples on the Northwest Coast (McKechnie and Moss 2016; Moss et al. 2017). To test if a similar recovery pattern is observed in the recovery of fish scales, we use fine mesh screens (6.35, 2, and 1 mm) to recover fish scales from coastal archaeological sites in Tseshaht and Wuikinuxv territories.

Methods

Fish scale and bone data described in this paper were collected with personnel, logistical support, and permissions from portions of Wuikinuxv and Tseshaht First Nation territories (Rivers Inlet and Broken Group Islands, respectively). Recovery methods and supporting references describing the archaeological context of these data are summarized in Table 2.0. To address *how fish scales preserve in archaeological contexts on the Northwest Coast*, we quantify patterns in fish scale preservation by comparing fish scales in terms of their relative abundance (number of recovered fish scales/L, number of identified fish scales/L) and ubiquity (frequency of occurrence in archaeological levels). Using these four variables we make predictions for fish scale preservation in coastal shell-bearing archaeological deposits on the Northwest Coast (see Table 2.1).

Table 2.0. Summary of methods used in fish scale recovery by site. For those locations where samples were obtained in the field by Aubrey Cannon: Cannon 2000 augering methods and Cannon 2013a,b are credited.

Sample Source	N sites	Fish scales identified to nearest taxonomic group (y/n)	Subsurface Sampling Method	Screen Size (mm)	Site Name & Number	Sample Volume *** (L)	Bone Identification & quantification
Ball et al. (2020)	1	*y	*Auger	6.35, 2, & 1	Zawias (EkSt-1)	4.0	Wigen (2020)
					Katit (EkSt-1)	34.6	
Cannon (2013a,b)	4	*y	Auger	2 & 1**	Katit (EkSt-1)	13.1	Cannon (2013 a, b); original bone count data shared with permission
					EjSv-1	.4	
					EjSv-9	2.3	
					Cockmi (EjSw-1)	32.7	
McKechnie (2014: Chapter 7)	8	n	Auger	6.35 & 2	N Cree (132T)	0.7	McKechnie (2014)
					S Cree (131T)	0.2	
					Upr Dicebox (129T)	33.0	
					Lwr Dicebox (83T)	39.0	
					Gilbert (82T)	14.6	
					Omoah (304T)	25.4	
					Wouwer (206T)	37.9	
					Keith (306T)	2.7	

* indicates the methods were conducted by the author

**. Cannon 2013 a,b uses > 2 mm to describe materials from 2 mm mesh screen and < 2 mm for those from 1 mm mesh screen

*** Sample volume is calculated using the inner diameter of the bucket auger. For example, a 7 cm diameter auger the volume of an auger level that extends from 15-20 cm would be 192.4 cm^3 or 0.19 L.

Table 2.1. Summary of variables predicted to affect fish scale preservation in archaeological sites with predicted effect on scale recovery (ubiquity, NSP/L), and abundance (NISP, NISP/L).

Variable	Predicted Effect	Rationale	Reporting Unit
Screen Size	Fish scale recovery and identification will increase with the use of finer screen sizes (i.e. 2 mm, 1 mm).	Fish bone recovery and taxonomic richness can increase with finer screen sizes (e.g., Moss et al. 2017). Fish scales of many common Northeast Pacific fish species are <6.35 mm (e.g., herring) and <2 mm (e.g. eulachon).	Categorical, 6.35 mm, 2 mm, & 1 mm
Degree of Scale Degradation	With increasing scale degradation will be more difficult to recover and identify with increasingly fragmentary scales scoring closer to 1)	Increasing degradation of scales will obscure or limit features required for securing identification (Casteel 1974; Salvatteci et al. 2012; Wheeler 1978)	Ordinal, see Table 2.4
Fish Bone	Fish scale abundance and taxonomic composition will closely approximate fish bone abundance and composition	Scales share some similar mineral composites with bone and keratin (O’Connor et al. 2015).	$NISP_{bone}$ $NISP/L_{bone}$ Ubiquity
Site Age (calibrated yrs B.P.)*	Fewer fish scales will be recovered from deeper (older) depositional periods	Progressively greater destruction of fish bones is noted in older depositional periods (Wigen and Stucki 1988); Additive effects of degradation over time can also lead to demineralization of keratin-rich remains in archaeological soils (O’Connor et al. 2015).	Calibrated radiocarbon dates (age ranges & age range midpoints)

*Site age is approximated using increasing depth as a proxy for increasing age. Radiocarbon age midpoints were used to establish age/depth relationships to interpret and approximate the age-categories of individual scale specimens.

Lab Methods

Washing, Screening, & Sorting

Fish scales were washed in window mesh and then sorted through three nested mesh sizes 6.35 mm, 2 mm, and 1 mm. Scales were recovered from each fraction using insect forceps (very thin, lightweight tweezers) with assistance from undergraduate and graduate volunteers from UVic 'Rockwash' (Figure 2.0).

Figure 2.0. Sample setup for picking archaeological fish scale samples.

Microscopy

Wet mounted scales were placed between two glass microscope slides to flatten relevant structures for digital photography following Patterson et al. (2002) and photographed using a Leica DM750 microscope equipped with a digital camera. Scale bars were retroactively added in Adobe Photoshop 21.2. These photos were used to create an open access digital archive of archaeological fish scales. Figure 2.1 summarizes the stages in microscopic photography.

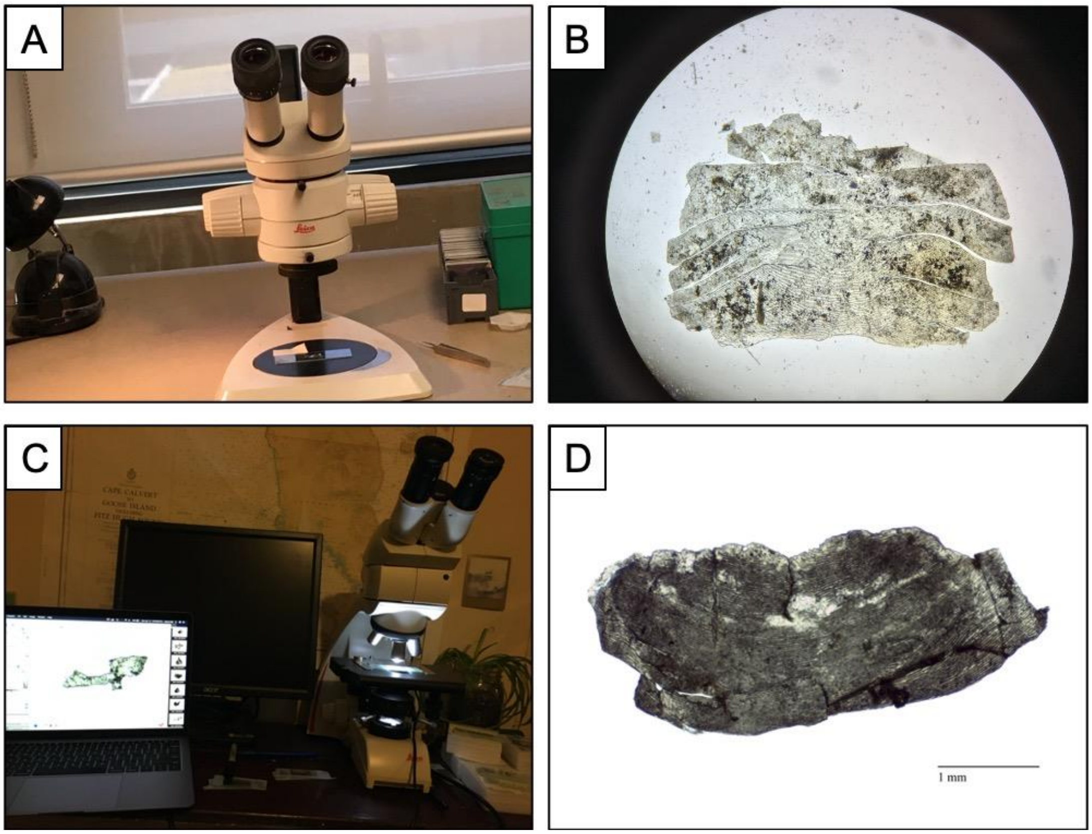
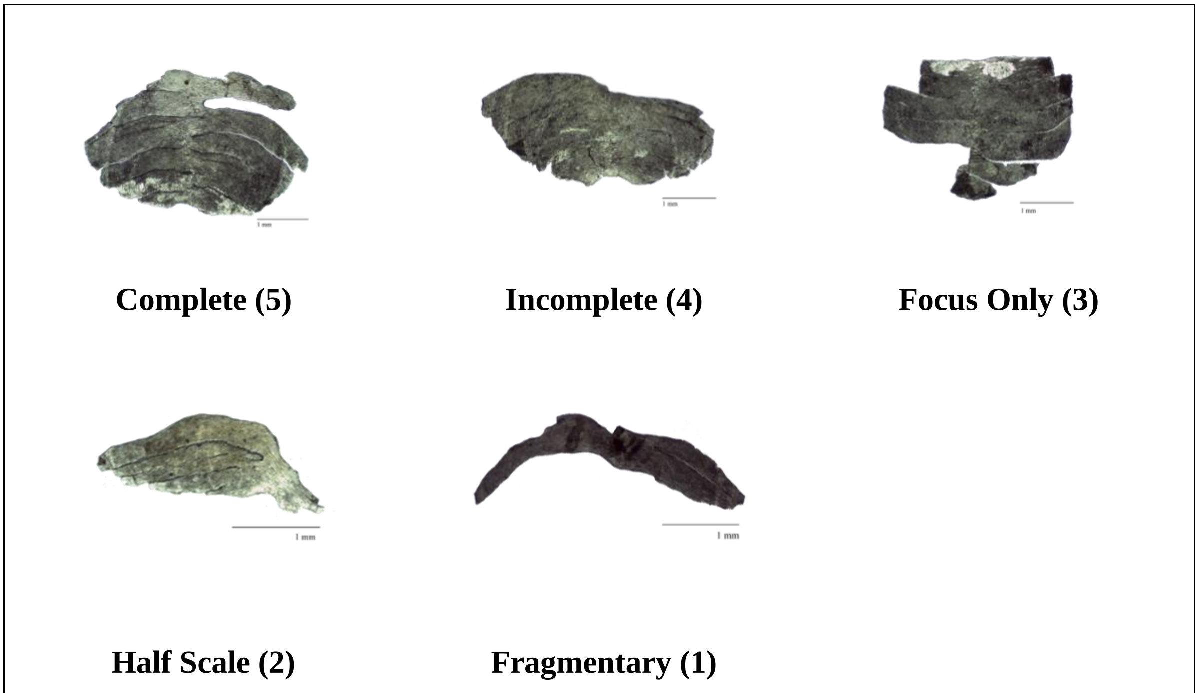


Figure 2.1. Summary of stages in microscopic fish scale photography. A. Slide mounting using a compound microscope to ensure relevant structures are visible in the field of view. B. Example of a photograph of a herring fish scale with proper mounting prior to digital photography. Scale is shown at (40X magnification) using a compound microscope and directional light. C. Digital microscope setup for scale photography using Leica DM750 microscope with a digital camera and Leica Acquire for Mac. D. Example fish scale micrograph with scale bar digitally added in Photoshop v. 2020.

Scale Degradation

Fish scale degradation was quantified used a modified categorical index of degradation that ranges from complete (least degraded) to fragmentary (most degraded) (Figure 2.11). Our degradation index borrows heavily from Salvatteci et al. (see Salvatteci et al. 2012: 57), who categorize Peruvian anchovy scales on a degradation scale according to the preservation of scale features. Our scale degradation categories have been developed for commonly occurring fish species on the Northwest Coast.



Complete (5)- Both lateral fields and focus are present
Incomplete (4)- One complete lateral field, focus, and a nearly complete opposing lateral field
Focus Only (3)- Focus is present but only a portion of the lateral field remains. Scale margins are absent.
Half Scale (2)- Scale has a partial focus but only half of the scale itself
Fragmentary (1)-Less than half of the scale remaining, the focus is not easily discernable or is completely absent.

Figure 2.11. Degree of scale degradation from 5 "Complete" to 1 "Fragmentary" fish scales. (adapted from Salvatteci et al. 2012, Figure 3, 56-58).

Quantification and Identification of Fish Scales

Fish scales and bones obtained from 2 mm and 1 mm mesh screens were counted and identified with the aid of a microscope and comparison with a physical reference collection of ~ 300 modern and archaeological comparative fish scales held at the University of Victoria Zooarchaeology Laboratory. We supplemented this physical comparative collection with Patterson et al.'s (2002) digital photographic scale atlas. All archaeological fish scales were identified to the most specific taxonomic designation possible based on scale morphology. Analysts Joanne Groot and Judy McArthur of the Pacific Biological Station, Nanaimo, BC, provided confirmation checks for a randomized sample of identified herring and salmon scale identifications submitted for ageing analyses based on digital scale images. Resulting identified fish scales were quantified by the number of identified specimens (NISP) (Grayson 1984), which are denoted as $NISP_{fsc}$ for the scales and $NISP_{b}$ for fish bones or as the number of identified fish scales per litre $NISP_{fsc}/L$ based on the calculated volumes of examined sediment. For fish scales from the Broken Group Islands, where scales have not yet been identified, a recovery index of the number of recovered fish scales per litre (NSP_{fsc}/L) is used in place of the NSP/L. We also describe the ubiquity of fish scales calculated based on their presence in examined auger levels in Rivers Inlet and Broken Group Island. sites

Radiocarbon Dates

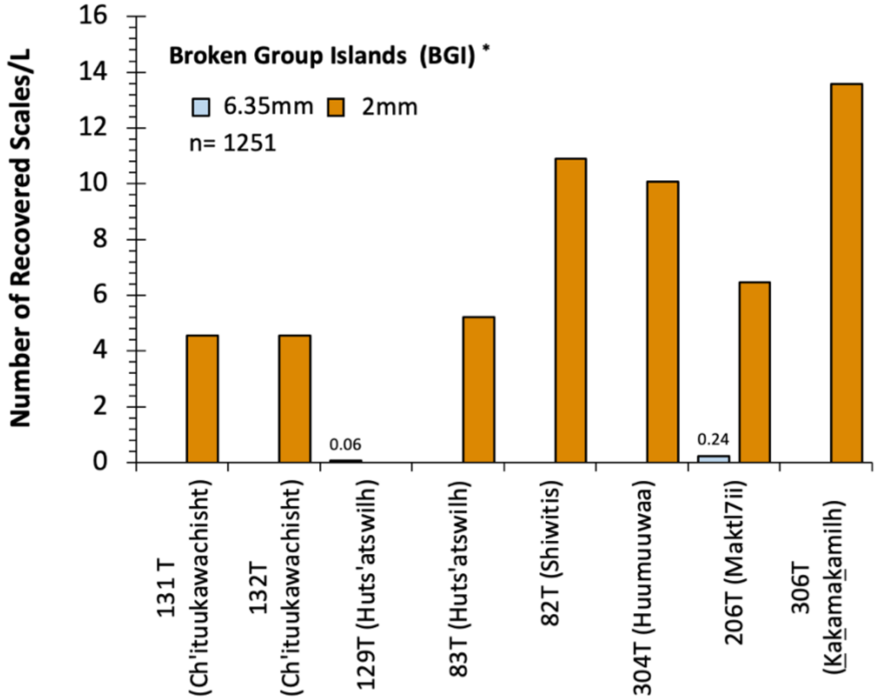
Radiocarbon dates provide the basis for our chronological interpretations of fish scale preservation. We draw on ten radiocarbon dates reported by Cannon (2013: 90) and two radiocarbon dates during the 2020 fieldwork at EkSt-1 (Appendix B, Figure 5.1). We recalibrated all radiocarbon dates using CALIB 8.2 (Stuiver et al. 2021) using the IntCal20 curve (Reimer et al. 2020). Additionally, we established a chronology for site age comparisons from median calibrated dates (i.e., the middle value of the radiocarbon age range or midpoint date) by calculating median age in calibrated date ranges and associating these dates with depth below surface ranges reflecting broadly comparable time periods.

Results

Variable 1: Screen Fraction Size

Fish scales were predominantly recovered from the 2 mm mesh screen fraction in all sites in the Broken Group Islands but a few scales were also present in the 6.35 mm mesh sizes. The 1 mm fraction for these sites has not yet been examined. Fish scales are recovered from the 2 mm and 1 mm fraction from the four Rivers Inlet sites. In the 2 mm fraction, there is a higher number of scales per liter in the BGI (6.9 scales/L), whereas, in Rivers Inlet sites, scales are most frequently recovered from the 1 mm fraction (3.4 scales/L, *see* Figure 2.2).

Fish scales identified to the nearest taxonomic order from Rivers Inlet were present in both 2 mm and 1 mm mesh sizes; however, more species and specimens were recovered from the 2 mm fraction (9 taxonomic groups, n=277 specimens, 95% of all identified fish scales; see Figure 2.21). Herring and northern anchovy are the most frequently identified species in the 2 mm fraction, but herring order and family designations (Clupeiformes, *Clupeidae*) outnumber anchovy in this fraction overall. Herring followed by salmon are the most frequently identified genera in the 1 mm fraction. One species, eulachon, is not identified in the 2 mm fraction but representative specimens were recovered from the 1 mm fraction.



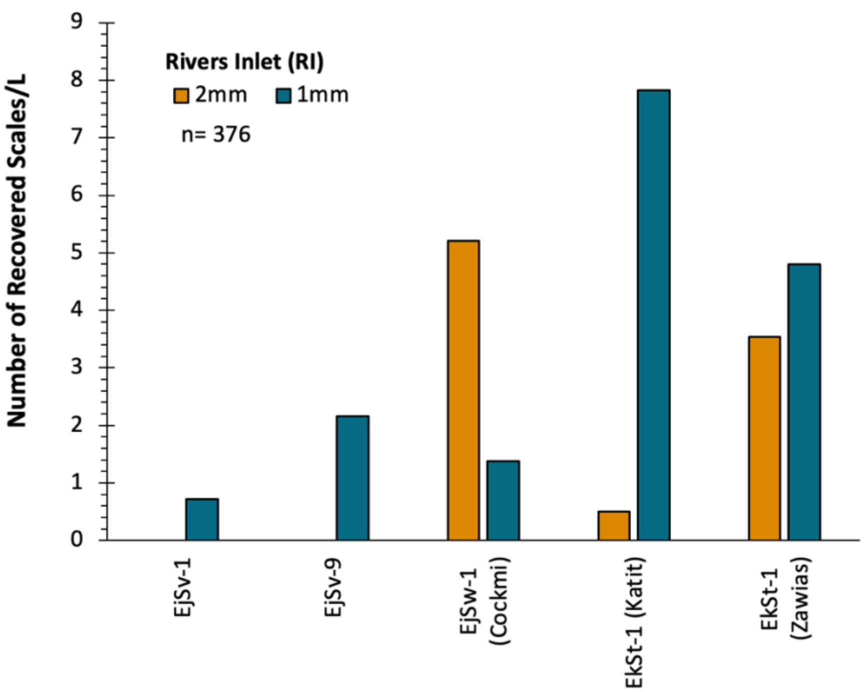


Figure 2.2. Number of recovered fish scales from itemized fine screen fractions for Rivers Inlet and Broken Group Island sites with fish scales. *Fish scales were not examined from the 1 mm fraction from the Broken Group Islands (McKechnie 2014). ** 6.35 mm fraction were not examined for fish scales for Rivers Inlet sites examined by Aubrey Cannon in 2004/2005 (Cannon 2013b).

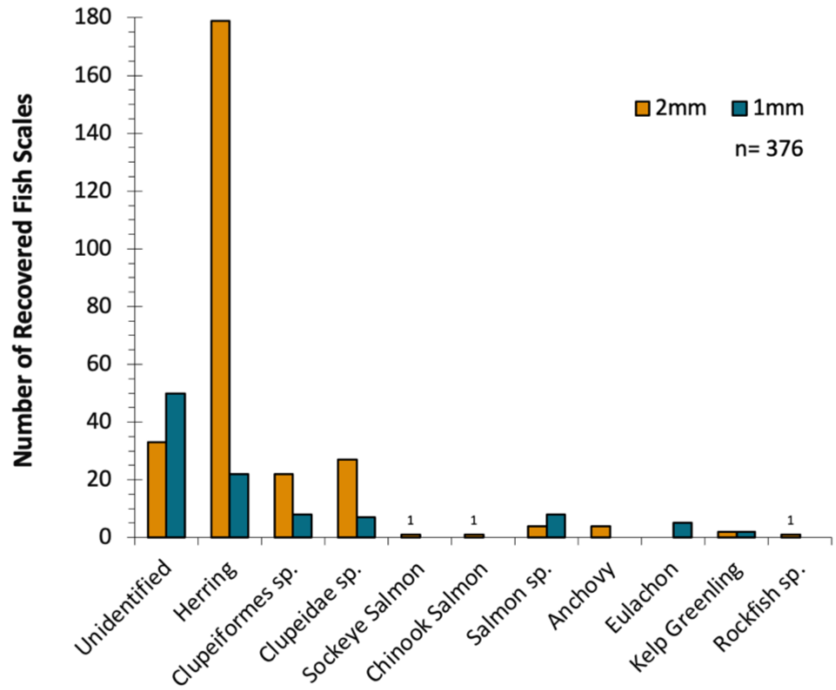


Figure 2.21. Fish scale preservation in 2 mm and 1 mm fraction by taxonomic group in Rivers Inlet sites including unidentified scales

Variable 2: Scale Degradation

The largest number of fish scales recovered per litre of sediment at Rivers Inlet sites had a degradation ranks between 3 to 5 (~ 2.17 scales per litre; Figure 2.3). Based on the categories in the degradation index in Figure 2.11, this indicates that in examined scales scale recovery increased where at least the focus preserves (degradation rank of 3) (Figure 2.3). For Rivers Inlet sites, 99% of fish scales with at least focus level preservation were identifiable to at least family or genus level (2.17 scales/L, Figure 2.3). Degraded scales (i.e., fragmentary and half scales) that are identifiable occur more infrequently (1.16 scales/L) (Figure 2.3). Pacific herring is the most frequently identified species (n=33; Figure 2.31). We additionally, found that the order and family-level taxonomic designations *Clupeiformes* and *Clupeidae* (which include herring) are the next two frequently identified groups for scales with focus only or greater preservation (Figure 2.31). Taxonomic identifications from ‘half scales’ or ‘fragmentary’ scales (i.e., <3 degradation scores) primarily achieved order and family level identification. Identified half (2) or fragmentary scales (1) included Clupeiformes (n=35) and Sebastes (Rockfish) (n=1) groups as well as a limited number of species-level identifications of Pacific herring (n=7).

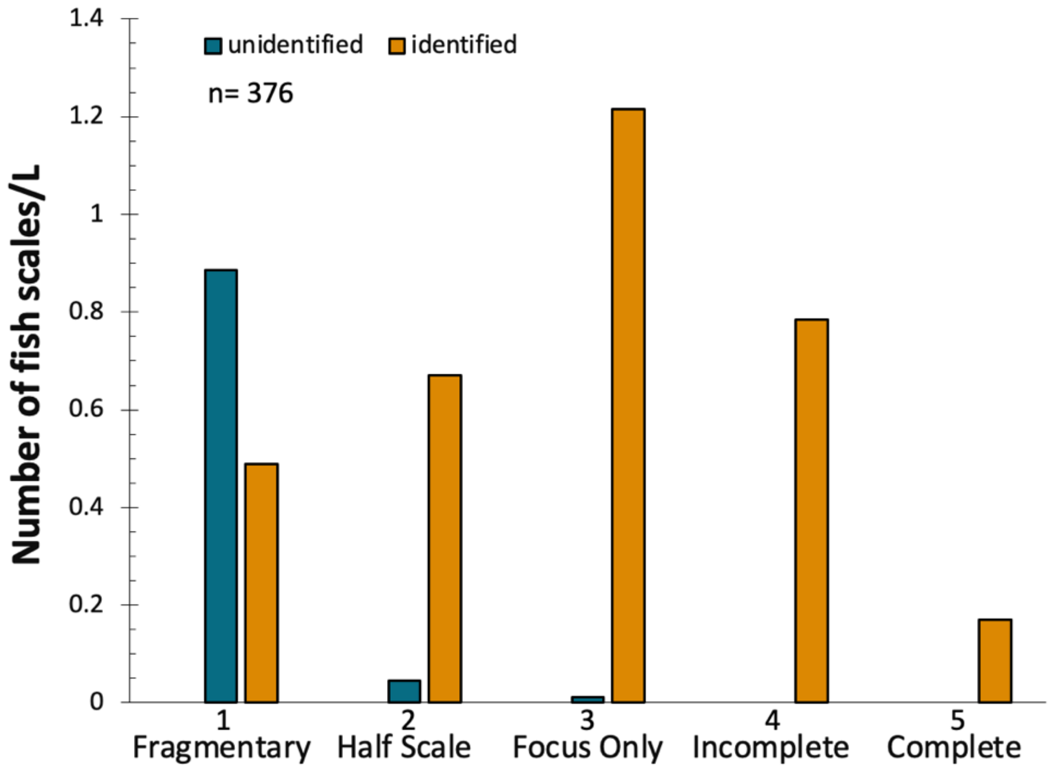


Figure 2.3. Fish scale preservation for identified and unidentified scales for all Rivers Inlet Sites. Degree of Scale Degradation is based on five categories (1 ‘Fragmentary’ to 5 ‘Complete’) summarized in Table 2.4. # of fish scales/L= the number of fish scales of each degradation type observed in the 86.7L of auger sediments examined for fish scales in Rivers Inlet.

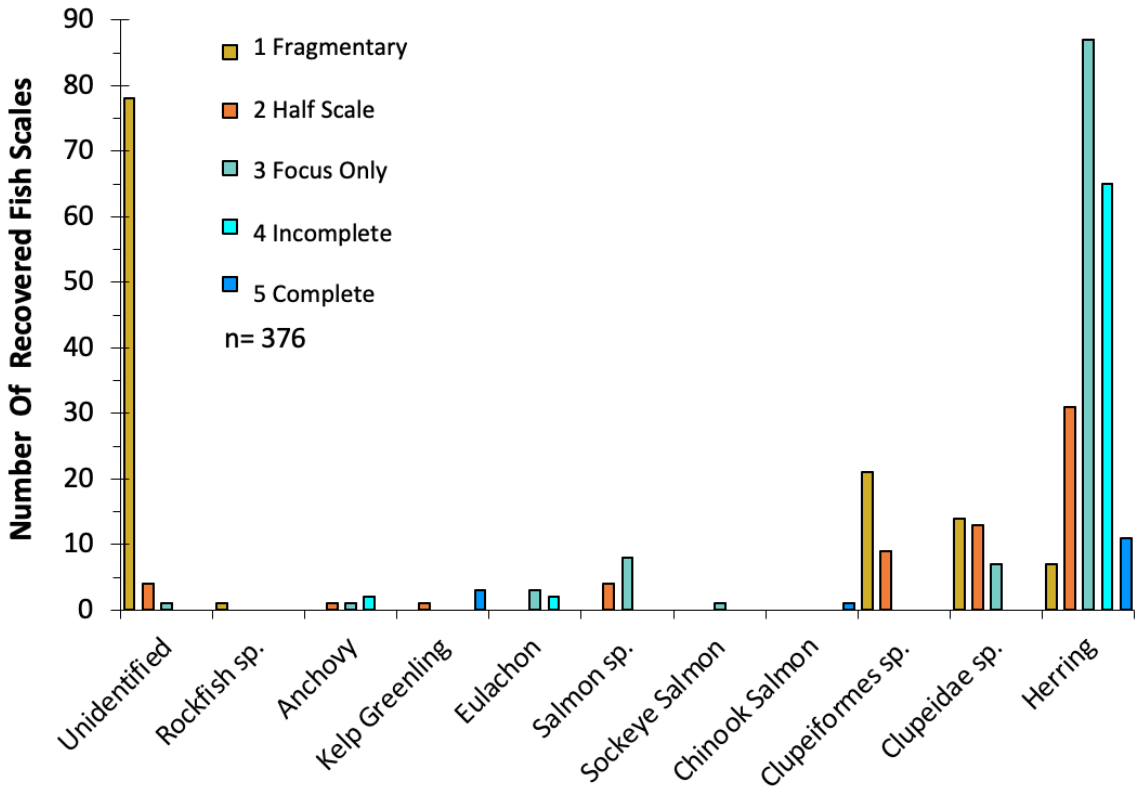


Figure 2.3.1. Fish Scale preservation for identified and unidentified taxon grouped for EkSt-1 and EjSw-1 by degree of scale degradation. Degree of scale degradation is based on five categories (1 'Fragmentary' to 5 'Complete') summarized in Table 2.4.

Variable 3: Fish Bone

The ubiquity of fish scales in both study regions across all examined levels is considerable and similar between regions, with scales occurring in 45.3% of levels in the Broken Group Islands and 44.4% in Rivers Inlet (Table 2.2). However, fish bone is four times more abundant per litre of recovered sediment than fish scales across the four study sites in Rivers Inlet (NISP/L_{bAVG}=26.93/L; NISP/L_{fscAVG}= 6.18/L) based on calculated examined sediment volumes (calculated from the auger diameter and depth range). Pacific herring is the most relatively abundant taxa in both fish scale and bone assemblages at EjSv-9 and EjSw-1, accounting for 42.1% and 47.1% of fish bones and 66.7 and 95.7% of identified scales, respectively (Figure 2.4). At EkSt-1, salmon is the most abundant taxon representing 59.3% of identified fish bone; Figure 2.8) followed distantly by herring which accounts for the second highest percentage of fish bone (i.e., 29% of identified fish bone; Figure 2.8).

Table 2.2. A comparison of fish scale ubiquity in Rivers Inlet and the Broken Group Islands.

Place Name/ Location	Borden #	Parks #	N Levels with fish scales	N Levels examined for fish scales	Ubiquity of fish scales
Huts'atswilh (Upper Dicebox Is.)	DfSh-79	129T	41	77	53.2%
Huts'atswilh (Lower Dicebox Is.)	DfSh-31	83T	40	77	51.9%
Shiwitis (Gilbert Island)	DfSh-29	82T	25	37	67.6%
Huumuuwaa (Village Is.)	DfSh-4	304T	37	62	59.7%
Maktl7ii (Wouwer Is.)	DfSi-19 & 30	206T	55	99	55.6%
Ch'ituukwachisht (South Cree Is.)	DfSh-82	132T	1	8	12.5%
Ch'ituukwachisht (North Cree Is.)	DfSh-81	131T	1	6	16.7%
Zawias (Rivers Inlet)	EkSt-1 (2020)	NA	12	73	16.4%
Katit (Rivers Inlet)	EkSt-1 (2005)	NA	14	22	63.6%
Cockmi (W. Walbran Is.)	EjSw-1	NA	23	55	41.8%
(W. Walbran Is.)	EjSv-9	NA	2	4	50.0%
(SE. Walbran Is.)	EjSv-1	NA	1	2	50.0%

Table 2.3. Number of identified specimens (NISP) and NISP per litre data for fish scale (fsc) and bone (b) specimens from auger sample deposits. EjSv-1 is excluded from this table as no fish scales were identifiable from this site and the overall sample size of fish scales and bones at this site is modest.

	EjSv-9				EjSw-1				EkSt-1											
	NISP		NISP/L		NISP		NISP/L		NISP				NISP/L				TOTAL NISP		TOTAL NISP/L	
	fsc	b	fsc	b	fsc	b	fsc	b	*fsc ('05)	*fsc ('20)	*b ('05)	*b ('20)	*fsc ('05)	*fsc ('20)	*b ('05)	*b ('20)				
Taxa																	**fsc**	**b**	**fsc**	**b**
Clupeiformes sp.	_		_	_	24		0.73	_	3	3	_	_	3.4	0.08	0.12	0.31	**30**	**0**	**4.14**	**0.43**
Clupeidae sp.	_		_	_	26		0.80	_	7	1	_	_	8.0	0.03	0.28	0.10	**34**	**0**	**8.75**	**0.39**
C. pallasi	2	232	0.87	17.31	128	1465	3.92	20.93	69	2	738	20	5.26	0.05	0.81	0.20	**201**	**2455**	**10.04**	**39.26**
E. mordax	_	100	_	7.46	3	220	0.09	3.14	1	_	7	_	0.08	_	_	_	**4**	**327**	**0.17**	**10.61**
Hexagrammos sp.	_	16	_	1.19		32		0.46			5	_	_	_	_	_	**0**	**53**	**0**	**1.65**
H. decagrammus	_	_	_	_	_	_	_	_	4	_	_	_	0.30	_	_	_	**4**	**0**	**0.30**	**0**
Oncorhynchus sp.	1	202	0.43	15.07	2	1374	0.06	19.63	4	5	1503	471	0.30	0.13	19.15	0.51	**12**	**3550**	**0.80**	**54.36**
O. nerka	_	_	_	_	_	_	_	_	_	1	_	_	_	0.03	_	_	**1**	**0**	**0**	**0**
O. tshawystscha	_	_	_	_	1	_	0.03	_	_	_	_	_	_	_	_	_	**1**	**0**	**0.03**	**0**
T. pacificus	_	_	_	_	1	17	0.03	0.24	_	4	282	6	_	0.10	0.24	0.41	**5**	**305**	**0.03**	**0.89**
Sebastes sp.	_	_	_	_	1	4	0.03	0.06	_	_	_	_	_	_	_	_	**1**	**4**	**0.03**	**0.06**
Anoploma sp.	_	_	_	_	_	1	_	0.01	_	_	_	_	_	_	_	_	**0**	**1**	**0**	**0**
Cottoidea sp.	_	1	_	0.07	_	_	_	_	_	_	_	_	_	_	_	_	**0**	**1**	**0**	**0.07**
NISP fish	**3**	**551**			**186**	**3113**			**88**	**16**	**2535**	**497**								
NISP/L fish			**1.30**	**41.12**			**5.69**	**44.47**					**17.31**	**0.41**	**20.61**	**1.53**				
*Examined Volume (L)_cal	fsc 2.31	b 13			fsc 32.7	b 70			*fsc '05 13.1	*fsc '20 38.6	*b '05 24.6	*b '20 9.8					TOTAL (L) FSC 86.7		TOTAL (L) B 117.81	

***Two separate sampling efforts at EkSt-1 are differentiated in the table by their sampling year '05 = 2005 sampling by Aubrey Cannon reported in Cannon 2013 a,b and '20 = 2020 sampling by Ball and McKechnie 2020. Sample volume is calculated using $V=\pi r^2 h$ to standardize volume comparisons between sites.**

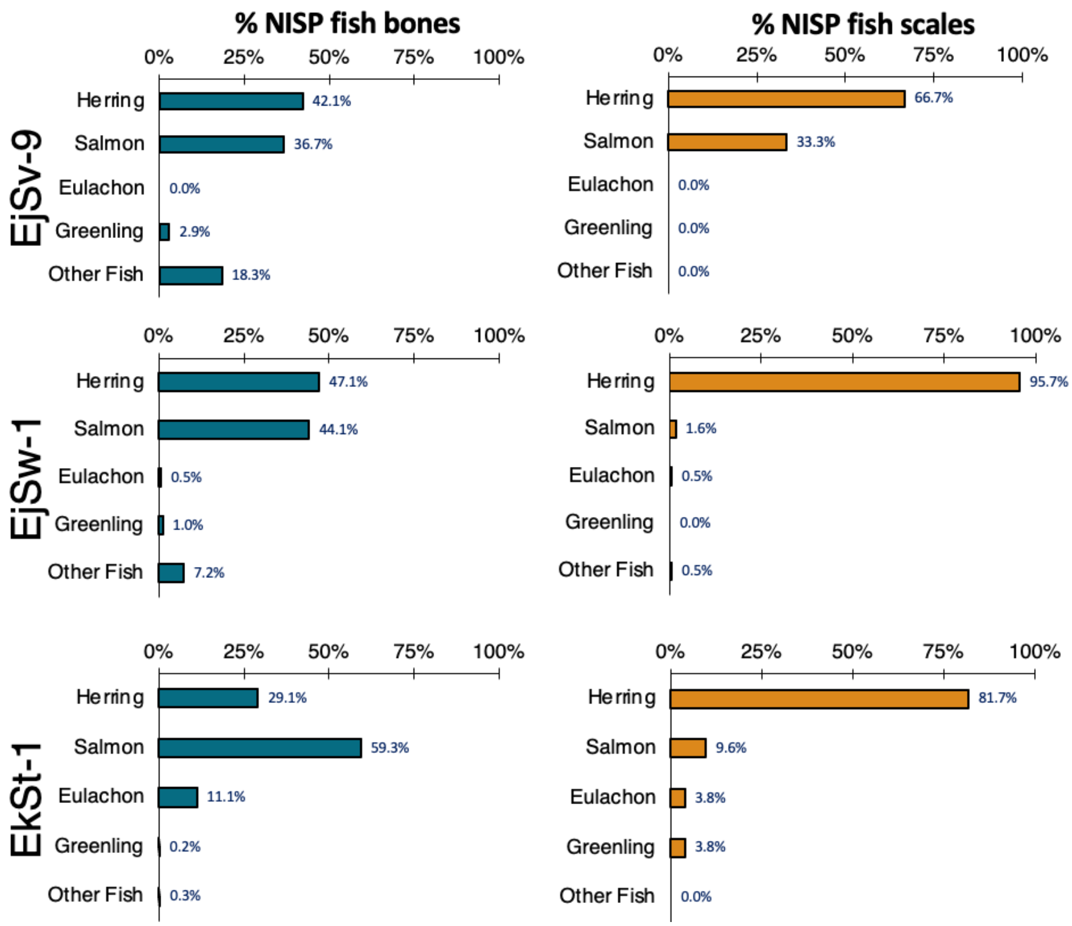


Figure 2.4. Relative abundance of fish bone and scale assemblages from EkSt-1, EjSw-1 (Cockmi), and EjSv-9 shown as the percent of total identified fish specimens. Zawias and Katit samples are combined in this figure (i.e., EkSt-1).

Variable 4: Site Age

Analysis of scale preservation by chronological period indicates a higher number of fish scales per litre of calculated volume are recovered from later period sites (i.e., those dating after 1000 cal. B.P.) (Figure 2.5). Approximately 5.7 fish scales/L are recovered from late sites and 2.6 scales/L from early sites in the BGI (Figure 2.5). Comparably, 1.4 scales/L are recovered from late sites and 2.7 scales/L from early for Rivers Inlet (Figure 2.5). The greatest observed recovered fish scales per litre in sites in Rivers Inlet is at Zawias (auger tests 8-11), where 4.9 scales/L are recovered from those deposits from 1000 years cal. B.P. or later. Kakmakamilh had the highest recorded recovered fish scales per litre for BGI sites at 13.7 scales/L respectively; these scales are from deposits that date to within the last 1000 years. The largest number of recovered scales for the early sites we observe are Ch'ituukawachisht sites (131T and 132T) (4.6 scales/L) and Zawias (EkSt-1) (3.5 scales/L) (Figure 2.5). Additionally, for Rivers Inlet sites we identify approximately 2.3 scales/L from late sites versus 0.99 per litre from early sites (Figure 2.51).

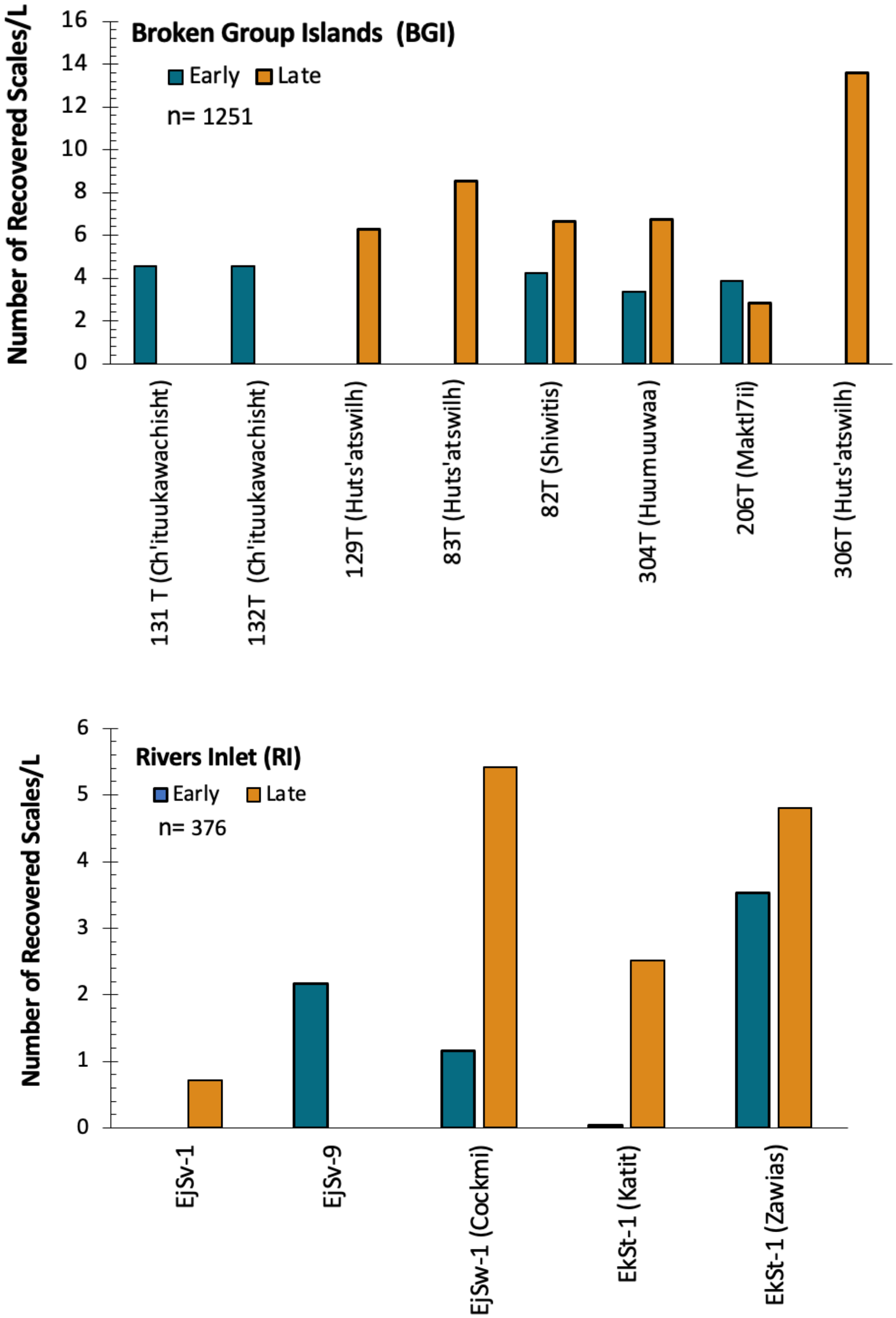


Figure 2.5. Number of fish scales recovered per litre of calculated volume from Early (prior to 1000 cal. B.P.) and Late deposits from BGI and Rivers Inlet (RI) archaeological sites. Includes unidentified scales for RI sites.

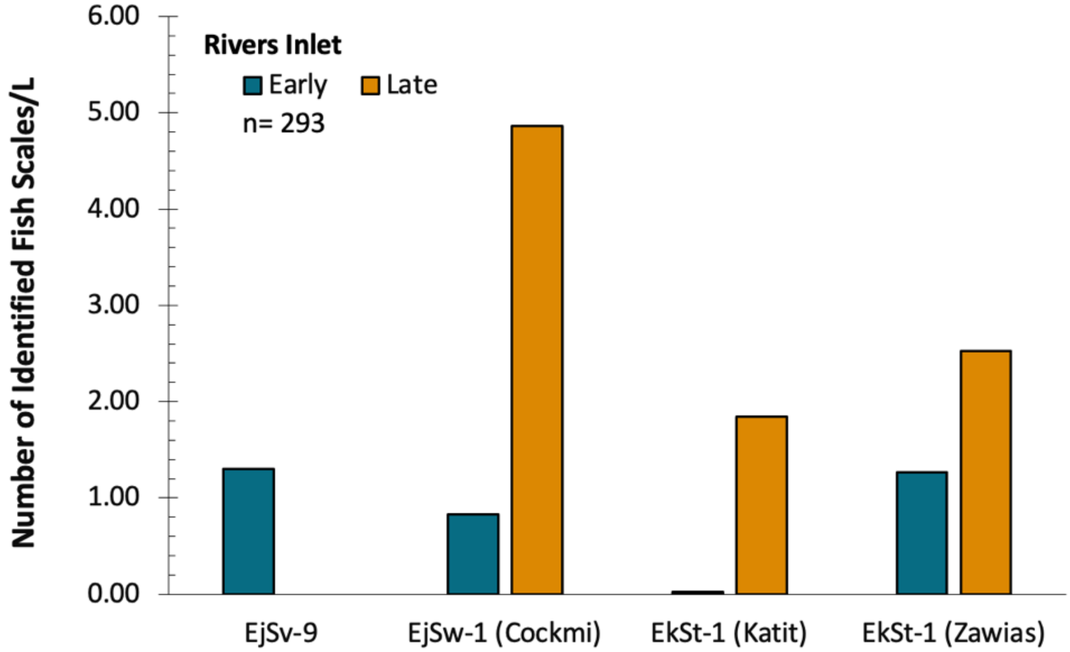


Figure 2.51. Number of fish scales identified per litre of auger sediment from Early (prior to 1000 cal. B.P.) and Late deposits Rivers Inlet archaeological sites. *Volume using the formula for calculating the volume of a cylinder with auger sample depth as *h* and diameter the distance across the circular auger bucket.

Table 2.4. Summary of site ages for sites with recovered fish scales. Site ages reflect median (mid-point) calibrated ranges in years before present. For an approximation of Rivers Inlet sites by depth, see Appendix B.

	Location	**Borden #**	**Parks #**	**Site Age (Late)**	**Site Age (Early)**	**Source**
Broken Groups Islands	***Huts'atswilh*** (Upper Dicebox Is.)	DfSh-79	129T	150	2500	McKechnie 2015
	Huts'atswilh (Lower Dicebox Is.)	DfSh-31	83T	350	900	McKechnie 2015
	Shiwitis (Gilbert Island)	DfSh-29	82T	150	1200	McKechnie 2014: Chapter 6
	Huumuuwaa (Omoah Is.)	DfSh-4	304T	400	1800	McKechnie 2015
	Maktl7ii (Wouwer Is.)	DfSi-19 & 30	206T	500	2400	McKechnie 2015
	Ch'ituukwachisht (South Cree Is.)	NA	132T	1400	2500	McKechnie 2014: Chapter 7
	Ch'ituukwachisht (North Cree Is.)	NA	131T	900	2200	McKechnie 2014: Chapter 7
	Kakmakamilh (Keith Island)	DfSh-17	306T	70	300	McKechnie 2014: Chapter 7
Rivers Inlet	***Zawias*** (Rivers Inlet)	EkSt-1 (2020)	NA	Historic	3000	Ball et al. 2020
	Katit (Rivers Inlet)	EkSt-1 (2005)	NA	150	600	Appendix B recalibrated age from Cannon 2013b
	Cockmi (W. Walbran Is.)	EjSw-1	NA	800	2600	Appendix B; recalibrated from Cannon 2013b
	(W. Walbran Is.)	EjSv-9	NA	400	3300	Appendix B; recalibrated from Cannon 2013b
	(SE. Walbran Is.)	EjSv-1	NA	400	1200	Appendix B; recalibrated from Cannon 2013b

Discussion

We examined four variables: screen size, scale degradation, fish bone abundance, and site deposit age to gain better insight into how fish scales preserve and how they can be recovered from coastal archaeological sites on the Northwest Coast. Analysis of fish scales from archaeological deposits in the Broken Group Islands and Wuikinuxv territory reveal that fish scales are considerably more common in archaeological deposits and are more promising for analytical study than previous studies suggest (cf. Casteel 1970; Troffe et al. 2017). Based on fish scales recovered from two distinct territories on the Northwest Coast we observe patterning in fish scale recovery that shows consistently that fine screening (i.e., 2 mm or 1 mm) is necessary to acquire sufficient samples of fish scales for further analyses. Additionally, our identification of fish scales from Rivers Inlet demonstrate that fish scales generally become more difficult to identify as they become more degraded (i.e., fragmentation of scales).

Fine Screening

Our results indicate that while fish scales in this study could be recovered from a variety of screen sizes (6.35 mm, 2 mm, & 1 mm), generally, 6.35 mm screens appear to be a less effective screen size for recovering fish scales than finer screen sizes where they are examined (Figure 2.2). We also observe that while 2 mm mesh may be adequate to recover fish scales and is the fraction where the majority of scales are recovered from BGI sites; our analysis of fish scales from Rivers Inlet show that scales of certain forage fish species (i.e., eulachon) are only recoverable from 1 mm mesh (Figure 2.21). These data are consistent with previous studies that find that fine screening (i.e., 2 mm and 1 mm) increases recovery of and taxonomic richness of fish bone assemblages, including forage fish such as smelts (*see* Moss and McKechnie 2016; Moss et al. 2017; Patton et al.

2019). Based on our findings, it seems likely that future studies seeking to recover fish scales will need to consider budgeting for fine screen recovery and/or a fine screening subsampling strategy to acquire a reasonable sample size of scales for analysis.

Scale Degradation

The results of this study indicate that fish scales from coastal archaeological deposits generally require at least foci level preservation for identifications at the level of family, genus, and species. Our results expand upon previous assessments of fish scales that have suggested that the peeling of margins in fish scales directly impacts their recovery and suitability for confident identification (i.e., Wheeler 1978). However, we could still provide identifications for more degraded fish scales to higher level herring taxonomic classification even when the focus did not preserve. This observation might reflect that Clupeidae have relatively consistent markers for identification at a variety of degradation states. Overall, these results stress a strong consideration of the degree of scale degradation as a means for assessing and selecting suitable fish scales for further identification and other kinds of analyses (e.g., ageing).

Recovery of Fish Bone

The relative abundance and ubiquity of recovered and identified fish bone do not appear strongly correlated with recovered fish scales. However, fish bones are approximately four times more numerous than fish scales at some sites in Rivers Inlet, despite fish scales being generally more abundant structures than bones in living fish (Table 2.3). From this, we surmise two potential hypotheses to explain the differences in preservation observed in fish and bone records. First is a potential differential taphonomic degradation in fish scales versus bones, whereby fish scales are more vulnerable to coastal archaeological deposits Or, second, that sedimentary processing and recovery of other archaeological materials negatively affect scales and result in higher degrees of scale degradation. Determining the specific taphonomic forces acting on archaeological scales and teeth from coastal archaeological deposits or the processing pressures (i.e., screening sediments, wet/dry sieving) in future studies would help to reconcile why fish bone is more frequently observed in archaeological deposits despite the biological reality that fish scales are more abundant structures on living fish. However, despite potential differences in preservation, these taxonomic identifications are remarkably similar for fish scales and bones assemblages in our case study. Accordingly, fish scales provide an additional line of evidence for strengthening the reliability of archaeological fish identifications, as recognized by Casteel (1974; cf. Nims and Butler 2017).

Fish scales also show promise for identifying additional species where species are difficult to distinguish from archaeological fish bone and where identification is only previously obtained using ancient DNA identification analysis. Our study demonstrates that fish scales can species-level identification for species including eulachon, which in fish scales are distinguishable from other smelts; for species only previously identified using ancient DNA identification (i.e., chinook salmon, sockeye salmon; see Cannon 2011); and to refine identification from genus to species-level for greenling (i.e., kelp greenling). Our identification results are significant in that they may refine potential reluctance to use fish scales for identification based on the limited success of previous studies on the Northwest Coast (*see* Troffe et al. 2017). We also determine that while physical comparative collections were more effective than available digital identification guide for our study region for determining species, particularly for *Oncorhynchus sp.* these atlases remain useful tools for narrowing down identifications to family and genus. This study lends further support to previous recommendations to use a physical comparative collection for identification of fish scales from archaeological deposits (Wheeler 1978; Casteel 1974) by establishing that physical comparative collections are crucial to the process of confident identification to species.

Site Age

Fish scales were consistently observed in nearly all time periods in examined site deposits from thirteen Northwest Coast archaeological sites spanning 3000 years to contact in Rivers Inlet and 2500 years to contact in Barkley Sound. These results suggest that fish scales regularly preserve in late Holocene coastal shell midden. However, our study also demonstrates that identified fish scales occur at higher densities per litre at sites dating to within the last 1000 years than at sites that date to prior to 1000 years ago. While a notably a larger number of sites in our sample date to within the past 1000 years than to earlier time periods (Table 2.4) we observe that fish scales are more frequently recovered from later time periods indicating that they are conditions in archaeological sites possibly linked to deposit age that may impact scale preservation. One potential venue for exploring this further could include testing for the potential compounding effects of scale degradation and site deposit age on fish scale recovery by examining how degradation scores vary through time within and between sites. Based on observations from our case study, we would predict that these kinds of further analyses would observe a greater proportion of more degraded scales in older depositional contexts. However, we recognize that other factors apart from site age such as sample handling, screening, and soil chemistry likely also affect scale recovery and require further consideration.

Conclusions

We demonstrate that fish scales represent a valuable but underrecognized source of zooarchaeological fisheries data from coastal archaeological sites on the Northwest Coast. Building on the important contributions of Richard Casteel in applying squamatology to archaeological analysis of fish scales, we demonstrate that large samples of fish scales can be recovered from coastal archaeological deposits on the Northwest Coast. We observe a range of culturally and ecologically important fish taxa spanning the last 3000 years using minimally destructive small volume bucket-auger sampling and screening methods that both complement and expand on existing records of documented taxa from archaeological sites in Wuikinuxv territory. Through this study, we identify considerations for the successful recovery and identification of fish scales including the use of fine screening and physical reference collections. We also identify considerations for sample selection for future studies of fish scales from archaeological deposits, such as prioritizing the identification of scales with at minimum focus level preservation. By advocating for increased attention to fish scale data and squamatological methods in archaeological study, we see potential to generate rich zooarchaeological fisheries data to be considered alongside other archaeological proxies of ancient Indigenous fisheries.

Chapter 3: Potential in Two-Eyed Seeing: Interweaving archaeological fisheries data with multiple ways of knowing to provide tools for community-based fisheries management

Introduction

Forage fish are salient fisheries for commercial, recreational, and Indigenous fishers alike. Over millennia these fish have shaped Indigenous lifeways and cultural practices on the Northwest Coast and have provided Indigenous fishers with vital influxes of protein, fat, and grease (especially eulachon) of high cultural, nutritional, and economic value (Mitchell and Donald 2001; Moody 2008). Forage fish, including Pacific herring (*Clupea pallasii*) and eulachon (*Thalecichthys pacificus*), have been identified as cultural keystone species for Indigenous peoples on the Northwest Coast (Garibaldi and Turner 2004; Thornton and Kitka 2015) and alongside other species (e.g., northern anchovy (*Engraulis mordax*), *surf smelt*) are common in archaeological records throughout the Northwest Coast (McKechnie et al. 2014; McKechnie and Moss 2016; Patton et al. 2019). Notwithstanding the disproportionate impacts of industrialization and colonization on Indigenous fisheries, many Indigenous communities on the Northwest coast continue to engage in traditional millennia-old practices of cultural care for these forage fisheries through rights, responsibilities to access and stewardship and hereditary governance and are actively renewing them as management strategies today (e.g., Atlas et al. 2021; Beveridge et al. 2020; Gauvreau et al. 2017; Green et al. 2013; Menzies and Butler 2007; Thornton et al. 2010; Turner et al. 2000).

Widespread reduction and restrictions on access to culturally significant fisheries, including forage fish, currently contribute to extensive ecological, cultural, and economic loss for local and global communities (Bennett et al. 2018; Pauly et al. 1998; Worm et al. 2009). In recent decades Indigenous fishers from the Wuikinuxv First Nation on British

Columbia's Central Coast have observed declines and changes in the availability of local forage fish populations. In particular, Wuikinuxv's management bodies (Wuikinuxv Stewardship and Wuikinuxv Fisheries) have identified concerns with declines in their major eulachon fishery along the Wannock River (Central Coast Indigenous Resource Alliance 2016; Wuikinuxv First Nation 2018) and their herring fishery (Central Coast Indigenous Resource Alliance 2016; Gerrard 2014; von der Porten et al. 2016; Walkus 2011).

Historical records indicate that eulachon were once incredibly abundant in Rivers Inlet and particularly in the Wannock River (Canada 1878-1914). An estimated 75-125 barrels of salted eulachon and 0.09 to 0.9 tonnes of smoked eulachon were transported annually from Rivers Inlet to the Skeena District between 1888 and 1892 (ibid.). Local catch records from Wuikinuxv community indicate that 4.54 tonnes of eulachon were taken from the Wannock River in 1971 (Fisheries and Oceans 1967-68 and 1971). Wuikinuxv community members interviewed in 2002 reported that the eulachon run along the Wannock River had been declining since the 1970s (Winbourne 2002). By the late 1990s, with virtually no eulachon eggs or larvae being recovered during community sampling efforts, out of self-preservation, Wuikinuxv's eulachon fishery was virtually non-existent (Berry and Jacob 1998). To our knowledge, 'no take' continues to be encouraged for the Wannock eulachon fishery, and community-based monitoring efforts are currently underway for local eulachon populations (for further description of local monitoring efforts, *see* Wuikinuxv First Nation 2020).

Pacific herring have also experienced considerable reductions and changes in accessibility on the Central Coast and in Wuikinuxv territory over the past several decades. The non-indigenous commercial herring fishery in British Columbia collapsed from intense overfishing and weak year-classes in the 1950s-1960s (Casavant and Pacific Wild Alliance 2021:22; Hourston & Haegele, 1980). Despite recovery and reopening after this coast-wide collapse, herring stocks more recently have shown low productivity and biomass in some BC herring designated units including the Central Coast (Cleary et al. 2018). Additionally, in 2018 following years of protests and discussions between the Heiltsuk First Nation and DFO, the Central Coast Commercial Roe fishery was closed (Central Coast Indigenous Research Alliance 2018; Fisheries and Oceans 2018). Locally, Wuikinuxv fishers have also noticed that they must go further afield to obtain herring spawn on kelp roe than they did ancestrally (Walkus 2011).

Our study focuses on contemporary, historical, and pre-contact villages in Wuikinuxv territory along the Wannock River and Walbran Island on the Central Coast of British Columbia (Figure 3.0). Many of these village sites are near documented eulachon spawning rivers (e.g., the Wannock River) and herring spawn areas (*see* Fisheries and Oceans 2016a,b), and areas where anchovy could also be accessed. We investigate archaeological village sites near documented forage fishing spawning areas to provide localized data to complement local community-based knowledge on three forage fish populations in Wuikinuxv territory: eulachon, herring, and anchovy. Archaeological data we examine from these sites span the onset of industrial and commercial fishing of herring and pre-date the following key events: local declines in eulachon in the 1970s, large scale commercial fishing, and industrial collapse of the Central Coast commercial herring fishery, that are hypothesized to contribute to twenty-first century declines in forage fish (*see* Moody and Pitcher 2010; Trotcha et al. 2020). Our research effort aims to provide archaeological fisheries data as complement to community-based knowledge on eulachon, herring, and anchovy for consideration in local fisheries management frameworks currently being undertaken by the Wuikinuxv First Nation (i.e., fisheries governance, co-governance, Guardian stewardship programs, and assertions of Indigenous law).

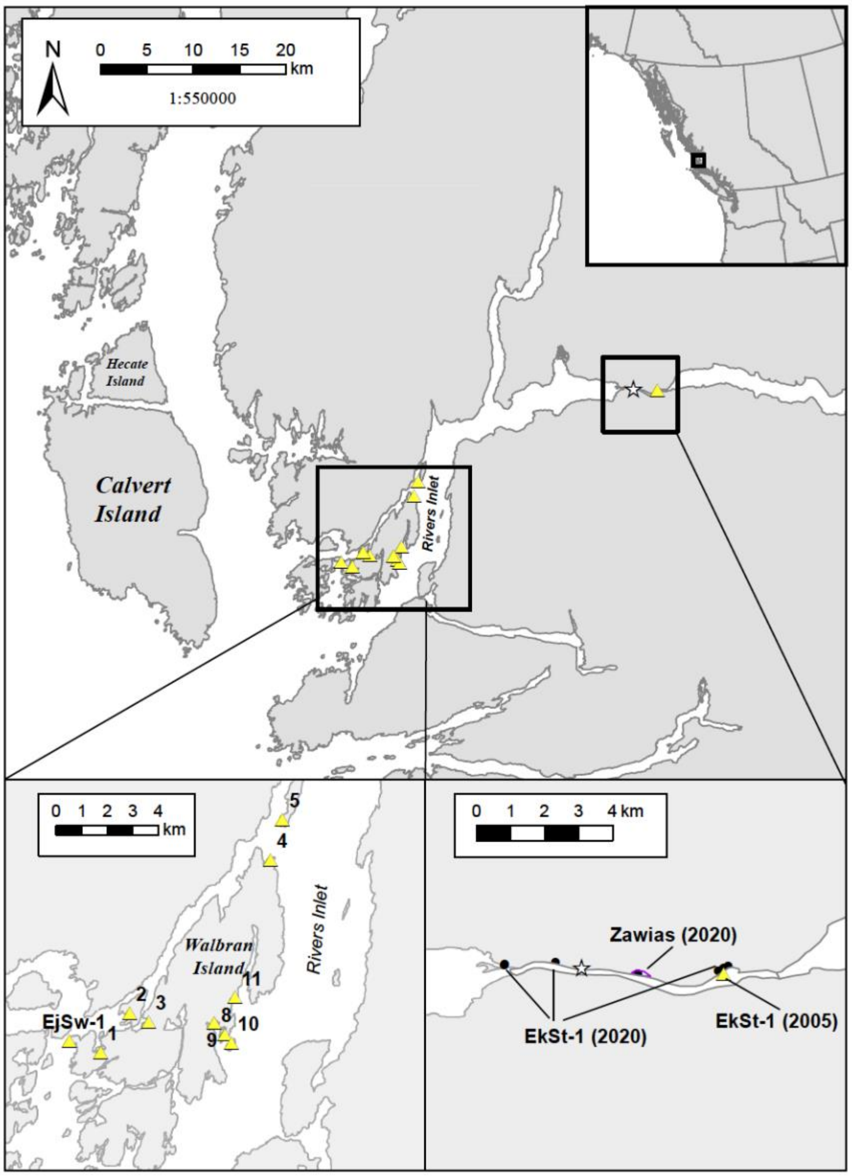


Figure 3.0. Map of archaeological sites in Rivers Inlet that have been subject to fine screen zooarchaeological analysis (Cannon 2013a, b). White star indicates the contemporary location of Katit village. 2004/2005 sites sample by Aubrey Cannon described in Cannon 2013a,b are indicated by yellow triangles. Sites numbers in the left inset are indicated by their respective number in the 'EjSv' Borden grid. 2020 auger sampling in Rivers Inlet is shown in black. A purple polygon indicates the location of Zawias, a named place within archaeological site EkSt-1, where we sampled three auger tests in 2020.

Two-eyed Seeing and Other Approaches to Mutual Understandings of community-based Indigenous fisheries

Grappling with declines in coastal fisheries has been limited by the availability and integration of pre-industrial data, resulting in short-term and inadequate baselines for many fish species (Pauly 1995). Underappreciated and unconventional data sources, such as archaeological data, Indigenous knowledge(s), and historical photographs, are increasingly being recognized as crucial archives for refining baselines for data-poor fisheries (Beaudreau and Levin 2014; Lotze and Worm 2009; McClenachan 2009; McClenachan et al. 2012; McKechnie et al. 2014; Moody 2008; Pitcher 2005; Salmen-Hartley 2018). However, despite increasing recognition that these unconventional data sources add valuable historical perspective, they often remain overlooked or (as is too often the case with Indigenous knowledges) appropriated or subsumed into Western fisheries management frameworks that serve Western scientific agendas.

Indigenous Knowledges and Archaeological Practice

Indigenous knowledges, in addition to providing data for fisheries management (e.g., Atlas et al. 2017; Eckert et al. 2018), can also support understandings of histories and past phenomena (Gauvreau and McLaren 2016). Indigenous knowledge(s) describe(s) a cumulative body of knowledge, practice, and belief(s) passed down through generations that document the relationship of living beings (including humans) with one another and their environment (Berkes 2018) but that are not separable from either the knowledge holder or its specific place-based context (McGregor 2004). Attempts to incorporate Indigenous knowledge(s) and perspectives in archaeological and anthropological inquiry are wrought with concerns of subsuming, appropriating, oversimplifying, and/or “cherry-picking” Indigenous knowledges (Cruikshank 2001;

Gauvreau and McLaren 2016; Martindale 2014; Martindale and Nicholas 2014; Moss and Wellman 2016; Nadasdy 1999). Strategies to avoid these pitfalls in archaeological practice include collaborating with Indigenous communities throughout the research process, including co-producing research objectives and questions, co-conducting fieldwork, and generating mutual knowledge about past landscapes and environments using archaeological methods (Atalay 2012). Although varied examples of community-based and centered research in archaeology utilize the above methods, they are generally associated with "Indigenous archaeology" or "Community-based archaeology," , which are conducted with, for, and by descendant communities (*see* Atalay 2012; Nicholas and Andrews 1997).

Archaeologists have developed approaches to pair archaeological data and perspectives with Indigenous knowledges in developing complementary accounts of past phenomena. A particularly rich literature exists where archaeologists pinpoint areas of overlap between Indigenous knowledges (particularly oral narratives) and archaeological data and worked to weave these perspectives to create more holistic understandings of past phenomena, Indigenous peoples, and histories (e.g., Gauvreau and McLaren 2016; McKechnie 2015; Martindale and Nicholas 2014). Additionally, some Indigenous archaeologists have taken it upon themselves to weave and simultaneously highlight Indigenous knowledge and archaeological practice in their communities (e.g., White 2006, 2011; Umeek [Atleo] 2007; Lyons and Reimer 2008; Yellowhorn 2002). These approaches, taken together, provide pathways towards a more equitable representation of ways to know the past. There is certainly strength and value in these existing archaeological approaches, which provide pathways towards more equitable representations of ways to know the past. However, a related framework more common in fisheries management applications, known as two-eyed seeing, may be more appropriate for addressing the pairing of archaeological fisheries data and Indigenous knowledge to generate accounts that serve community-based fisheries managers.

Two-eyed seeing

Two-eyed seeing (*Etuaptmumk* in Mi'kmaw) as envisaged by Mi'kmaw Elder Dr. Albert Marshall embraces "learning to see from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of mainstream knowledges and ways of knowing, and to use both these eyes together, for the benefit of all" (Barlett et al. 2012: 335). Two-eyed seeing creates a parallel view, where knowledge shares can consider each perspective to work towards mutual outcomes and decisions that strengthen approaches to fisheries access, reconciliation, and management (Reid et al. 2020). Reid et al. (2020) discuss the strength of two-eyed seeing through several case studies, including co-produced knowledge on the sustainable management of an Indigenous Mi'kmaw eel fishery between the Eskansoni First Nation and Western fisheries scientists on *Unama'ki/*Cape Breton Island. In this case study, two-eyed seeing, despite the identified limitations of reconciling two vastly different ways of knowing (i.e., Indigenous knowledge and Western fisheries science), led to greater recognition of Mi'kmaw knowledge systems in endangered species legislation (Giles et al. 2016; Reid et al. 2020).

Two-eyed seeing also addresses that fisheries management is by nature a forward-looking discipline. The Mi'kmaw cultural conservation concept *netukulimk,* which underlies two-eyed seeing, calls on managers to consider their decisions beyond time scales typically considered by Western fisheries science by considering the next seven generations (McMillan and Prosper 2016; Bartlett et al. 2012:336). The future-looking orientation embedded of *netukulimk* makes two-eyed seeing particularly conducive to the future-oriented challenges of fisheries management. Unsurprisingly, two-eyed seeing has experienced increasing uptake in fisheries management and conservation (e.g., Giles et al. 2016; Raincoast Conservation Foundation 2020; Reid et al. 2020).

Forward-looking principles for responsibility, care, and management of environments and species are present in many Indigenous communities (Reid et al. 2020). Therefore, it may be more appropriate to utilize existing local concepts when working with non-Mi'kmaw communities in conjunction with two-eyed seeing. In line with previous research, we advocate for two-eyed seeing as a framework for knowledge pairing that has the flexibility to be guided by future-oriented and community-specific cultural principles of care, responsibility, and management (also *see* Reid et al. 2020: 4). In Wuikinuxv territory, the principle of *na na kila* calls on community to 'look ahead' or to ' watch out for someone'. *Na na kila* appears to be a particularly appropriate guiding principle in Wuikinuxv territory given its previous use in locally engaged ecosystem-based management for assessing the future of human-fish-bear relationships in Wuikinuxv territory (Adams et al. 2019: 12). Given *na na kila's* forward-looking orientation, in its English translation of 'to look ahead', we see it as an appropriate concept to use in conjunction with two-eyed seeing to pair Wuikinuxv and Western knowledges.

Two-eyed seeing's future orientation separates it from approaches to knowledge pairing in collaborative and community-based archaeology (cf. Edinborough et al. 2017;

Gauvreau and McLaren 2016; Martindale and Nicholas 2014; McKechnie 2015). Approaches in archaeology for pairing archaeological perspectives with Indigenous knowledges generally aims to better understanding local histories and the past (e.g., Gauvreau and McLaren 2016) rather than explicitly address the future. Therefore, while archaeological research can have contemporary consequences (e.g., Hogg and Welch 2020; Martindale 2014), the fundamental aims of knowledge pairing between archaeological and Indigenous knowledges traditionally address questions about the past. Comparably, this research aims to generate information for consideration within management and restoration planning, which is future-oriented. Given the future-oriented aims of our research, we view the future-looking management framework of two-eyed seeing as most appropriate for pairing archaeological fisheries data and Wuikinuxv fisheries knowledge. However, we acknowledge that our use of two-eyed seeing is an extension of existing structures of doing archaeology with, for, and by Indigenous communities.

Considering Archaeological Data in Service to Indigenous Fisheries

Many Indigenous Nations already appreciate the value of deep time accounts of ancient Indigenous fisheries. First Nations are also increasingly recognizing that zooarchaeological data can provide temporally expansive and place-specific data on ancient Indigenous fisheries that complement knowledge already held in communities (e.g., White 2006; Gauvreau et al. 2017). Previous archaeological research establish that Heiltsuk oral narratives documenting human-herring relationships are complemented by archaeological records from the village sites referenced in these narratives (Gauvreau et al. 2017). Namu, an important village site which is referenced in the “Raven Obtains

Herring" narrative, has archaeological evidence for consistent herring use by 7000 years ago (Cannon et al. 2011; Gauvreau et al. 2017). In conjunction archaeological and Indigenous knowledge, in this case, highlight longstanding and sustained fishing of herring in Heiltsuk territory and establish archaeological fisheries data as key data for temporally anchoring practices of fishing discussed in oral narratives. We argue that the rich history of fishing documented in zooarchaeological records (*see Cannon* 2013a, b; Duffield 2017) and oral accounts in Wuikinuxv territory also hold promise for making these connections when researchers consider archaeological and Indigenous knowledge accounts in parallel.

Archaeological fisheries data also have contemporary legal implications and consequences for descendant communities who may wish to assert contemporary fishing rights or challenge colonial bodies over access, harvesting rights, and commercial control of their fisheries. In several Supreme Court of Canada decisions: *R. v. Sparrow* 1990, *R. v.* Gladstone 1996 and *Ahousaht Indian Band v. Canada* 2008, 2011, archaeological fisheries data were used to demonstrate the cultural importance of fishing, to prove aboriginal right to harvest and trade, show evidence of fishing nearshore and offshore, respectively. However, archaeological knowledge can also be disputed in court if it is not rigorously supported (*see* Hogg and Welch 2020: Table 2; Martindale 2014). In these cases, archaeological fisheries data can fail to hold up to legal standards of evidence or proves insufficient on their own, thereby contributing to the weakening of Indigenous claims and access rights in court (Martindale 2014; also *see Lax Kwa'alaams Indian Band v. Canada* 2008: paragraph 17-18; *Lax Kwa'alaams Indian Band v. Crown* 2011). Consequently, archaeological analyses, although often oriented in the past, have contemporary consequences for Aboriginal rights and title. Appropriately, the outcomes of research for potential future Indigenous claimants require careful consideration by archaeologists in the conception, collection, and interpretation of archaeological data, to meet legal standards of evidence and their moral obligations to descendant Indigenous communities (Hogg and Welch 2020; Martindale 2014).

We contribute work of the above orientation by grounding our collection and analysis of archaeological fisheries data in Wuikinuxv territory in a community-based research framework (e.g., Castelden et al. 2012; also *see* Atalay 2012) and by discussing archaeological fisheries data and Indigenous knowledge accounts using two-eyed seeing. We aim to demonstrate that two-eyed seeing allows for mutual feedback and equitable representation of Indigenous and archaeological ways of knowing ancient Indigenous fisheries. We describe archaeological fisheries evidence: age-at-harvest, abundance, and fishing technology obtained from coastal archaeological village sites in Wuikinuxv First Nation that span the last 3000 years. We use these fisheries data to consider what contributions archaeological data can make to better understandings Indigenous forage fisheries in Wuikinuxv territory and beyond. Our case study focuses on archaeological data and Indigenous knowledge on three forage fisheries in Wuikinuxv territory: Pacific herring, eulachon, and northern anchovy. We establish past baseline data from a combination of archaeological and local Indigenous knowledge to attempt to extend upon the temporal baselines typically used by conventional fisheries managers.

Methods

Our research effort in service to the Wuikinuxv First Nation pulls from the tenets of community-based participatory research (Castleden et al. 2012), community-based archaeology (Atalay 2012: Table 3), and the step-wise framework for applying two-eyed seeing to fisheries research (Reid et al. 2020: Figure 4). We establish our research within community-based participatory research and two-eyed seeing as a collaborative effort between Wuikinuxv First Nation Stewardship (WFNS), Wuikinuxv First Nation Fisheries (WFNF), and the Hakai Institute's *Nearshore Ecology Program* where all parties co-organized to generate research questions and outcomes and that builds off of previous research of this orientation undertaken by Aubrey Cannon in Wuikinuxv territory (see Cannon 2013a, b).

The step-wise framework for applying two-eyed seeing described by Reid et al. 2020 consists of six stages: mutual research interest; identification of required tools; research co-development; co-evaluation and community validation; shared recognition and co-benefits; and long-term relationship. Following a two-eyed seeing framework, we identified mutual research interests early on to develop a research plan that aimed to refine current baselines on Wuikinuxv forage fisheries (particularly eulachon) using archaeological data. We then co-developed and evaluated several iterations of a research proposal with outlined roles and responsibilities for archaeologists and community members (Ball et al. 2019). During this phase, WFNS and Wuikinuxv council identified appropriate research targets, selected study sites, and provided community validation and consent for archaeological work on reserve in Wuikinuxv territory, including further testing of archaeological samples from previous research in the territory (*see* Appendix C; Ball et al. 2020). During archaeological fieldwork in 2020, WFNF and Wuikinuxv Guardian watchmen provided logistical and fieldwork support. A report on archaeological work was generated with shared recognition of Wuikinuxv involvement in this work that addresses WFNS priorities for heritage preservation, identification, and stewardship (*see* Ball et al. 2020). Our work is a continuation of a long-term relationship between scientific research facilitated by the Hakai Institute, Aubrey Cannon, and the University of Victoria and the Wuikinuxv First Nation.

Archaeological Sources of Data

To provide a proxy for the past abundance of forage fish in Wuikinuxv territory, we compile minimum age-at-harvest and abundance data and preliminary data on a traditional eulachon fishing feature from archaeological sites in proximity to forage fish spawning habitat and harvesting areas in Wuikinuxv territory. Fish scales and bones span contact to 3000 cal. B.P. (Appendix B). Our data set includes fish bone and scale data obtained during February 2020 fieldwork (Ball et al. 2020) and the results of previous archaeological work conducted by Dr. Aubrey Cannon in 2005 and 2006 (Cannon 2013a,b). Most of our fish bone data are compiled with permission from data reported in Cannon 2013a,b that were identified by Aubrey Cannon, Nadia Densmore, and Brandi Lee MacDonald. However, additional fish remains from Zawias were identified by Rebecca Wigen. The first author (Alyssa Ball) recovered and identified fish scales with confirmation from Fisheries and Oceans Canada analysts Joanne Groot and Judy McArthur at the DFO's Pacific Biological Station, Nanaimo, BC.

Abundance

To evaluate relative abundance of herring, eulachon, and northern anchovy, we examine identified fish scales from four archaeological sites in the vicinity of Rivers Inlet in Wuikinuxv territory: EjSv-1, EjSv-9, EkSt-1 (Katit and Zawias), EjSw-1 (Cockmi) and compiled data for n= 8978 identified fish bone specimens from Cannon (2013a,b), and

Wigen (2020) from seven additional sites in Rivers Inlet. Data were itemized using standard descriptive and quantitative measures following zooarchaeological and squamatological conventions. We evaluated the proportional abundance of forage fish bones and scales using rank order in terms of NISP (number of identified specimens) and percent NISP of all identified fish species in line with previous work we view these data as a proxy for the relative abundance of these fish in archaeological deposits filtered by taphonomic processes in archaeological deposits rather than equivalent to catch data (e.g., Moss and Cannon 2011; Hopt and Grier 2018; McKechnie 2014). In compiling these data, we recognize the effect of cultural butchery practices on fish scale and bone recovery of particular species. For example, eulachon bones and scales may be particularly underrepresented in archaeological records, given the potential adverse effects of fermentation and boiling during the production of oil may affect preservation of scale and bones (see Patton et al. 2019; also see Nicholson's 1992, 1996 experiments demonstrating the adverse effects of boiling on fish bone survival).

Age-at-harvest

To estimate age-at-harvest in archaeological forage fisheries in Wuikinuxv territory, we employ squamatological methods for ageing fish scales and provide a minimum age for a subsample of identified herring fish scales. DFO analysts provide age data according to the conservative methods applied to intact scales obtained from live fish in contemporary herring stock assessment. Accordingly, only confidently identified annuli were counted, likely underestimating age (Hamer 1989). These analysts identified herring as the most suitable specimens for ageing archaeological fish scales based on the sample size and state of preservation in scales submitted for analysis. Unfortunately, we could not obtain age estimates for the identified and confirmed eulachon or anchovy scales due to insufficient preservation of annuli and smaller sample sizes. We provide successful minimum age estimates for (n=20) herring scales using the established convention of counting paired summer and winter growth zones, with one zone pair representing one year of growth or an annulus (NOAA 2018). Figure 3.1 illustrates this methodology on an estimated minimum age three herring scale from our sample.

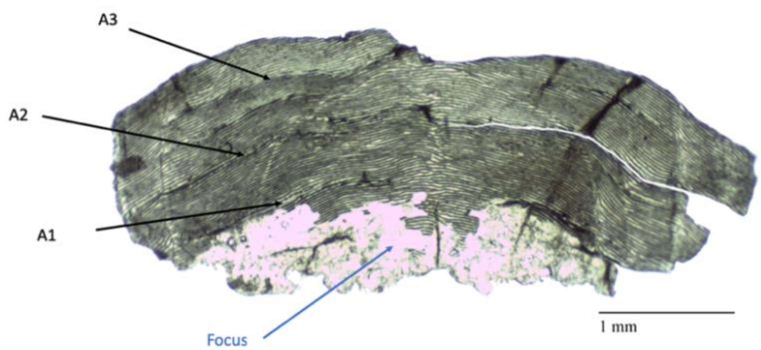


Figure 3.1. Example of a minimum age 3 herring scale from archaeological deposits in Wuikinuxv territory. "A" indicates annulus or year band and are numbered in sequential order from the scale's origin "focus".

Analysis of Fishing Feature in the Wannock River

Immediately following our February 2020 fieldwork, co-author Jennifer Walkus took an aerial photograph of the Wannock River and riverbank adjacent to the named place Zawias "Eulachon Town" near an area where we obtained auger samples during fieldwork in February 2020 (*see* Figure 3.4). Zawias is a well-known eulachon fishing location, one of Wuikinuxv's old reserve locations, and the birthplace of Hereditary Chief, Yàxzi Jack Johnson (Brown 2011: 24). In this photo, numerous fishing features consisting of linear arrangements along the bottom of the riverbed are visible. These rock arrangements are comprised of cobbles and boulders arranged parallel to the shoreline and are located below several canoe runs. At a scientific advisory meeting, we heard from multiple community members about the method of harvesting eulachon using eulachon traps located near this feature (Quadra Centre for Coastal Dialogue 2020). We document the physical extent of these archaeological fishing features, including each canoe run along the riverbank and the rock channels in the Wannock River bed. With georectified multispectral imagery of the Wannock River obtained by the Hakai Institute geospatial team we created an initial map of this feature including its dimensions, total area, and the number of visible rock alignments and canoe skids/runs.

Community-based Fisheries Knowledge

We incorporate Indigenous community-based fisheries knowledge on forage fisheries in Wuikinuxv territory from a literature review of ethnohistorical, ethnographic sources, oral narratives, personal communications, and previously published interviews with Wuikinuxv people and fishers. Our review targeted direct or indirect references in text and video mediums to the three study species: eulachon, herring, and anchovy; local river or water bodies; and local village sites by their English or Oowekyala names; however, community-based principles that had previously discussed regarding management in previously published works were also included regardless of their direct association with the aforementioned literature search criteria. We also include two informal voluntary personal communications with Wuikinuxv community members, Jennifer Walkus and hereditary chief Ted Walkus. These data are not a comprehensive take on all Wuikinuxv knowledge of our study fisheries but intend to establish a baseline for community knowledge and management of herring, eulachon, and anchovy in Wuikinuxv territory.

These local knowledge accounts permitted additional perspective on ancient Indigenous fisheries in Wuikinuxv territory and influenced our sampling strategies in the field, including site selection for archaeological sampling. We view these accounts as consistent with the idea that cultural teachings are lifelong processes that "serve as methods of conservation and regulation for fishing…" (Green et al. 2015: 57). Accordingly, our summary of community-based fisheries knowledge in the following section represents more than mere cultural stipulations for harvesting forage fish but rather are lived practices and responsibilities related to forage fish.

We consider community-based fisheries knowledge alongside archaeological fisheries using a framework of two-eyed seeing. Figure 3.2 shows how two-eyed seeing compares to other approaches for weaving community-based fisheries knowledge and archaeological fisheries data using three potential scenarios for knowledge pairing. Our research effort aims towards the third situation shown in Figure 3.2 (bottom), representing two-eyed seeing and relies on "true collaboration" to reach mutually beneficial outcomes. True collaboration here follows the use of the term "collaboration" by Martindale and Nicholas (2014: 436), which calls for "full, transparent, and equal sharing of power and decision-making…".

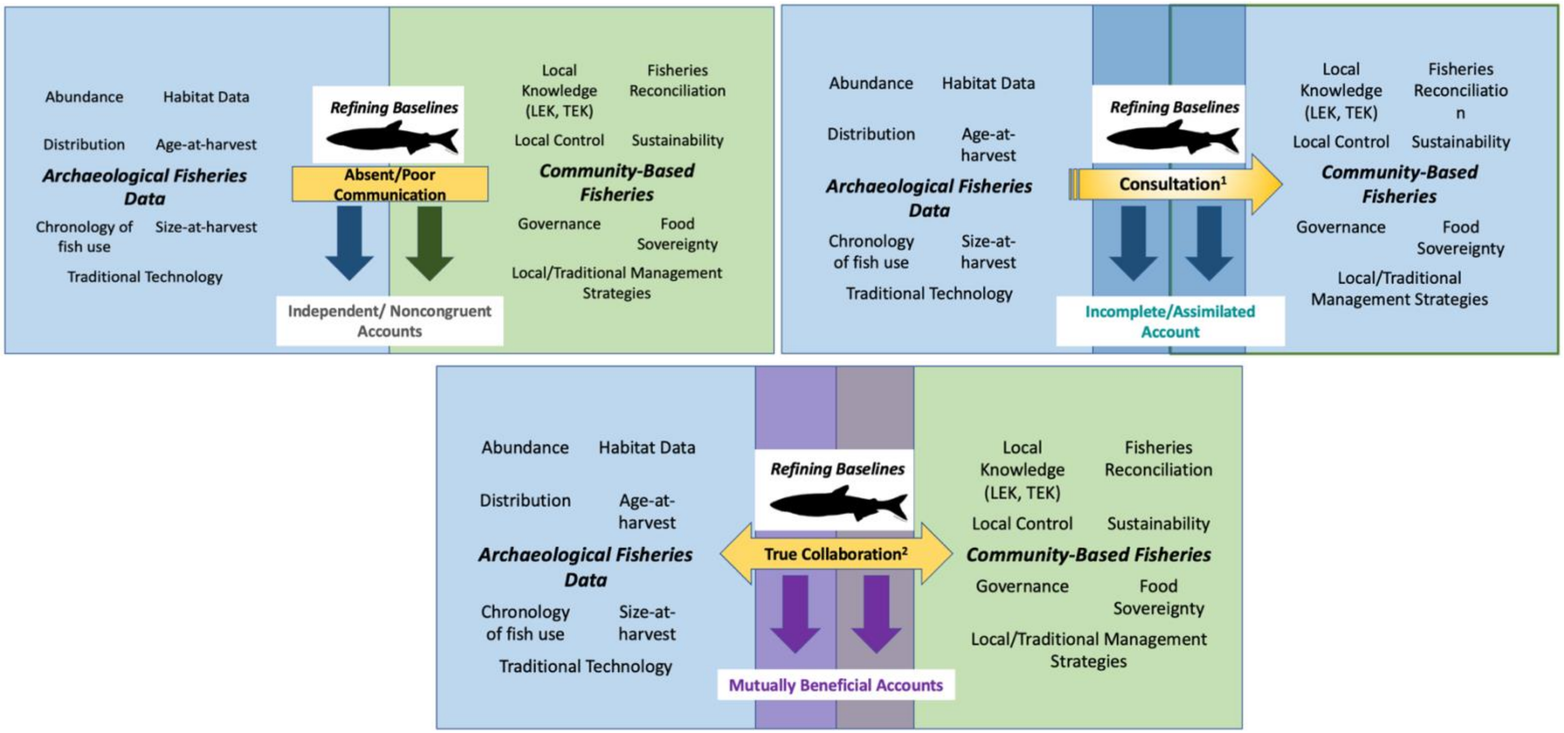


Figure 3.2. Conceptual framework detailing the flow of knowledge and data (Archaeological fisheries data and Community-based fisheries knowledge) reflecting attempts to refine past fisheries baselines. We identify three scenarios where these accounts may attempt to be paired. (1) No communication (Top left): when archaeological fisheries data and community-based fisheries knowledges fail to inform or acknowledge one another, resulting in singular understandings of past shifting baselines. (2) Consultation (Top right): attempts are made to incorporate elements of community-based fisheries (particularly Indigenous knowledge) into archaeological data but they fail to appropriately consider community context and, in doing so, produce outcomes that subsume or appropriate other ways of knowing often in favour of Western-oriented conclusions (although the reverse can also occur). (3) True collaboration (Bottom) both archaeologists and Indigenous communities are involved throughout the entire research process to weave the strengths of their knowledges towards a mutually beneficial outcome —this approach approximates *Two-Eyed Seeing.* Diagram is informed by Reid et al. 2020.

Results

Relative Abundance of Forage Fishes

We recover archaeological fish scale and bone for forage fish from Wuikinuxv First Nation territory from deposits dating from contact to 3000 cal. B.P. based on recalibrated radiocarbon dates reported by Cannon (2013a) and those obtained in February 2020 from Zawias (Appendix B). The highest ranked fish taxa in terms of NISP include three forage fish: herring, eulachon, and anchovy but also include salmon (*Oncorhynchus* sp.). The highest rank order fish taxa in examined Rivers Inlet sites are Pacific herring (occur in 70% of sites in Rivers Inlet) followed by salmon (occur in 50% of sites in Rivers Inlet) (Table 3.0, Table 3.1). Herring bones occur in every site at an overall higher relative abundance than other forage fish (Figure 3.3). Site chronology further establishes that herring and salmon taxa as targets of Wuikinuxv fishers throughout the late Holocene (Cannon 2013b). Northern anchovy and eulachon are the third and/or fourth ranking fish overall in examined scale and bone assemblages (Figure 3.32). Northern anchovy rank third overall in fish bone assemblages (Figure 3.32) and fourth in scale assemblages (Table 3.0, 3.1). Anchovy accounts for up to 30% of all identified fish taxa in fish bone assemblages (Figure 3.3). Eulachon rank fourth overall in bone assemblages and third in fish scales assemblages (Table 3.0, 3.1) and up to 11% of all identified fish bones in the six sites where we recover and identify eulachon bone in our study area (Figure 3.3). Unlike herring, eulachon and anchovy, although high ranking, are not as consistently present and abundant throughout all eleven sites in our case study.

Table 3.0. Rank order of the six most abundant (NISP) fish taxa in examined fish scale assemblages. Rank order is indicated by the colour gradient (darker shades represent ranks 1–4, lighter shades 5-6). Salmon sp. (*Oncorhynchus*) are included as "Salmon" to allow for comparisons with the fish bone assemblage. Forage fish are indicated by tan text.

Rank Order	**All Sites Combined** (n=229, 4 sites)	**Cockmi** (n=136)	**Katit** (n=78)	**Zawias** (n=12)	**EjSv-9** (n=3)
1	Herring	Herring	Herring	Salmon	Herring
2	Salmon	Anchovy	Salmon	Eulachon	Salmon
3	Eulachon	Salmon	Kelp Greenling	Herring	
4	Anchovy	Rockfish	Anchovy	Sockeye Salmon	
5*	Kelp Greenling	Eulachon			
6	Rockfish, Chinook Salmon, Sockeye Salmon	Chinook Salmon, Sockeye Salmon			

Table 3.1. Rank order of the nine most abundant (NISP) fish taxa in examined fish bone assemblages. Rank order is indicated by a colour gradient (darker shades represent ranks 1–4, lighter shades 5-7). Forage fish are indicated by tan text.

Rank order	All Sites	*Cockmi* (EjSw-1)	*Katit* (EkSt-1)	*Zawias* (EkSt-1)	EjSv-9	EjSv-1	EjSv-2	EjSv-3	EjSv-4	EjSv-5	EjSv-8	EjSv-10	EjSv-11
1	Salmon	Herring	Salmon	Salmon	Herring	Herring	Herring	Herring	Herring	Herring	Herring	Herring	Salmon
2	Herring	Salmon	Herring	Herring	Salmon	Anchovy	Salmon	Anchovy	Salmon	Salmon	Salmon	Salmon	Herring
3	Anchovy	Anchovy	Eulachon	Eulachon	Anchovy	Salmon	Anchovy	Salmon	Greenling	Eulachon	Anchovy	Anchovy	Greenling
4	Eulachon	Greenling	Anchovy		Greenling		Greenling		Anchovy	Rockfish	Greenling	Greenling	Anchovy
5	Greenling	Eulachon	Greenling		Sculpin		Rockfish & Sablefish		Rockfish			Rockfish	Eulachon
6	Rockfish	Rockfish										Dogfish	
7	Sablefish	Sablefish											
8	Sculpins & Dogfish												

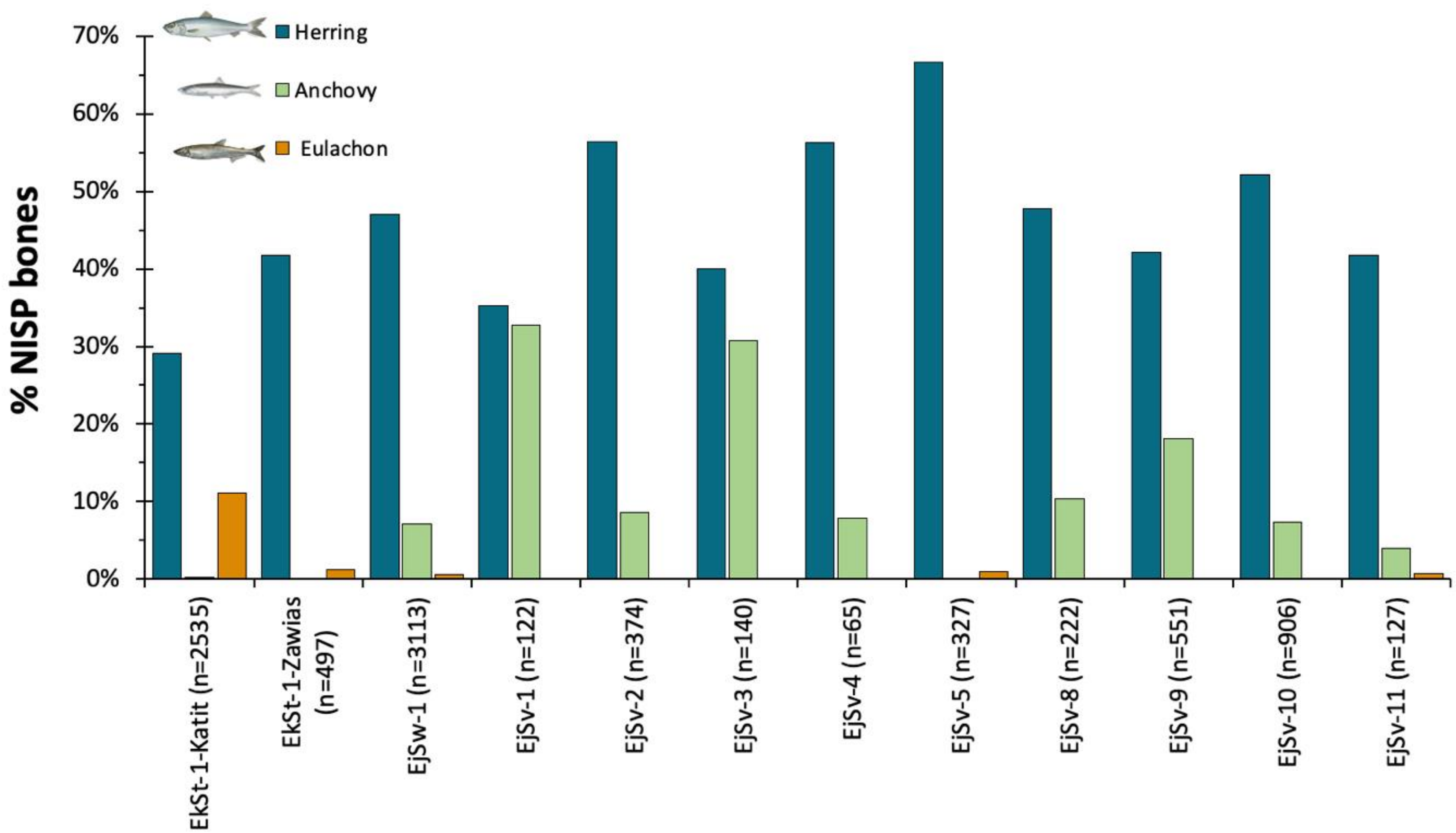


Figure 3.3. Bar chart showing percent identified forage fish from fish bone assemblages in eleven Rivers Inlet archaeological sites relative to other identified fish species. Total NISP of fish bone for each site is indicated by (n= " "). Data obtained from Cannon (2013) and Wigen (2020).

Herring Age Composition

Minimum age is successfully estimated for (n= 20) Pacific herring scales [(EjSw-1 (n=7); EkSt-1 (n=13)]. These fish scales are from deposits that range in age from 100 to 400 cal. B.P. (Appendix B). Average minimum age in examined archaeological herring scales was age 1.8 (~2 ±1 year). Broken down by archaeological site, the average minimum age was 1 ±1 year at Cockmi (EjSw-1) and 2 ±1 year at Katit (EkSt-1) (Figure 3.3). Seventy percent of all examined archaeological fish scales are from age classes: age 1 or 2 (Figure 3.31). Minimum age at harvest estimates for other highly abundant species, including other forage fish and salmon, were unsuccessful (i.e., salmon), or due to sample quality and sample size inappropriate for age analysis (i.e., eulachon).

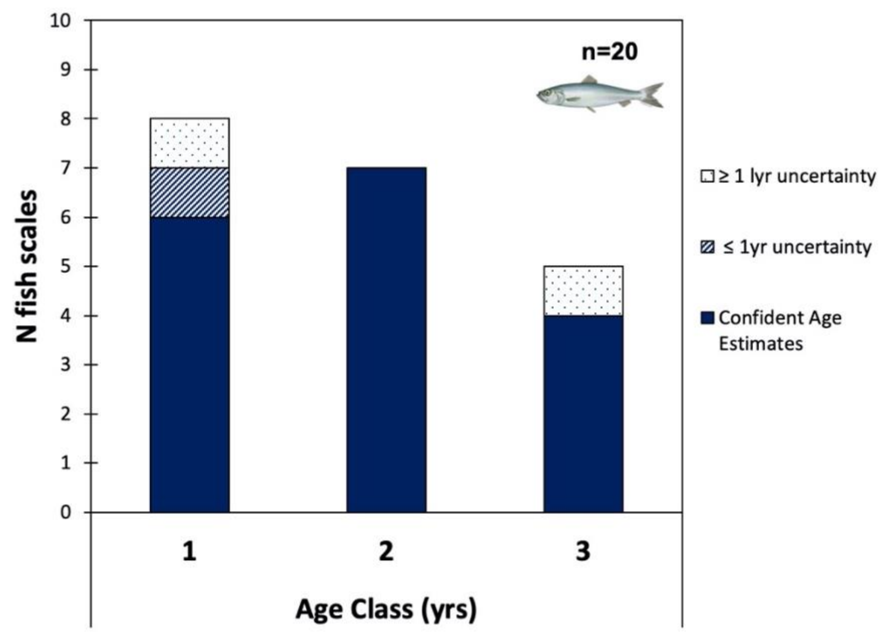


Figure 3.3.1 Minimum age estimates from herring fish scales from two archaeological sites in Wuikinuxv territory: Katit (EkSt-1) and Cockmi (EjSw-1). Patterned bars show fish scales where age estimates were uncertain (e.g., ≥ 1yr indicates that the fish scale could be either age 1 or 2).

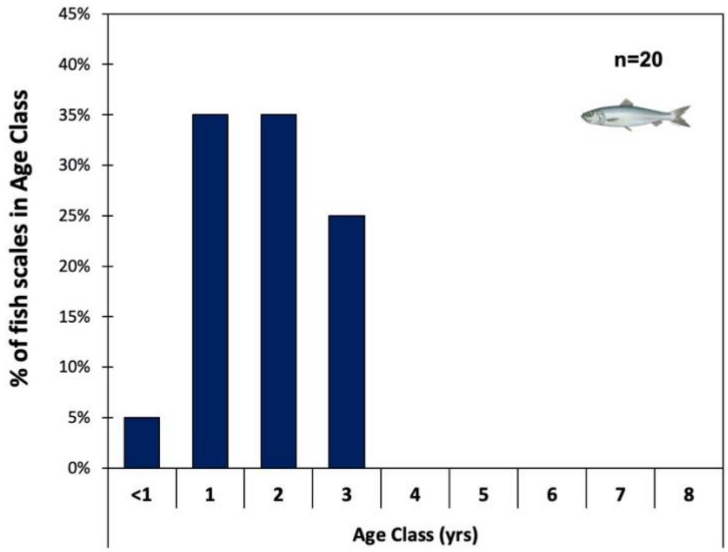


Figure 3.32. Percent of fish scales by herring spawning age classes using minimum age estimates from archaeological fish scales in Wuikinuxv territory. Scales where ages were uncertain or fell between age classes are rounded down to the most conservative minimum age estimate. (e.g., 0-1 is rounded down to <1 age class and 3-4 to 3 age class).

Fishing Feature at Zawias

The feature adjacent to Zawias, along the bottom of the Wannock River, consists of at least 18 linear rock alignments and 10 canoe runs (Figure 3.4, 3.41). The physical extent of the rock alignments in the riverbed covers approximately 15,000 m^2 (Figure 3.41). These rock alignments may have been partially exposed at low water levels during the winter spawning season but likely channeled schools of fish making their way upriver. To our knowledge, this kind of riverbed harvesting feature is not extensively documented in any published ethnographic resources, nor is it a previously recorded archaeological site in Wuikinuxv territory or elsewhere on the Northwest Coast.

However, community members describe a nearby eulachon fishing trap that matches the description and illustration of eulachon nets and fishing traps used by Tsimshian and Nuxalk (Bella Coola) peoples (Stewart 1977: 95; Moody 2008: Figure 3.5). The eulachon trap complex described by hereditary chief Ted Walkus is part of a series of canoe channels used by Wuikinuxv peoples to harvest eulachon (Quadra Centre for Coastal Dialogue 2020; Ted Walkus, personal communication, 2021). According to Ted Walkus, Wuikinuxv peoples would anchor their canoes to fish for eulachon from long “windsock-like” nets attached to wood pilings (Quadra Centre for Coastal Dialogue 2020). Eulachon, according to Ted Walkus, were directed into these nets as they migrated upstream with the inflowing tide (Ted Walkus, personal communication, 2021). Once the net was full of eulachon, fishers would bring a canoe alongside the trap, raise the net rings with a hooked wooden stick, and roll the net into the canoe to empty it (Ted Walkus, personal communication, 2021). Once empty, these traps could be reset on an ebb tide (Ted Walkus, personal communication, 2021).

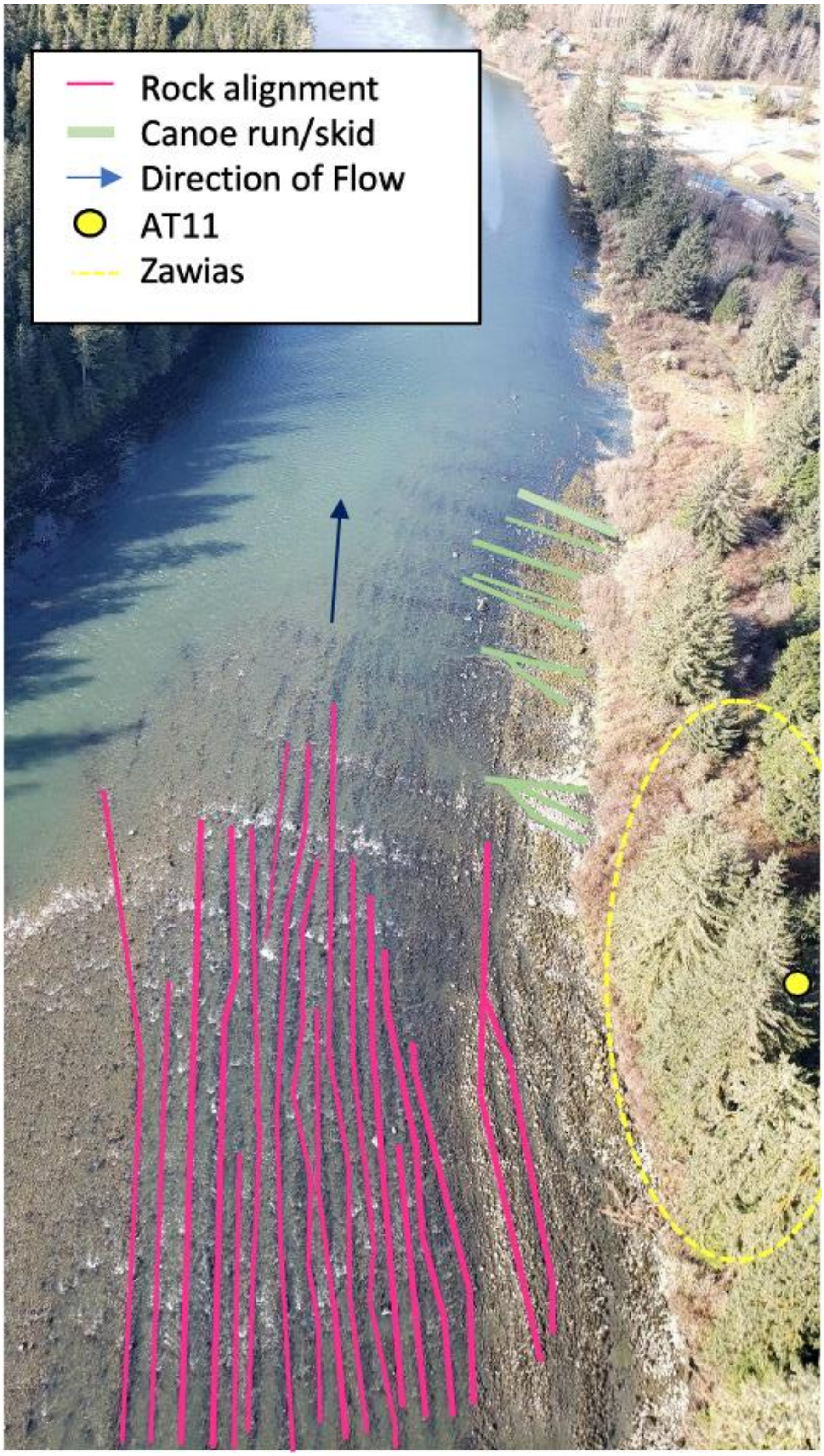


Figure 3.4. Annotated representation of the observed feature along the bottom of the Wannock River using an aerial photo provided by Jennifer Walkus, Wuikinuxv First Nation.

Figure 3.4.1. Map of eulachon fishing feature relative to the location of auger tests undertaken at Zawias in February 2020. Geospatial imagery provided by the Hakai Institute. Map by Iain McKechnie.

Community knowledge of the state and management of local forage fisheries

Our analysis of the ethnohistorical literature shows that several cultural protocols corresponding to social responsibilities towards and stewardship of eulachon are present in Wuikinuxv territory. Table 3.3 describes stipulations governing access to eulachon included rules regarding silence around spawning rivers and staying out of the water during the spawn, and that recently widowed individuals should avoid travelling along spawning rivers. Further clarification from Ted Walkus establishes that the use of eulachon fishing traps was contingent on whether all eulachon had been given a chance to spawn (Ted Walkus, personal communication, 2021; Table 3.3). Other discussions of forage fish in the literature highlight the connection between eulachon and herring fisheries and show associations between these fisheries and local place names (Table 3.3). We did not encounter references to northern anchovy during our literature review or from correspondence with the Wuikinuxv Stewardship office.

Contemporary Wuikinuxv perspectives on fisheries in published interviews with community members emphasize contemporary reductions in local eulachon populations from pre-industrial stocks and hypothesize climate change as a significant contributor to these declines (Table 3.31). These accounts also note changes in the availability of spawn-on-kelp herring in particular locations in the territory (Table 3.31).

Table 3.3. Deep time community-based fisheries knowledge on forage fish in Wuikinuxv territory

a. Jennifer Walkus recalls helping her father maintain canoe runs at Zawias as a child (Jennifer Walkus, personal communication, 2020)
b. Ted Walkus shared the importance of anchoring canoes to large wooden posts set in the riverbed during eulachon fishing.

Species	**Observation**	**Source**
Cultural Protocols		
Eulachon	*A father warns his son that if people were to 'lie across' their zacxven (eulachon) trap (i.e., drown) or take too many eulachons during the early run, the eulachon may not return*	The story of *Lhàxviý-s Mdema'xa' pkv* as told by Chief Simon Walkus Sr. documented in as Hilton and Rath 1982:143-149
Eulachon	*Widows and widowers abstain from eulachon fishing areas and from travel along the shore of Wannock River itself for ten months period after their partner's passing*	Hilton and Rath 1982: 227
Eulachon	*Wuikinuxv informant Alfred Thompson reports several instances where death and the wrongdoings of widowers are connected to poor eulachon returns to the Wannock River in the mid 1800s.*	Documented in Hilton and Rath 1982: 227
Eulachon	*Strict rules on silence and staying out of the water during eulachon season*	Clifford Hanuse, Wuikinuxv Nation personal communication cited in Haggan et al. 2006:13)
Eulachon	*Would wait until after most of the eulachon had spawned before setting eulachon nets in the downstream end of the Wannock River*	Hereditary Chief, Ted Walkus, Wuikinuxv First Nation, personal communication, 2020
Not species specific	*Skilled hydrological engineering to enhance spawning and rearing habitat by creating back eddies for fish to rest*	Evelyn Windsor, Wuikinuxv Nation, cited in Jones 2002)
Not species specific	*Wuikinuxv Nation principle of Na na kila "to watch over someone and look ahead for them"*	*see* Adams 2019: 12 used as a guiding principle for investigating human-salmon-bear dynamics in Wuikinuxv territory

Species	**Observation**	**Source**
Further Discussion/References to Eulachon and Herring		
Herring & Eulachon	*Herring are believed to meet the eulachon at the mouth of Rivers Inlet, at which time they would tell the eulachon, "You may give your grease to them now. We have given them our eggs."*	Olson 1954: footnote 1
Eulachon	*The months of March and April are associated with Oowekyala terms that reference eulachon (i.e. April was identified as tcaHSAM "eulachon moon" and March with zàxvsam "the month when the eulachons come"*	Oowekyala Language Project 1983 cited in Compton 1993: 370
Herring	*The month of February is associated with Oowekyala term thiqalaxsgam , which refers to the time "when the water turns milky with herring spawn"*	Oowekyala Language Project 1983 cited in Compton 1993: 369-370
Eulachon	*Oowekyala place name Zawias "eulachon town"*[a]	Brown 2011:24 noted as the birthplace of hereditary chief, Yàxzi Jack Johnson; Jennifer Walkus, personal communication 2020; also *see* First Voices 2020; 'Wuìkala phrases.
Eulachon	*Wuikinuxv peoples identify the arrival of eulachon runs by the arrival of seagulls (Larus occidentialis)*	Winbourne and Dow 2002
Eulachon	*Twins have the power to control fish runs "Once a twin was playing on the river beach where the people were awaiting the eulachon run. A man scolded him, but the boy said nothing. That night the boy told the people to set the nets. The next morning only the man who had scolded him had a full net but the net was full of herring…"*	Olson 1954: 226
Herring	*Kwa'kumi (likely Cockmi described by Cannon 2013a,b) , which refers to "hole at point" is a camping place on Walbran Island where people went to gather herring eggs, seaweed, and other seafoods*	Olson 1954: 214

Table 3.31. Recent observations regarding forage fish in Wuikinuxv territory

Species	Observation	Source
Eulachon	*Eulachon run has been poor since 1994*	Frank Johnson, Wuikinuxv First Nation, personal communication 2007, quoted in Moody 2008: 40
Eulachon	*Large eulachon run previously returned to the Clyak River (Moses Inlet) but has not been observed since the 1940s*	Winbourne 2002 cited in Moody 2008: 39
Eulachon	*"I do think eulachon was an early harbinger of climate change. Because there's next to no eulachon"*	Jennifer Walkus quoted in Whitney et al. 2020: Table 3
Herring	*Have to go further afield to harvest herring spawn on kelp than they did traditionally; can no longer access herring roe reliably right at the head of Rivers Inlet*	Jennifer Walkus, Wuikinuxv First Nation in "Herring in Wuikinuxv Territory, Rivers Inlet" video, Walkus 2011

Discussion

Archaeological and Indigenous community-based fisheries knowledge in our case provide complementary evidence of the tremendous value and salience of forage fish in Wuikinuxv territory over the last three millennia. In the following subsections, we address these two accounts through a framework of two-eyed seeing guided by the Owekyala principle *na na kila*. We establish four contributions from this knowledge pairing for future use by community-based fisheries managers in Wuikinuxv territory:

1. Reconstructing characteristics of past fish populations from archaeological fish bone and scale assemblages
2. Describing changes in fish populations between pre-industrial and post-industrial times

3. Community-informed site identification and interpretation of traditional fishing technologies
4. Documenting deep time baselines where ethnographic records may be limited

Reconstructing characteristics of past fish populations

The time depth of archaeological deposits associated with our minimum age data establish a pre-industrial baseline for the Wuikinuxv herring fishery that expands upon previously established age composition data for Central Coast herring. Our age-data are from scales from archaeological deposits dating to 100 to 400 years ago , which precedes the time series data on the Central Coast herring fishery derived and projected from seine-captured samples collected between 1971-2016 by DFO (Fisheries and Oceans Canada 2016c). While our data exists at a much coarser resolution, our scale age estimates suggests variability in minimum age for herring harvested by Wuikinuxv peoples ranging between 1-3 ± 1 year with an average age of 1.8 ± 1 year. Approximately 70% of our sample has minimum ages of 1 or 2 from archaeological sediments dating to the last 400 years. Comparatively, 10% of all herring in a DFO survey of the Central Coast fishery were age 1 or 2 fish in 2015, and a much greater proportion of recovered age classes as much as 60% are age 4 (Fisheries and Oceans 2016c).

While there is a possibility that degradation in scales may constrain our age estimates, our data indicate that herring of multiple age categories were harvested by Wuikinuxv peoples and harvested outside of spawning time over the past 400 years. The high rank of herring in both scale and bone assemblages across all eleven village sites we examined in Wuikinuxv territory and regional data showing herring were consistently occurring through time in Central Coast archaeological sites (McKechnie et al. 2014; McKechnie and Moss 2016) strengthen this hypothesis. Overall these archaeological observations allow for consideration that herring may have been accessed and fished at more times throughout the year than is currently appreciated in ethnographic and archaeological discussion of ancient Indigenous herring fisheries (cf. Cannon 2011; Gauvreau 2015).

Comparably, community-based fisheries knowledge represented in Table 3.3 highlight an association between herring harvest and spawning time. Community accounts and a selection of oral narratives revealed reference to the Oowekyala term for February, *thiqalaxsgam*, which refers to the time "when the water turns milky with herring spawn" alluding that spawning time was a key time for harvesting herring and/ their roe. Regional analyses of seasonality in herring fishing on the Central Coast have interpreted these oral narratives and the like as indicating that spawning age fish were a major target of pre-industrial Indigenous fishers (cf. Cannon 2011; Gauvreau 2015). However, this does not necessarily exclude the possibility that other age classes were targeted at other times of the year.

Despite seeming divergence in archaeological and local Indigenous accounts, pairing these accounts through two-eyed seeing allows for consideration that localized herring fishing likely occurred at more times of the year in pre-industrial fisheries and that Indigenous fisheries may have included a variety of age classes. Additionally, if our minimum age estimates are reflective of frequently targeted age classes, an implication is need to better understand the role of resident juvenile herring populations in Rivers Inlet and how mixed-age harvest models (i.e., roe, juveniles, spawners) can be incorporated into ecosystem-based fisheries management models as opposed to single-age stock models (i.e., roe or spawners) (cf. Shelton et al. 2014). To clarify if substantial harvest of mixed-age herring occurred, we see promise in further sampling of midden deposits combined with community-based interviews and incorporation of age-composition data from contemporary Indigenous food fisheries as additional points of comparison.

Our case study in minimum age estimation from archaeological fish scales demonstrates that Pacific herring scales from Northwest Coast archaeological sites are suitable candidates for estimations of age-at-harvest. Considering our results, we argue that there is a high likelihood that fish scales can be recovered and analyzed from many coastal archaeological sites to improve age-at-harvest data for many Indigenous herring fisheries. To strengthen future minimum age estimates from archaeologically recovered herring scales, we recommend further evaluation of taphonomic factors involved in scale fragmentation and refining what biological measures are appropriate for ageing scales from archaeological deposits to determine what degree archaeological scales might underestimate minimum age-at-harvest.

Changes in local fish populations

Archaeological records show consistency in herring fishing by Indigenous fishers on the Central Coast through time (Cannon 2013b; McKechnie et al. 2014) suggesting that herring were consistently available to Indigenous fishers in the past. Our results are further localized confirmation of this pattern. We find that herring ranks first and second, respectively in all examined fish scale and fish bone records including at Katit , which is near the head of Rivers Inlet. Further, our minimum age data, provided they do not underestimate age-at-harvest establish a point of comparison that pre-dates existing baselines for the presence of resident juvenile herring at Katit. This observation is significant as it establishes the possibility that ancient Wuikinuxv fisheries were relying on resident non-migratory populations of herring at the head of the inlet that have since diminished or disappeared in addition to transporting fish back from other harvest locations closer to the mouth of the Inlet for further processing (e.g., smoking, drying).

Community knowledge , such as that shared by Jennifer Walkus (Table 3.31), lends additional strength to this hypothesis (Walkus 2011). Jennifer's observation that Wuikinuxv peoples have to go further afield (i.e., beyond the head of Rivers Inlet) to harvest spawn on kelp/spawn on bough than they did traditionally alludes to the possibility that ancient Wuikinuxv fisheries were relying traditionally on locally adapted non-migratory populations of herring for several millennia. By pairing this knowledge with archaeological data, we find consistency between our results and the hypothesis that given their widespread archaeological abundance, contemporary herring populations may represent remnants of previously more abundant and diverse metapopulations (*see* Speller et al. 2012; Petrou et al. 2021). Herring declines and the possible truncation of genetic diversity and potential changes to local availability between pre-industrial and post-industrial times have uncertain consequences for their overall abundance and resilience (Speller et al. 2012) and their management (Okamato et al. 2020:9). We argue in line with Speller et al. (2012), that prioritizing further studies targeting the identification of potential locally adapted herring stocks in deep time may be of value for community-based managers wishing to reassert traditional rights and responsibilities shaped around local populations and for Wuikinuxv fisheries managers wishing to reconcile reduced availability of herring roe at the head of Rivers Inlet with classification the current classification of this area as having medium to major spawning habitat (*see* Fisheries and Oceans 2016b).

Community-informed site identification and interpretation of traditional fishing technologies

Direct knowledge and experience sharing by community members through this work identified the named place Zawias or "Eulachon Town", which falls within the boundary of the same archaeological site as Katit (EkSt-1), as a place suitable for archaeological sampling targeting the recovery of eulachon. Extensive zooarchaeological study prior to our analyses had not targeted this location, but rather an additional community identified priority within the EkSt-1 site boundary centred on an island in the centre of the Wannock River, which was the historical location of Katit village until 1935 (Cannon 2013a). Despite only a half-day of auger sampling, archaeology Zawias yielded a considerable expansion on the zooarchaeological history of eulachon fishing in the territory and within EkSt-1 from deposits dating to within last 600 years (Cannon 2013a) to the last 3000 years to contact and is further testament to the strengths of community-assisted site selection (cf. Gauvreau and McLaren 2016).

Archaeological work at Zawias sparked the sharing of a photograph of a very large and unique archaeological fish harvesting feature not described or recorded in previous archaeological work in the territory. Given the linear nature of the rock channels in this feature and community descriptions of eulachon fish technology nearby, we believe it represents intentional human modification of the riverbed to form channels that would improve the funnelling of eulachon into eulachon nets and provide access by canoe alongside the trap to collect captured eulachon during low water levels. Paired community knowledge and archaeological data also establish that eulachon fishing methods similar to those illustrated in Stewart 1977:96 and Moody 2008:Figure 3.5 may leave tangible remnants in the river bed in the form of extensive networks of immersed linear rock features. These features represent previously undocumented archaeological evidence of eulachon harvesting that archaeologists should be aware of the potential for in eulachon spawning rivers on the Northwest Coast. With further research, including a site visit and recording, we hope to clarify the depth, dimension, and function of this particular feature to assist future efforts to locate similar features elsewhere on the Central Coast.

Our observations add detail to existing knowledge of the collaborative and highly structured nature of fishing at seasonally aggregated and community monitored fisheries (cf. Atlas et al. 2017; Atlas et al. 2020). We argue that community knowledge of eulachon fishing along the Wannock River and the extent of the associated harvesting feature (i.e., ~15000 m^2) are testaments to the cooperative practice of fishing eulachon and the labour involved in constructing and maintaining this feature. Importantly, this feature has elements that indicate it was designed to be shared by multiple users simultaneously and in such a way that harvests could be readily monitored from shore; this feature is highly accessible and visible from two named places (i.e., Zawias and Katit) within the boundary of one archaeological site (EkSt-1) and based on the number of channels would have allowed for multiple eulachon traps to be set up across the river bed.

Paired archaeological and Indigenous perspectives on this eulachon fishing feature in the Wannock Riverbed and Zawias can provide direction for community-based fisheries managers. Given the strict cultural protocols that governed eulachon harvest (see Table 3.3), this eulachon fishing technology represents a selective community-managed harvesting technology and traditional infrastructure with the intent of maintaining resilience in local eulachon populations to ensure future harvests. Archaeological dates obtained during our fieldwork further attest to time depth of this fishery by establishing records of eulachon in cultural deposits in proximity to the eulachon fishing feature that data back to 3000 years ago. These data demonstrate the resilience of eulachon harvest over millennia and lend further support to arguments that overharvest of eulachon in local Indigenous fisheries is unlikely to be responsible for recent reductions in contemporary Indigenous fisheries (*see* Moody and Pitcher 2010). Additionally, acknowledging the deep time legacies of eulachon in archaeological records provides additional data that Indigenous communities, including Wuikinuxv, may wish to consider on their own terms in ongoing Nation to Nation fisheries negotiations in DFO Integrated Fisheries Management Plans. While revitalization of traditional scales and management of fisheries will require substantial returns of eulachon to the Wannock river, the cultural care and knowledge of traditional eulachon fishing described by Ted Walkus and in Table 3.1 provides promising directions for Wuikinuxv fisheries managers if local populations were to stabilize (cf. Atlas et al. 2021; Menzies and Butler 2007; White 2006; 2011). Collectively pairing observations of the archaeological record and local community knowledge will aid place specific strategies for monitoring and managing fisheries (cf. Thompson et al. 2020).

During this research, we recognized that cultural preparation practices of processing eulachon for grease have consequences for the archaeological visibility and recovery of eulachon remains (Patton et al. 2019). Therefore, we acknowledge that eulachon is likely systematically underrepresented in our archaeological data in comparison to herring and salmon and may be more important and historically abundant in ancient Wuikinuxv fisheries than our results suggest. With respect to our case study at Zawias, which we know is a key location for processing of eulachon for their grease, we see further potential to strengthen archaeological estimates of past eulachon abundance through ethnoarchaeological methods and community engagement. One suggestion that emerged through this work is collaborative ethnoarchaeological archaeological research between archaeologists and Indigenous communities who currently harvest eulachon. As Jennifer Walkus describes, future research needs to better understand the loss of scales and bones in archaeological records and could be refined by documenting the number of scales shed and scales and bones discarded during grease processing to better establish the relationship between the amount of grease produced and the number of fish remains generated during processing (Jennifer Walkus, personal communication, 2021).

Document deep time baselines for Indigenous fisheries where the ethnographic record may be limited

Archaeological fisheries data support a significant role for northern anchovy in ancient Wuikinuxv fisheries. Anchovy occur in 79% of all sampled sites and are the third most ubiquitous taxa on the Central Coast (McKechnie and Moss 2016: Table 1 & 2). Consistent with these broader regional assessments, anchovy are highly ranked in fish scale and bone records in Rivers Inlet (Table 3.0, 3.1). However, previous discussions and our review of ethnohistorical and documented oral narratives in Wuikinuxv territory reveal that comparatively little is known about Indigenous anchovy fisheries from ethnographic records (McKechnie and Moss, 2016). To our knowledge the only discussion of anchovy fishing by Indigenous peoples is by Sproat (1865) in the Barkley Sound region. Pairing archaeological and local community accounts on anchovy , therefore, gives the impression that Indigenous anchovy fisheries may have limited ethnographic but good archaeological visibility.

We also consider the limited discussion of Indigenous anchovy fishing both regionally on the Northwest Coast and in Wuikinuxv territory in the ethnographic record as a potential artifact of early ethnographers' abilities and choices rather than a reflection of anchovy's importance to ancient Wuikinuxv fishers. Butler's (2004:445) discussion of ethnographers Lewis and Clark's misidentification of what we now know to be eulachon as "anchovie" in the Lower Columbia lends support to this hypothesis. Accordingly, it seems plausible that cases where ethnographers may have failed to distinguish between different species of forage fish notable inaccuracies or gaps in documenting community knowledge may occur that may account for our observations of Wuikinuxv's anchovy fishery.

Archaeological data on anchovy, however, remains significant to community based managers given that current local approaches to management of fisheries in many Indigenous communities acknowledge that species dynamics within ecosystems can be inextricably linked. Our anchovy rank abundance data may be of interest to community-based fisheries managers as points of comparison for managing forage fish species given that contemporary anchovy fisheries in contrast to other culturally important fisheries are relatively abundant and stable (Di Dario 2021; NOAA 2021).

Conclusion

Our research is further indication that Indigenous knowledge and archaeological knowledge represent invaluable but partial accounts of historical information (cf. Martindale 2014; McKechnie 2015), yet when paired they can strengthen claims about the past with implications for the future. We demonstrate in our case study in Wuikinuxv territory that archaeological fisheries data, when appropriately contextualized by community-initiated research questions, can provide data in service to Indigenous stewardship and management of contemporary Indigenous herring, eulachon, and anchovy fisheries. We also establish that equivalent lines of data to those used in contemporary management such as age-composition are accessible in archaeological contexts and can be used by communities to interpret change in their fisheries since the onset of industrial fishing.

Our results advocate for increased inclusion of more nuanced and inclusive accounts of ancient Indigenous fisheries including more complete descriptions of species that are often overlooked by contemporary fisheries managers, those that may have poor ethnographic visibility, and provide more complete descriptions of traditional fishing technologies as tools for management. Further, they demonstrate context-specific points of resilience in eulachon and herring fisheries over millennia in ancient Indigenous fisheries to bring to bear on current local and regional declines in these fisheries and that bring renewed perspective on supporting community-based managers with locally contextualized archaeological fisheries data.

Chapter 4: Conclusions and Directions for Future Work

Introduction

Fish and fishing are fundamental aspects of human life on the Northwest Coast. This thesis explored how fish have shaped Wuikinuxv lives by considering archaeological and ethnohistorical data pertaining to fish from Wuikinuxv First Nation territory on British Columbia's Central Coast and considered how an under-researched faunal archive – fish scales – could complement zooarchaeological and community understandings of ancient Indigenous fisheries.

Evidence presented in this thesis indicates that fish scales are reliably recovered from coastal shell-bearing archaeological sits on the Northwest Coast that span the last 3000 years. Fish scales provide relative abundance and species identification data and contain annual landmarks for estimating minimum age-at-harvest in ancient Indigenous fisheries. My research establishes fish scales as additional archives for these data that can complement the results of ancient DNA, stable isotope analysis, zooarchaeological analyses, and historical records by broadening perspectives on ancient Indigenous fisheries.

In the following sections, I review the central research questions of this thesis. Following this, I evaluate the implications of research discussed in this thesis for archaeological study of fish scales and the use of archaeological fisheries data to address the concerns of community-based fisheries management.

Review of Research Questions

Question 1: Are fish scales recoverable and identifiable to species from archaeological contexts on the Northwest Coast?

Yes. As shown in Chapter 2, fish scales regularly preserve in coastal archaeological deposits and help to reconcile taxonomic identifications in two different areas of the Northwest Coast: Rivers Inlet and the Broken Group Islands. I also show how recovery method, processing, age, and bone content are related to the preservation of archaeological fish scales from coastal shell-bearing sites. My analyses were informed by itemized scale data, scale identification data, and fish bone identification data (NISP). Drawing on squamatological and zooarchaeological methods, I argue that archaeological fish scales are a more ubiquitous and valuable archive for understanding archaeological fisheries than is generally appreciated.

Relative quantification of observed fish scales according to recovery method (i.e., screen size); relative bone abundance; scale degradation; and age of deposits showed that screen size and scale degradation, in particular, influence not only the recovery of fish scales but the success of squamatological identification and ageing analysis. I observe that with the increasing deterioration of key structures (i.e., degradation) such as the focus (centre of the scale), fish scales become more difficult to identify to genus and species-level. I also observe that fish scales of particular taxa (e.g., herring) may be more easily identified than others when scales are more degraded. These observations demonstrate scale degradation as a crucial factor for future researchers to consider when selecting suitable fish scales for identification and analysis.

I also observe that although fish scales are recoverable from a variety of fine screen sizes (6.35 mm, 2 mm, 1 mm), 6.35 mm fraction generally yields comparatively few fish scales and is not appropriate in isolation for effective scale recovery. Comparably, I observe that while 2 mm fraction may be adequate for recovery of the scales of many fish species the scales of certain species (e.g., eulachon) are only recovered from smaller (1 mm) screen fractions. These results show that recovery of targeted fish species in fish scale assemblages requires fine screening (2 mm or 1 mm) consistent with previous studies in the recovery of fish bone (*see* Moss et al. 2017), but that for small-scaled species, such as eulachon, 1 mm screen mesh is necessary. With this suggestion in mind, I acknowledge that given the significant time investment of fine screening, the fine screening of the entirety of material (especially with 1 mm mesh) will not always be possible. Accordingly, I recommended a subsampling protocol for 1 mm screen fractions or the targeting of small volume auger or column samples to solidify efforts to recover fish scales.

Question 2: Can archaeological fish scales provide age data?

Yes. As shown in Chapter 3, I was able to obtain minimum age data estimates by counting visible annuli on preserved archaeological fish scales. These data provide past age-at-harvest baselines for herring fisheries in Wuikinuxv territory and are the first example of minimum age estimates for fish scales from archaeological deposits on the Northwest Coast. These data also establish that the ageing of herring from fish scales found in archaeological deposits, in particular, is a more feasible undertaking than is currently appreciated. However, we balance this with an understanding that these minimum age estimates may underestimate the true age-at-harvest of past fish specimens due to deterioration of the margins of the scale during their preservation in archaeological deposits and the limited number of scales subjected to ageing analysis in this study.

Average minimum age-at-harvest for herring fish scales in this study are 1.8 ± years, consistent with juvenile aged herring (Hay and McCarter 1998). My results therefore may suggest the harvest of mixed age herring including juvenile populations that had yet to migrate to offshore pelagic environments, which would expand on current interpretations about the narrow seasonality of herring harvest focused primarily on spawning-age fish on the Central Coast (Cannon et al. 2011) and addresses the possibility that localized herring fishing occurred at more times of the year than is generally appreciated. However, I acknowledge my minimum age data are limited in their capacity to test this particular hypothesis given our limited sample size of age-herring scales and that scale age data may reflect the conservative nature of DFO analyst assessments of age where only confidently identified growth rings were assessed. Provided additional comprehensive regional sampling and analysis of fish scales, however, I feel confident the patterns in age-at-harvest in Indigenous herring fisheries on the Northwest Coast from archaeological fish scales that I discuss here can be further clarified.

Question 3: How can archaeological fisheries data address the contemporary concerns of community-based fisheries?

Chapter 3 demonstrates how archaeological fisheries data from Wuikinuxv territory can contribute data for community-based fisheries management. My analysis in this chapter pairs data on three culturally significant Indigenous fisheries: eulachon, herring, and northern anchovy from archaeological sites in Wuikinuxv territory; these data include a subset of minimum age assessments for herring scales and rank order dating reflecting the relative importance and abundance of these fisheries based on similar proportions of these taxa in scale and bone assemblages. My results show that eulachon, herring, and anchovy rank in the top three to four most highly ranked fish taxa at most sites in archaeological assemblages dating from 3000 cal. B.P. to contact in my Wuikinuxv case study. These data showed promise in addressing contemporary community-based fisheries concerns by providing points of comparison such as age-composition that are equivalent to metrics used for management by federal fisheries management bodies. A major theme in my results is that pairing archaeological data with complementary lines of community based fisheries knowledge can establish more concrete and context-specific points of comparison for local managers, including clarifying change in local fish populations over time, and providing baseline data on ancient Indigenous fisheries such as anchovy that have limited ethnographic visibility.

An additional contribution of this thesis is that it deepens understandings of the archaeological history of ancient Indigenous eulachon fisheries. Data generated from community knowledge of place and archaeological sampling at the place name Zawias "eulachon town" documented the use of a eulachon fishing feature represented by channels in the riverbed as described by Ted Walkus and Jennifer Walkus accompanied by a record of eulachon in archaeological deposits by 3000 cal. B.P. Accordingly, my research establishes eulachon fishing in Rivers Inlet as at least 3000 years old extending on previous archaeological assessments of the age of this fishery (i.e., Cannon 2013a) by several millennia.

My results also establish that the harvest of eulachon along the Wannock River entailed cooperative management centered on seasonally aggregated eulachon runs. I provide evidence of a very large feature consisting of constructed linear alignments in the bottom of the Wannock River. Given the size of the feature (~15000m^2) and abundant evidence of stipulations over access and control I conclude that traditional practices of eulachon fishing in Wuikinuxv territory entailed forethought and management efforts to ensure resilience over several millennia. These data are significant to community-based managers in Rivers Inlet as they provide complementary deep time legacies of relationship and management of eulachon that communities including Wuikinuxv may wish to leverage on their own terms in ongoing Nation to Nation fisheries negotiations in DFO Integrated Fisheries Management Plans. I also argue that although revitalization of traditional scales and management eulachon will require substantial returns of eulachon to the Wannock river, there is still abundant potential for revitalization of traditional eulachon fishing practices and responsibilities to be undertaken by local managers if local populations were to stabilize in the future (cf. Atlas et al. 2021; Menzies and Butler 2007; White 2006, 2011).

Discussion

Contributions to Fisheries Archaeology: Fish Scales

Fish analyses in this thesis contribute additional data to supplement zooarchaeological fisheries data reported in Rivers Inlet (see Cannon 2013a,b.). This research is the first example of the successful recovery and analysis of fish scales from archaeological deposits in coastal British Columbia. Second, analysis of these fish scales refine species-level identifications at Katit (EkSt-1) from the genus level identification of *Hexagrammos* reported in Cannon 2013 to kelp greenling *Hexagrammos decagrammus*. Third, I provide the first discussion of age-at-harvest in Pacific Herring from Rivers Inlet sites and the Central Coast using zooarchaeological fish scale data. Fish scale analyses also provide complementary data on previously identified salmon species identified from aDNA at Katit (see Cannon et al. 2011) by securing additional identification of sockeye and chinook salmon. and when viewed alongside fish bone records from Rivers Inlet are consistently support a heavy reliance on forage fish over the last 3000 years.

Contributions to Fisheries Archaeology: Forage Fish

Contributions to Fisheries Zooarchaeology in Wuikinuxv Territory

This research expands archaeological perspectives on past eulachon fisheries in Wuikinuxv territory. Prior to this research, eulachon were recorded in archaeological deposits in Rivers Inlet at Katit (EkSt-1) dating to 600 years ago (Appendix B; Cannon 2013a,b). My results expand on archaeological antiquity of eulachon in Rivers Inlet previously established within the boundary of EkSt-1 and Rivers Inlet. I recover eulachon bone from a the named-place Zawias within the boundary of EkSt-1 in direct association of archaeological deposits dating to 3000 cal B.P. I also provide the first archaeological description of a eulachon harvesting feature consisting of eighteen linear rock channels in the Wannock River. With significant input from community members and based on my reading of the ethnographic record on eulachon fishing, my findings establish this feature as a potentially widespread but under documented fishing technology on the Central Coast worthy of further study.

Contributions to Fisheries Zooarchaeology on British Columbia's Central Coast

Fish scale analyses in this thesis refocus on previous observations of the high ranking in NISP record of forage fish from archaeological deposits on the Central Coast and Wuikinuxv territory. In this research, I build on earlier studies that emphasize the importance of these ancient Indigenous fisheries on the Central Coast of British Columbia (see Cannon 2013a,b; 2000a; Duffield 2017; McKechnie and Moss 2016; McKechnie et al. 2014) by establishing complementary lines of data on identified fish taxa. In line with these authors, I find that herring, anchovy, and eulachon occur in relatively high abundance, and rank in the top four ranked species in fish remains records (bones and scales) in Rivers Inlet. Collectively, these data reveal the longstanding and consistent availability of forage fish on British Columbia's Central Coast over several millennia.

This thesis also describes some significant complementary and additional data on eulachon specific to archaeological sites in Rivers Inlet. I observe from compiling data from previous zooarchaeological studies (i.e., Cannon 2013a,b) that eulachon recovered from village sites near eulachon spawning locations are more abundant than in other archaeological sites in Wuikinuxv Territory. Eulachon account for 11.2% of identified fish species at Katit, which is near a known eulachon spawning River; whereas at EjTa-13, which is located a sufficient distance from known eulachon spawning areas, eulachon only makes up 1% of identified fish species (Duffield 2017). Eulachon's presence in Rivers Inlet sites (observed in 42% or 5 out of 11 sites) is also consistent with descriptions of eulachon presence in archaeological sites in the Central Coast region by McKechnie and Moss (2016) where smelts (including eulachon) are present in 42% of examined sites. My findings provide considerations for building more robust eulachon datasets in the future that are consistent with considerations for eulachon recovery on the North Coast (cf. Patton et al. 2019) including fine screening and sampling near known eulachon spawning locations to improve recovery potential for eulachon bones and scales.

Potential Challenges to Squamatological Studies of Archaeological Fish Scales

Our analyses of fish scales identified four challenges to fish scale analysis. Two of these challenges are methodological: 1) inadequate recovery of fish scales due to inappropriate screening; 2) access to a physical reference collection; and two are related to preservation: 3) scale resorption; and 4) potential underestimation of age-at-harvest.

The Importance of Screening

As addressed in Chapter 2 and the previous section of this chapter screen size appears to impact fish scale recovery. My case study showed a notable difference in fish scale recovery between 6.35 mm (1/4") and 2 mm for archaeological contexts where both screen sizes were employed. My research draws attention to the fact that screen sizes >2 mm and possibly even 2 mm screens may be too large to capture the scales of small-scaled fish (e.g., smelts, juvenile fish, juvenile salmon), which are generally < 2 mm in diameter. For this reason, where fine screen sizes are not employed in fish scale analyses, practitioners should be aware of potential biases in fish scale identification that may result from screening strategy. Failure to use fine screen methods during bulk sample may also, as my case study in Chapter 2 suggests, result in the underrepresentation of recovered fish scales from coastal archaeological deposits. I argue, therefore, that inadequate screening remains a key consideration for the near lack of comprehensive studies of fish scales from Northwest Coast archaeological sites.

I also address in Chapter 2, that with increasing degradation scales become harder to identify. While several factors likely contribute to the observed degradation of fish scales in archaeological deposits, it remains to be considered how screening and processing might affect degradation in observed scale assemblages. One hypothesis that remains to be tested that I introduce in Chapter 2 is whether post depositional agitation in metal mesh screens, washing, and other processing impact the integrity of recovered fish scales more so than they do bones, given that scales are generally more fragile. To address this hypothesis, future studies might examine the potential effects of post depositional agitation by examining cumulative effects and patterning between screen size recovery and observed degradation of scales (i.e., does increased processing result in the recovery of more degraded scales). Additionally, these future studies could also explore and evaluate different treatments of wet and dry screening methods to fish scales to determine if particular methods contribute to increased degradation of recovered fish scales. Collectively these studies should aid in clarifying what appropriate steps should be taken to minimize post-depositional breakage in fish scales.

Access to a physical reference collection

This research confirms that identifications from a physical reference collection is essential to fish scale analysis and identification. I found that a physical reference collection was necessary for identifying salmonids (*Oncorhynchus* sp.) and where identification from Patterson et al. 2002's photographic atlas proved difficult due to lacking comparative photos of juvenile scales and need to observe landmarks from a variety of scales to secure species-level identification as well as for rockfish (*Sebastes sp.*) that can be difficult to identify to species from scales in general. I recognize that photographic atlas and other imagery are widely available, however, I found that these resources are limited in their ability to establish species-level identification. Instead I suggest limiting the use of photographic atlas to establishing a baseline for what range of fish species are present in one's study area and on a case-by-case basis to determine order and family level identifications. Where physical comparative archaeological scale collections are not available, I suggest that modern scales can be used and point future researchers to fish scale archives readily available in fisheries science labs as a useful place to start. Additionally, future considerations for establishing fish scale comparative collection could include acquiring representative fish scales from multiple locations along a fish, which would account for the fact that specific scale locations on a fish may have specific scale morphologies (Casteel 1974; Patterson et al. 2002: Figure 2).

Resorption

Resorption was cited as a reason DFO analysts were unable to age 33% or 6/18 *Oncorhynchus sp.* fish scales (see Figure 4 for an example of one of these scales). Reabsorption is the process by which a fish reabsorbs the nutrients in its scale (often during times of nutritional stress), causing a deformity in the scale itself, often near the annuli (Elliot and Chambers 1996: 5). During spawning, resorption of scale material may occur that leaves irregular margins that can be incorporated into the scale after growth resumes and obscure key ageing features in the scale (Mosher 1969; Davis and Light 1985; Rideout and Tomkiewicz 2011). Reabsorption is an unpredictable phenomenon that can affect many fish species but is particularly pervasive in semelparous Salmonids and is typically associated with spawning fish (Alaska Department of Fish & Game n.d.). Scale reabsorption, therefore, can result in misidentification of spawning check and age if the mark left behind by resorption is indistinct or in cases where it is quite distinct may even obscure annuli (Elliot and Chambers 1996; Hernandez et al. 2014). Reabsorption presents a challenge for archaeologists hoping to age fish scales on the Northwest Coast since many culturally significant and commonly observed fisheries in archaeological records are frequent harbourers of scale reabsorption (e.g., salmon *Oncorhynchus sp*.).

Additionally, based on our unsuccessful attempts to age salmon scales due to reabsorption in our sample, I recommend that future ageing analyses of salmonids, in particular, should work to identify and troubleshoot for signs of resorption in specimens before undergoing ageing analysis to avoid selecting samples that are inappropriate for age estimation.

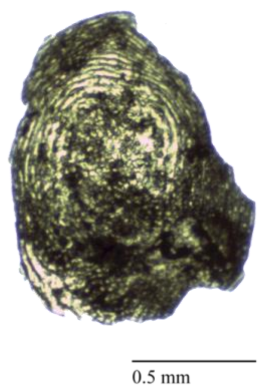


Figure 4.0. Salmon (*Oncorhynchus* sp.) scale specimen from archaeological site EkSt-1 (Zawias) in Wuikinuxv territory with marks showing evidence of resorption.

Potential Underestimation of Age-at-Harvest

There is also need to balance the promise in archaeological fish scale age analysis with the state of preservation in fish scales in archaeological records relative to those obtained from living fish contemporary environments. Age underestimation may occur in archaeologically recovered fish scale specimens when they are incredibly degraded as they do not preserve outer annuli rings. In Chapter 3, I argue archaeologists can control for this issue by providing ranges of error (in years) in their age estimates and by picking specimens with at least the focus intact (*see* fish scale degradation scale, Figure 2.11). Additionally, there is need to further consider to what degree fish scales aged from archaeological deposits might underestimate true age-at-harvest. I feel confident that further ageing of archaeological fish scales from multiple contexts of varying deposit age and preservation can establish if archaeologists can meet biological standards of confidence for ageing fish scales or, if additional considerations regarding the assessment of minimum age should be made for archaeological specimens. Alternatively, I see potential for evaluating the degree of underestimation of true age-at-harvest in ancient Indigenous fisheries through experimentation and compiling of community-based knowledge regarding targeted age-classes in Indigenous fisheries where oral historical, community-based interview, and other records are available.

Future Directions for Squamatological Archaeology

More comprehensive sampling and future study of fish scales from Northwest Coast archaeological sites hold promise for improving understandings of past Indigenous fisheries and for providing data for contemporary community-based fisheries management. As mentioned, fish scales are relatively ubiquitous in shell-bearing archaeological sites in the Broken Group Islands and Rivers Inlet and further itemization and analysis of fish scales recovered from other archaeological sites in the Northwest Coast can help to reconcile the true ubiquity and preservation of fish scales in archaeological deposits. I see further directions building on my work related to fish scale preservation that could include experimental archaeology that examine how taphonomic conditions including soil chemistry, processing effort affect the condition of recovered fish scales and might explain discrepancies in abundance in fish scale vs. bone records that account for bones being up to four times more abundant in my study sites.

I feel that the fish scale ageing method for herring obtained from archaeological sites in Wuikinuxv territory can be usefully applied to additional archaeological herring scale assemblages. I see this effort as worthwhile given that it would increase the geographic scope for evaluating pre-industrial age composition as a point of comparison for herring management. I also see potential through collaboration with paleobiological scale analysts to use this method to examine age-at-harvest for other species, broadening the relevance of these age analyses in the study of ancient Indigenous fisheries and in Indigenous fisheries management.

Closing Thoughts

This thesis explores the historical ecology of forage fishing in Wuikinuxv territory on the Northwest Coast of North America. Combining the study of archaeological materials, ethnographic and contemporary Indigenous accounts, and fisheries survey data, I document the potential for archaeological data to provide temporally anchored and biologically relevant data on fish that may be of use in management applications at a variety of geographic and management scales. By aspiring towards the eventual integration of archaeological relative abundance and age data with conventional fisheries management data I hope to build capacity towards reconciling the longstanding view of archaeological data by Western fisheries managers as limited in its analytical potential. Additionally, by pairing archaeological fisheries data and community-based fisheries knowledge through two-eyed seeing I demonstrate that researchers can develop comprehensive and nuanced understandings of context specific points of changes in the abundance, availability, and reliance of ancient Indigenous fisheries. Data in this thesis build upon the contributions of previous archaeological research to argue that archaeological fisheries data can be undertaken in service to Indigenous communities to provide valuable age composition and comparative abundance data in a diverse range of targeted and culturally vital forage fisheries on the Northwest Coast. Amidst contemporary declines in culturally significant fisheries that are only expected to accelerate over the next decade, I hope the data and ideas put forth in this thesis can assist in forging pathways that uphold reconciliation and reassertion of Indigenous lifeways and responsibilities to the management of Wuikinuxv and Northwest Coast fisheries.

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Appendix A: Microscopic Photography and Analysis of Archaeological Fish Scales

Overview

Appendix A summarizes the methodology used to photograph and analyze 376 fish scales from archaeological shell-bearing sediments from British Columbia's Central Coast in Wuikinuxv territory to create digital archives for their identification and ageing. This can be used as a resource for future recovery and identification of archaeological fish scales, particularly for prepping specimens for fish scale ageing analyses.

Fish Scale Analysis and Identification

Most marine fishes on the Northwest coast possess a covering of scales over the outer surface of their bodies. These scales consist of variety of types: here we discuss four major types of fish scales (Figure 5.0). In particular cycloid and ctenoid scales show considerable variation in their forms permitting their use for identification purposes.

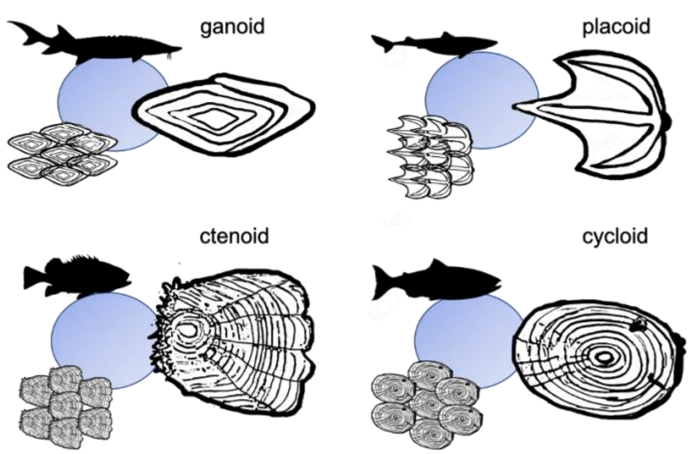


Figure 5.0. Common scale shape types with examples of Northwest Coast fishes. Ganoid: diamond shaped, hard, and thick; scales are formed from ganonine (e.g., sturgeons). Placoid: 3-layered scales with a pulpy vascular core, a middle layer composed of dentine, and the outer layer is made of hard vitrodentine (e.g., dogfishes). Unlike other types scales do not grow in size as the fish size increases. Ctenoid: have tiny comb-like protrusions on the posterior of the scale (e.g., rockfishes). Cycloid:

Growth rings relate to the age of the fish, scales are thin, circular and covered by a thin layer of epidermis and mucus (e.g., salmon). Figure by Alyssa Ball.

Analysis of Fish Scales

Currently there is no standard practice for fish scale analysis and recovery in archaeology. However, Casteel (1974, 557, 561-562) provides some guidelines for identifying fish scales. Some of Casteel's recommendations appear to be adopted in more recent examples of archaeological fish scale studies (e.g., Guilland et al. 2017). Casteel recommends that all fish scale analyses 1) use a species-specific reference atlas and physical reference collection with modern fish scales 2) secure scale identifications with supportive zooarchaeological from the same faunal assemblage. In line with these recommendations, we use a combination of physical and digital reference collections (Figure 5.1).

Figure 5.1. Reference collections used for fish scale analysis. Top left: Patterson et al. 2002 *Atlas of Common Squamatological (Fish Scale) Material in Coastal British Columbia*; Top right: Mounted modern scales on microfiche slides in the UVic Zooarchaeology Lab Physical Reference Collection;

Bottom: University of Victoria Zooarchaeology Lab Reference Collection Photo provided by Iain McKechnie.

Mounting and Photography of Archaeological Scale Collections

Fish scale photography involves three steps three steps, wet slide mounting, photography using a digital microscope and free software (*Leica Acquire for Mac*).Various methods have been used to mount fish scales from palaeobiological and biological specimens. The easiest mounting method was to allow the scales to sit in freshwater for a short period of time (~15 minutes) (cf. Patterson et al. 2002). During this process care was taken to keep scales moist so that they did not curl or fracture prior to positioning the cover slide. Once they become malleable, scales can be mounted between glass. Pairs of standard laboratory glass slides were found to be suitable as well as microfiche slides (cf. Patterson et al. 2002). This method was used to mount 372 fish scales from 1 mm and 2 mm mesh fractions individually onto glass slides. Each mounted scale was labelled with provenience information including site Borden number, auger test ID, depth below surface (DBS), and fraction size (1 mm or 2 mm).

Although acetate peels also permit microscopic examination, many preserved scales in archaeological sites are likely too fragile for the pressing process. Comparatively dry mounting of scales proved ineffective given the potential for scales to move between the slides and potential breakage during mounting.

Digital Photography

Scales were photographed using a Leica DM750 microscope with digital camera and processed using *Leica Acquire for Mac*. Each scale was given a digital ID and labelled with its associated provenience information. Scale bars were then added retroactively in Adobe Photoshop V. 2020 based on microscopic photographs of a known scale. All scales for publication were photographed using transmitted light to produce the characteristic “fingerprint” image. Photographs of these fish scales are available as open access digital files associated with this thesis (https://osf.io/vxz2f/?view_only=52172ebd23174a52ab7efde996c4db34).

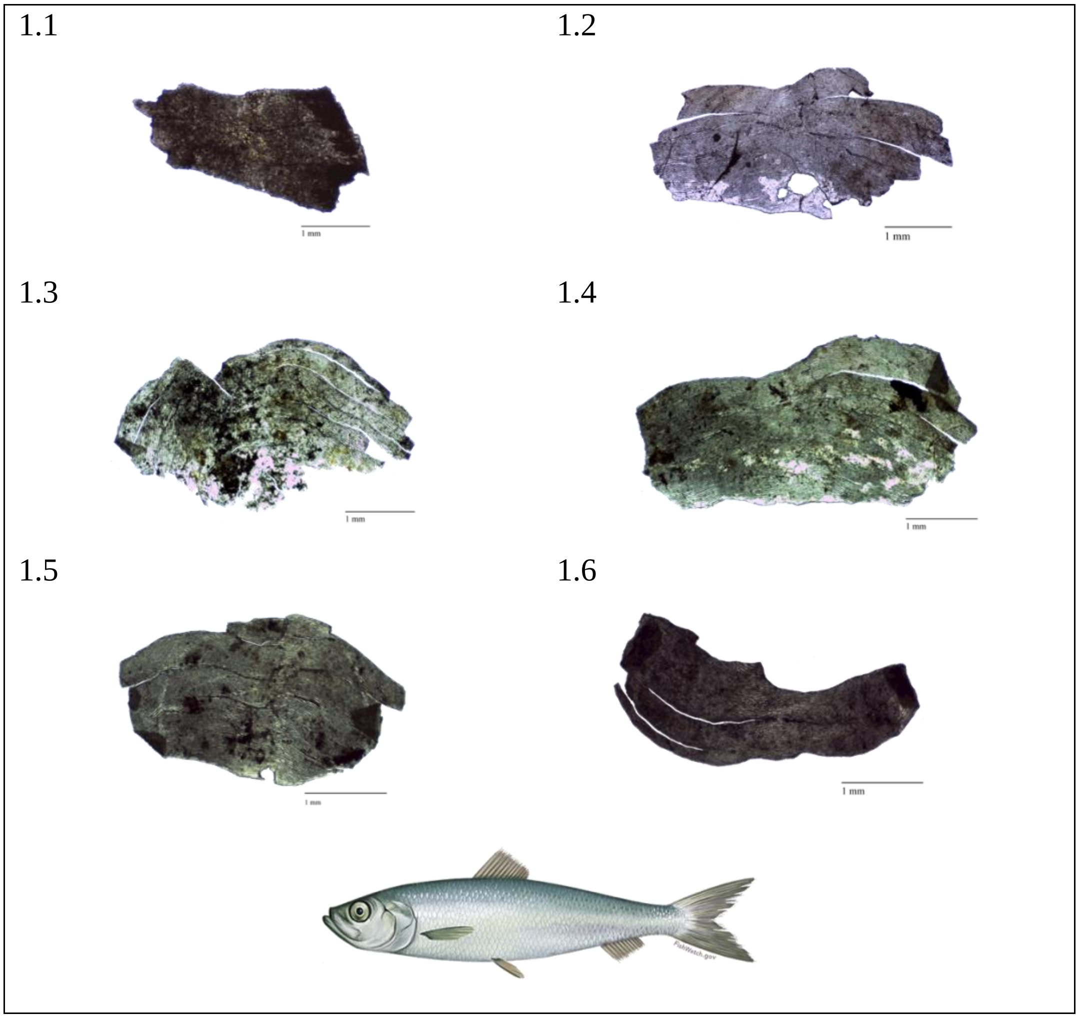
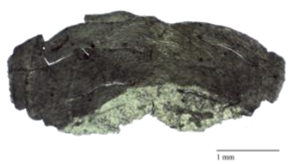
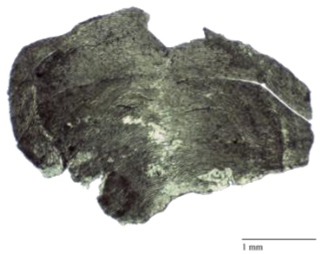


Figure 5.2. Examples of identified herring scales from archaeological sediments in Rivers Inlet. 1.1: AT10:2 (Zawias EkSt-1); 1.2: B7:11 (Katit EkSt-1); 1.3: B11:1 (Katit EkSt-1); 1.4: C18:8 (Cockmi EjSw-1); 1.5: C17:20 (Cockmi EjSw-1); 1.6: C17:12 (Cockmi EjSw-1).

Aged Herring Scales

Table 5.0. Aged fish scales from Cockmi (EjSw-1)

Scale Image	Provenience	Minimum Age (yrs)	Other Comments from DFO Age Analysts
	**Site:** EjSw-1 Auger :(Scale Number): C17:3 **DBS:** 263-271 Fraction: 2 mm	1	just counting visible annuli
	**Site:** EjSw-1 Auger (Scale Number): C17:7 **DBS:** 263-271 Fraction: 2 mm	3	just counting visible annuli
	**Site:** EjSw-1 Auger (Scale Number): C17:13 **DBS:** 263-271 Fraction: 2 mm	1	just counting visible annuli
	**Site:** EjSw-1 Auger (Scale Number): C17:19 **DBS:** 263-271 Fraction: 2 mm	3	just counting visible annuli
	**Site:** EjSw-1 Auger (Scale Number): C17:20 **DBS:** 263-271 Fraction: 2 mm	2	just counting visible annuli

	**Site:** EjSw-1 Auger (Scale Number): C17:22 **DBS:** 263-271 Fraction: 2 mm	2	just counting visible annuli
	**Site:** EjSw-1 Auger (Scale Number): C17:25 **DBS:** 263-271 Fraction: 2 mm	2	just counting visible annuli
	**Site:** EjSw-1 Auger (Scale Number): C17:26 **DBS:** 263-271 Fraction: 2 mm	3	just counting visible annuli
	**Site:** EjSw-1 Auger (Scale Number): C18:8 **DBS:** 271-287 Fraction: 2 mm	1	just counting visible annuli
	**Site:** EjSw-1 Auger (Scale Number): C18:20 **DBS:** 271-287 Fraction: 2 mm	2	just counting visible annuli

Site: EjSw-1

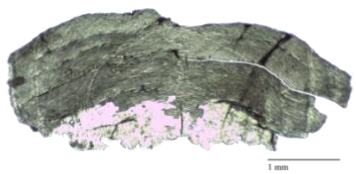
Auger (Scale Number): C18:21

DBS: 271-287

Fraction: 2 mm

3 or 4

just counting visible annuli



Site: EjSw-1

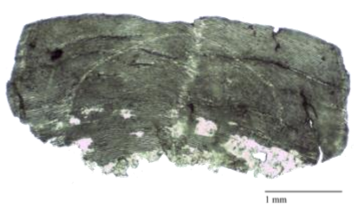
Auger (Scale Number): C18:22

DBS: 271-287

Fraction: 2 mm

3

just counting visible annuli



Site: EjSw-1

Auger (Scale Number): C18:37

DBS: 271-287

Fraction: 2 mm

2

just counting visible annuli

Site: EjSw-1

Auger (Scale Number): C22:2

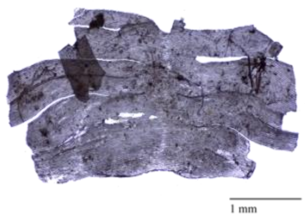
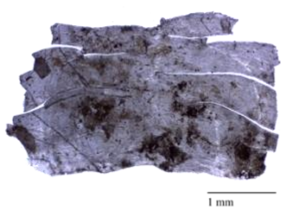
DBS: 328-338

Fraction: 2 mm

1 +/- 1 year

Very large 1^{st}?

Table 5.1 Aged fish scales from Katit and Zawias (EkSt-1)

Scale Image	Provenience	Minimum Age (yrs)	Other Comments from DFO Age Analysts
	**Site:** EkSt-1 Auger :(Scale Number): B7:2 **DBS:** 112-128 Fraction: 2 mm	1	just counting visible annuli
	**Site:** EkSt-1 Auger :(Scale Number): B7:8 **DBS:** 112-128 Fraction: 2 mm	2	just counting visible annuli
	**Site:** EkSt-1 Auger :(Scale Number): B8:3 **DBS:** 128-143 Fraction: 2 mm	1	just counting visible annuli
	**Site:** EkSt-1 Auger :(Scale Number): C4:1 **DBS:** 74-93 Fraction: 2 mm	2	just counting visible annuli
	**Site:** EkSt-1 Auger :(Scale Number): C5:6 **DBS:** 75-90 Fraction: 2 mm	1	just counting visible annuli

	**Site:** EkSt-1 Auger :(Scale Number): C5:17 **DBS:** 75-90 Fraction: 2 mm	1	just counting visible annuli
	**Site:** EkSt-1 Auger :(Scale Number): C5:19 **DBS:** 75-90 Fraction: 2 mm	1 +/- 1 year	Large vague 1st?

Appendix B: Radiocarbon Dates and Auger Sample Locations

Age-Depth

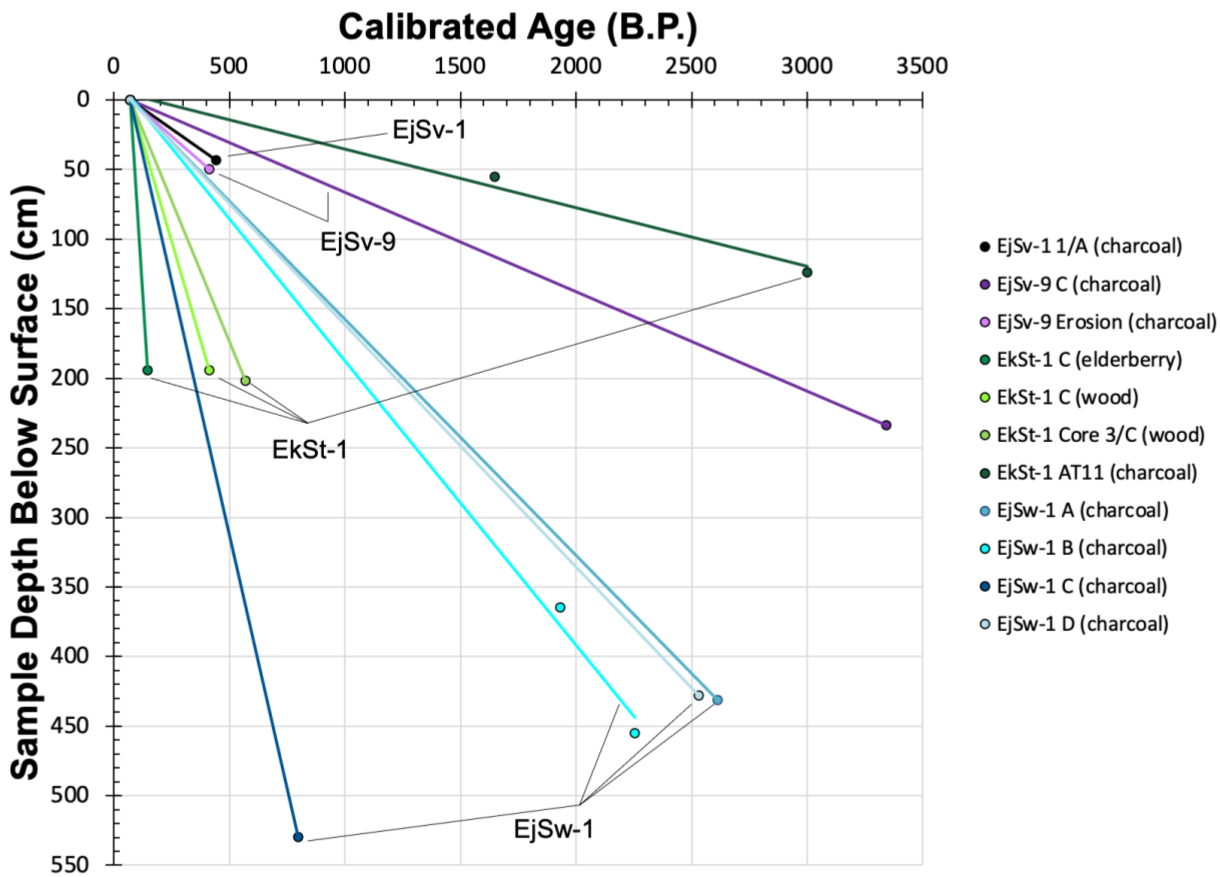


Figure 6.0. Age -depth plot for Rivers Inlet sites examined for fish scales. Note that linearity is approximated here to establish generalized age ranges for scale specimens from particular depths below surface for the purpose of establishing relative age of fish scale specimens.

Table 6.0. Midpoint radiocarbon dates for Rivers Inlet sites examined for fish scales. Dates are calibrated using Calib 8.2 (Stuiver et al. 2021) and IntCal20 (Reimer et al. 2021). *Calibrated ages and midpoint values are given as calibrated years B.P.

Borden Number	Local Name	BETA#/Lab Code	Sample Location	14C Age	+/-	Calibrated* Lower	Calibrated* Upper	Midpoint Age*	Sample Depth (cm)	Material
EjSv-1	NA	232932	core 1/A	450	40	335-349	454-549	442	28-43.5	charcoal
EjSv-1	NA	224631	core1/B	1310	40	1181-1215	1219-1307	1244	148.5-150	charcoal
EjSv-9	NA	232936	erosion exposure	330	40	316-407	421-508	412	50	charcoal
EjSv-9	NA	224635	core 1/C	3060	40	3240-3414	3420-3445	3343.5	233-234	charcoal
EjSw-1	Cockmi	206516	auger C	830	40	690-804	862-906	798	530	charcoal
EjSw-1	Cockmi	212122	core 2 /Auger A	2560	40	2438-2788	NA	2613	430-431	charcoal
EjSw-1	Cockmi	281380	core 3 /Auger B	2280	40	2157-2265	2298-2353	2255	454-455	charcoal
EjSw-1	Cockmi	2811381	core 5 /Auger D	2000	40	2356-2545	2629-2704	2530	426-428	barnacle
EjSw-1	Cockmi	281382	core 3 /Auger B	1930	40	1826-1852	2027-2035	1930.5	363-364.5	charcoal
EkSt-1	Katit	206517	auger C	370	40	316-407	421-508	412	190-194	wood
EkSt-1	Katit	212123	core 3/C	460	40	503-561	595-635	569	200.5-202	wood (cedar)
EkSt-1	Katit	312269	auger C	190	30	0-34	252-290	145	184-194	seeds (red elderberry)
EkSt-1	Zawias	UOC-12865	AT11	1753	29	1549-1553	1568-1712	1648	50-55	charcoal
EkSt-1	Zawias	U0C-12866	AT11	2905	37	2935-3167	NA	3051	118-124	charcoal

Figure 6.1. Map of the eleven auger samples from within EkSt-1 from 2020 sampling effort relative to 2005 sampling in the EkSt-1 site boundary by Cannon 2013 (in red). Auger samples AT 8-11 are Zawias, AT1-7 are Katit.

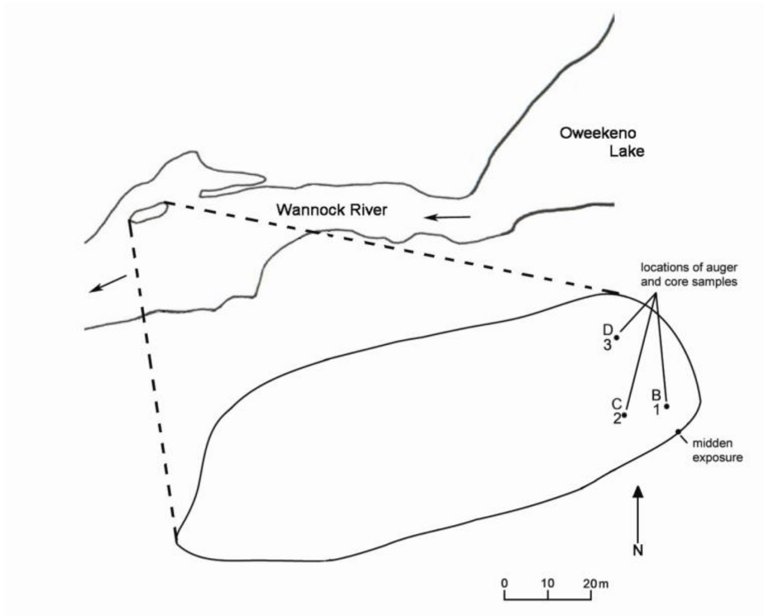


Figure 6.2. Site map EkSt-1 showing auger sampling locations B-D (Cannon 2013a: Figure 65).

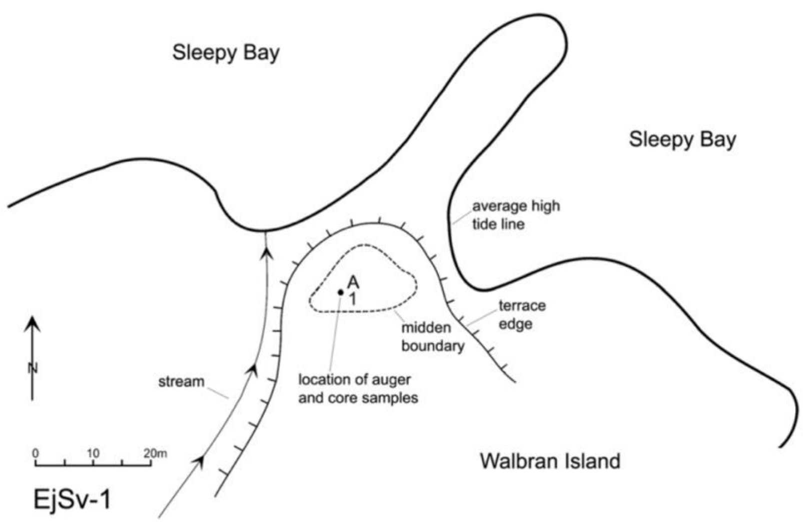


Figure 6.3. Site map of EjSv-1 showing auger sampling locations (Cannon 2013a: Figure 6).

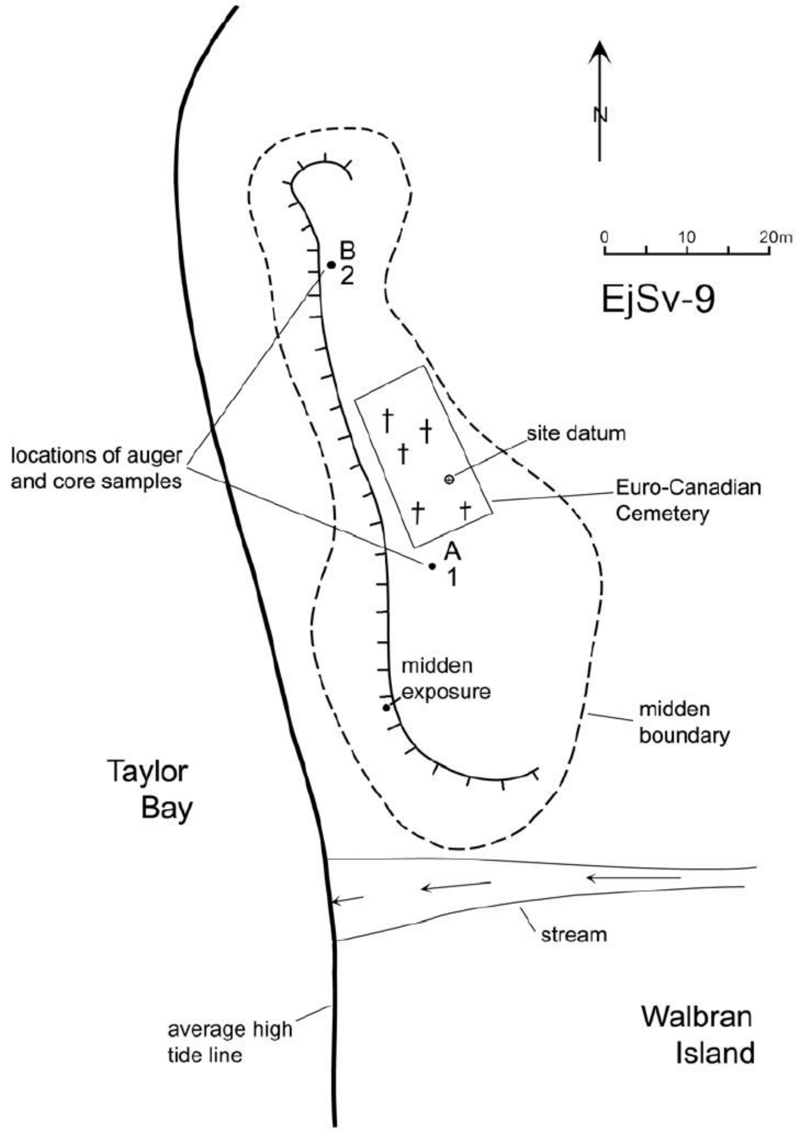


Figure 6.4. Site Map EjSv-9 showing Auger sampling locations A & B (Cannon 2013a: Figure 30).

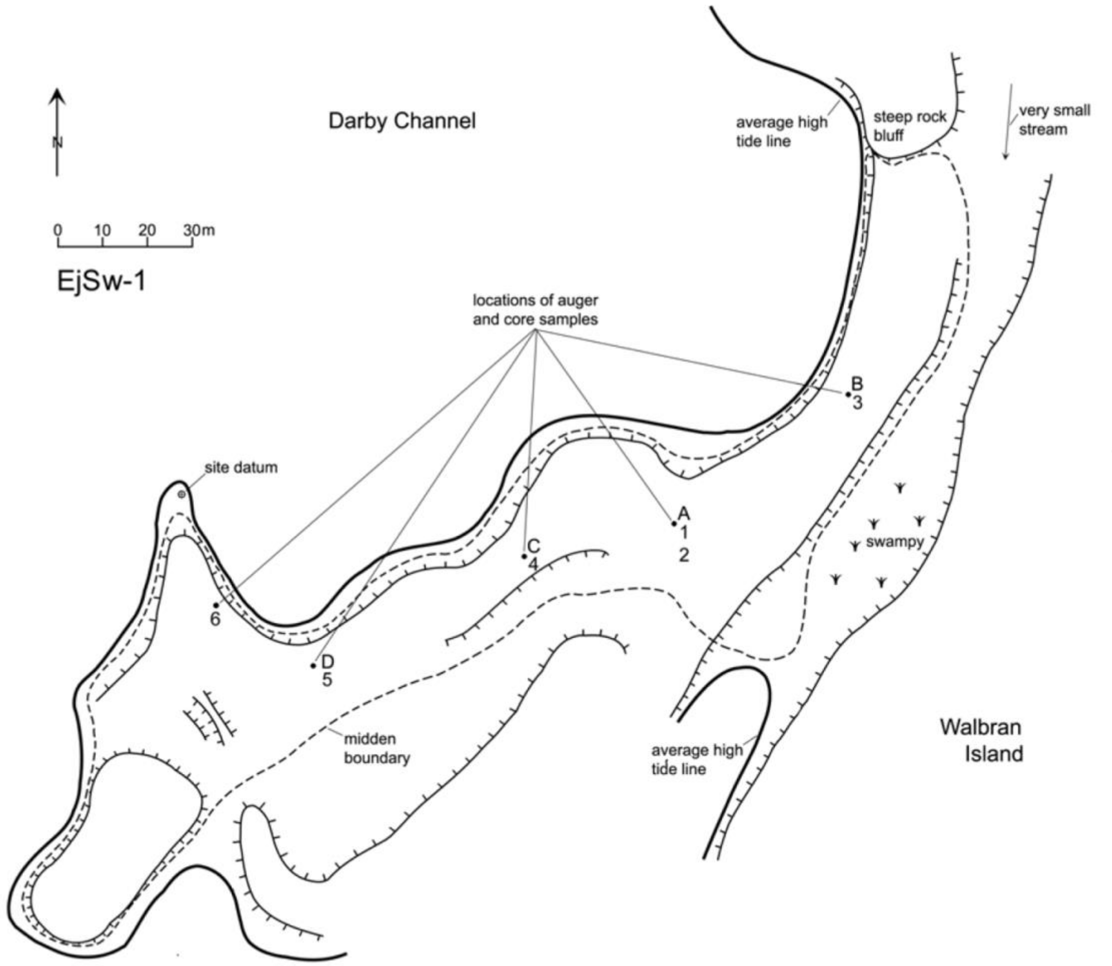


Figure 6.5. Site Map EjSw-1 (Cockmi) showing Auger sampling locations (Cannon 2013a: Figure 52).

Appendix C: Wuikinuxv Letter of Permission

Wuikinuxv Nation
Oweekeno Village, Rivers Inlet, c/o Bag 3500
Port Hardy, BC, V0N 2P0
Administration Office Phone: (250) 949-8625
Administration Fax: (250) 949-7105

Nov 29, 2019

To Whom it May Concern

The Wuikinuxv Nation would like to work with Alyssa Ball on a archeological project involving eulachon.
We would like to do field work on Wuikinuxv lands and archaeological materials, specifically to:

1) Perform small scale archaeological sampling along the Wanukv (Wannock) river bank and at Kilbella with a proposed date for fieldwork in early January (date TBD). These samples will later be screened and any fish scales recovered will be identified and analysed at UVic.

We give permission to access, sort, and analyse any fish scales or otoliths that may be preserved

- in historical sediment samples from projects conducted in the 1970s that are currently in storage at the Royal BC Museum in Victoria (sites EkSp-1 and EkSp-13).
- taken under permit 2005-204/206 from the village sites of Katit (EkSt-1) and Cockmi (EjSw-1) (see Figure in attached proposal)

Alyssa recognizes that as a part of this work she recognizes that the community reserves the right to determine a suitable permanent repository for archaeological fish scales recovered through this analysis, and to control the use and publication of data related to this collaborative project and Alyssa's MA thesis.

Further details regarding research and data sharing agreements will be laid out in a research protocol between the Wuikinuxv Stewardship Committee, Alyssa Ball, and her supervisor Iain McKechnie. This research protocol could be based on the existing research protocol agreement for the Wuikinuxv Bear Project to ensure community interests and goals related to this proposed research are met.

[redacted]
Chief Councillor
Wuikinuxv Nation