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The Rise of Vancouver and the Collapse of Forage Fish: A Story of Urbanization and the Destruction of an Aquatic Ecosystem on the Salish Sea (1885–1920 CE)

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Abstract
Since its establishment as a Euro-Canadian settlement in the mid-nineteenth century, the marine ecology surrounding Vancouver in British Columbia, Canada, has been negatively impacted by urban development, habitat destruction, poor fisheries practices, and pollution. Focussing on forage fish – herring, smelt, and eulachon – we present the results of an extensive meta-analysis including an archaeological, ethnohistoric, and scientific/regulatory literature review of Indigenous and commercial fisheries' harvesting records to track the early historic collapse of these fisheries from about 1885–1920 CE. We identify significant reductions in the major forage fish fisheries around Vancouver within decades of the initial Euro-Canadian settlement. These severe negative effects occurred long before scientific description of local ecosystems had begun, and the magnitude of these effects went generally unrecognized and/or are poorly understood. We argue that this is a case of the shifting baseline syndrome (SBS): each generation of researchers mistakenly assumes that modern ecological conditions they encounter approximate their natural pre-contact state.

Keywords Historical ecology · Forage fish · Shifting baselines · Fisheries · Vancouver · British Columbia · Canada

Introduction

As elsewhere, Canadian fishery management strategies are based on the maintenance of an escapement population that ensures stock repopulation and the harvest of the surplus fish beyond that limit (Fisheries and Oceans Canada, 2006; Garcia et al., 2009:308; Pauly, 2019:90–91). In most cases, the escapement populations and harvest targets are based on stock assessments that were established in the latter half of the twentieth century and are taken as historical baselines. A major problem with this approach is that these baselines are used to guide management strategies when they represent already severely impacted ecosystems. Thus, this management regime, at best, perpetuates this degraded ecosystem state.

Situated on the eastern margin of the Salish Sea, the city of Vancouver is known for its surrounding beauty and environment. The marine and riverine waterways support substantial fisheries, rich and diverse local fisheries, and many other abundant seafoods. From the perspective of the Tsleil-Waututh Nation (TWN) and other Coast Salish peoples with histories spanning many thousands of years, the modern local marine and riverine environments are a shadow of their former abundance. We argue that while these perceptions are pervasive, historical and ongoing negative impacts on local marine resources remain severe and greatly underestimated.

We present historical-ecological research on three species of forage fish – herring (Pacific herring, *Clupea pallasii*), smelt (surf smelt, *Hypomesus pretiosus*), and eulachon (*Thaleichthys pacificus*) – that identifies progressive collapses of each of these fisheries in the order of 99% within a few decades of European colonization of the Vancouver area. These collapses occurred more than 60 years before scientific documentation and research into the marine ecosystems of this region began, and it is these severely depressed

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modern populations that are used to inform current fisheries strategies. Modern First Nations are continuously consulted by various levels of government regarding acceptable levels of project-related impacts on local ecosystems in their territories. Additional minor ecological impacts characterized as "not significant" in relation to modern ecological baselines appear to Indigenous peoples as highly significant compared to their ancestors' lived experiences and oral histories, wherein such species were described as prolific. For example, it is relatively straightforward for the Canadian Environmental Assessment process to identify "no impacts" of a particular project on Coast Salish eulachon fisheries because such fisheries have not occurred in generations.

We argue that all the scientific and regulatory literature regarding these forage fish in the Vancouver area since about 1920 CE has documented populations already within the critical zone defined by Fisheries and Oceans Canada as resulting from "serious harm, but due to over-fishing, other human-induced mortality, or changes in population dynamics not related to fishing" (Fisheries and Oceans Canada, 2006:4). Species identified as being within the critical zone are usually precluded from additional harvests to allow populations to recover (Fig. 1). Our primary focus is these historical changes to forage fish abundance from about 1885–1920 CE, well-prior to scientific/ecological baseline studies.

The scientific baseline of the marine ecology of the waters surrounding Vancouver developed in the latter half of the twentieth century does not describe the environment prior to impacts from commercial fisheries, pollution, and habitat loss, but rather a severely depressed ecological system with key formerly hyper-abundant species (e.g., herring, smelt, and eulachon) reduced by more than 99% from their nineteenth-century levels. This has resulted in each generation of researchers assuming that the conditions they observe are the historical baseline, known as shifting baseline syndrome (SBS) (Baum & Ransom, 2004; Dulvy & Kindsvater, 2017; Pauly, 1995, 2019; Pinnegar & Engelhard, 2008). In Canada, this historically distorted policymaking perspective of both federal and provincial governments leads to the mismanagement of both current and future fisheries (Sumaila & Pauly, 2011).

The recognition and concern regarding shifting baselines come from an understanding that many of the world's resources, including those from the global oceans, are severely depleted because of human activity (Pauly, 1995, 2019), and historical baselines provide more favourable conditions with which to establish management and conservation goals. Pauly (1995:430) argues that because researchers accept "as a baseline the stock size and species composition that occurred at the beginning of their careers," it may be impossible to fully understand what has changed in an ecosystem without considering the deep history of the ecosystem (Vellend et al., 2013). Regarding harvesting by Indigenous peoples, SBS diminishes the profound changes experienced across generations and normalizes impaired ecosystem states. To conserve resources and ecosystems over the long term, it is more favourable to conserve them at or restore them to conditions that are sustainable

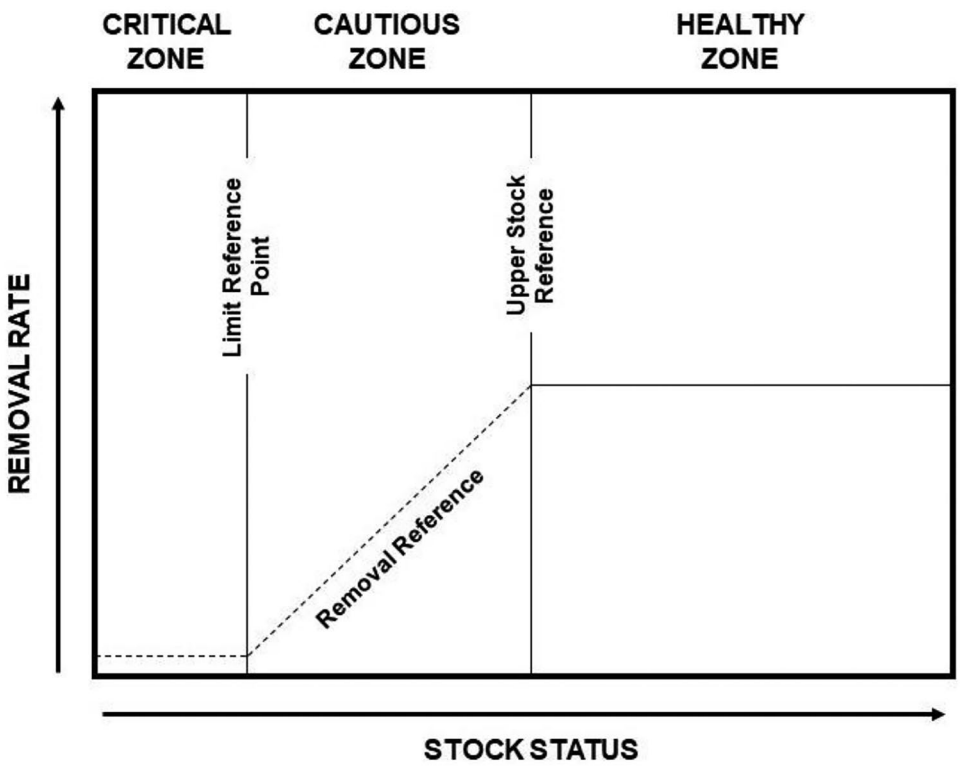

Fig. 1 Diagram summarizing Canadian fisheries management framework with a precautionary approach (Fisheries and Oceans Canada, 2006:4)

and healthy both for individual species and for whole ecosystems (Rick & Lockwood, 2012:46). Historical baselines can be estimated using archaeological, historical, archival, and ethnographic data. They can help researchers and managers understand the history of ecological changes driven by both natural and anthropogenic forces (Rick & Lockwood, 2012:46).

Historical ecology is a cross-disciplinary research program spanning foci that both include and exclude human impacts and behaviour that seeks to read the history "inscribed, sometimes subtly" on the world (Balée, 2006:77). Historical ecologists bring a range of disciplinary perspectives to the study of the impacts of human behaviour on the land and waterscapes. Marine historical ecology focuses these efforts on the marine environment and the ocean's ecological history (Lotze et al., 2011:137) to bring the understanding of past impacts to assess the current state of the ocean and plan for the future.

In an effort to overcome this problem of shifting ecological baselines, and to gain a clearer understanding of the historical-ecological changes to forage fish since pre-contact times (pre-1791/1792 CE), we present the results of a meta-analysis consisting of an extensive review of relevant archaeological, historical, ethnographic, cartographic, and scientific/regulatory data, and oral history, Indigenous place names, and traditional use study (TUS) information for references to harvesting herring, smelt, and eulachon. Following Pauly et al. (1998) "Back to the Future Approach," we present a range of ethnohistorical and scientific/regulatory information to track the trajectory of change in abundance of these taxa through the early historic period of Vancouver's colonization. Identifying the major historical reductions in taxa abundance provides insight into past ecological conditions of this area prior to the onset of colonization and industrialized fishing practices. The major theme is the near-total collapse, over a few decades of Euro-Canadian colonization between 1885 CE and about 1920 CE, of an area very rich in fish stocks that had supported thousands of Indigenous Coast Salish people for millennia. We do not attempt a quantitative assessment of former forage fish populations but rather highlight critical qualitative and quantitative descriptors of these fish to estimate the scale of their depletion in the historic period.

Cultural and Historical Background

Forage fish (herring, smelt, and eulachon) are keystone species in local food chains (Thornton, 2015:214). Their importance to pre-contact Coast Salish subsistence (and trade) has become increasingly apparent to regional archaeologists who have traditionally focused on salmonid fisheries (see Coupland, 1991; Lepofsky et al., 2007; Lepofsky & Caldwell, 2013; McKechnie et al., 2014). Consequently, reductions in their abundance result in a corresponding decrease in species that prey upon them, such as waterfowl, coho (*Oncorhynchus kisutch*) and Chinook salmon (*Oncorhynchus tshawytscha*), seals (Harbour seal, *Phoca vitulina*), sea lions (Steller sea lion, *Eumetopias jubatus*), dogfish (*Squalus acanthias*), and sturgeon (White sturgeon, *Acipenser transmontanus*), thereby compounding the impacts on Coast Salish people. From the perspective of the TWN, a Coast Salish group whose territory centers on Burrard Inlet (including the Port of Vancouver), colonial development and policies have displaced approximately five generations from most of their fishing and harvesting areas, and concurrently caused the collapse of their subsistence economy that supported local Indigenous cultures here for millennia (Fig. 2).

Before European settlement of Vancouver, the region, a significant point of land surrounded by the sea and bisected by the Fraser River (Fig. 2), supported dense populations of Indigenous Coast Salish peoples. Burrard Inlet and the Salish Sea supported rich populations of marine fish, marine mammals, and shellfish, while rivers and lakes supported a large range of local and anadromous species. Archaeological research indicates that Ancestral Coast Salish peoples lived here in large, relatively permanent settlements near the shore and subsisted primarily on local marine and riverine resources, beginning at least by about 1500 BCE (Borden, 1970; Burley, 1980; Carlson et al., 2017; Charlton, 1980; Clark, 2013; Coupland, 1991; Lepofsky et al., 2007; Matson & Coupland, 1995; Matson, 1976a; Morin et al., 2018). Except for an apparent increase in the use of herring around ~ 500 BCE and the later (~ 1200 CE) dominance of herring at many sites (Butler & Campbell, 2004:364–365, 374), the following ~ 3500 years of ancestral Coast Salish settlement and resource use in this region are generally dominated by continuity, lacking pronounced cultural breaks or shifts in subsistence strategies (Clark, 2013; Morin et al., 2018, 2021a).

The Northwest Coast of North America was explored relatively late by Europeans (1770s – 1790s CE) and then settled (1840s-1860s CE) as European powers scrambled to assert their authority over this distant region. Early European exploration focussed on a search for the fabled Northwest Passage but rapidly reoriented towards trading in sea otter and later beaver pelts, from which traders reaped enormous profits in China and Europe (Clayton, 2000; Fisher, 1992). The Spanish were the first Europeans to visit the Vancouver area in 1791 CE. The following year Spanish and British expeditions further explored the region, including what would become known as Burrard Inlet and the Port of Vancouver (Lamb, 1984:594; Wagner, 1933:33, 186, 212). The establishment of Fort Langley (1827 CE) and Fort Victoria (1841 CE) partially reoriented Indigenous exchange relationships and introduced potato cultivation to the Coast Salish but had little impact on the marine and riverine ecology of the region (Harris, 1997; MacLachlan, 1998; Suttles, 1951, 1998). Actual colonization of the region by substantial numbers of Euro-Canadians followed First Contact by ~ 70–100 years, slowed by logistical difficulties and lack of good agricultural land (Harris, 1997).

Colonization of the Vancouver area was stimulated by the discovery of gold on the Fraser River in 1858 CE

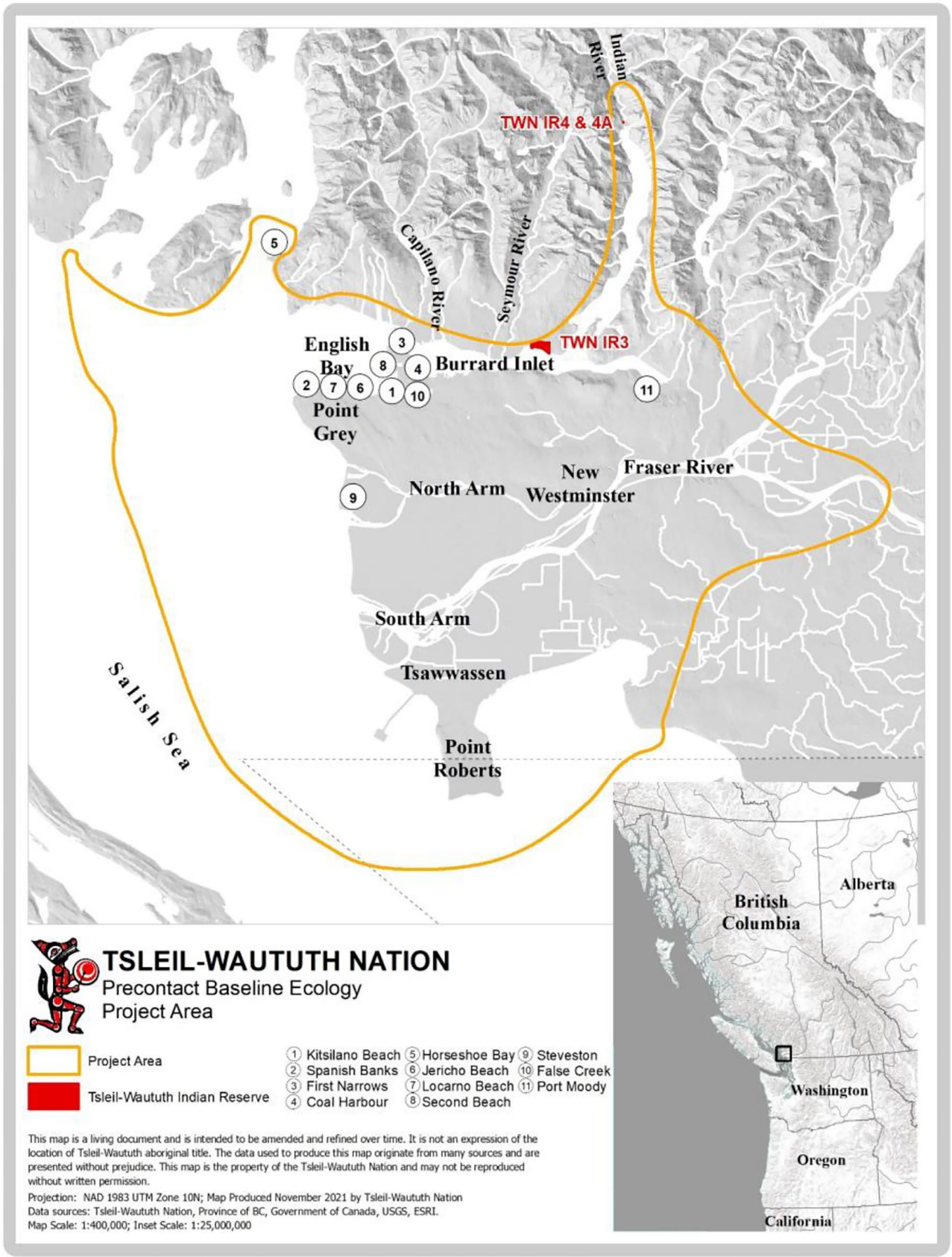

Fig. 2 The project study area

(Barman, 1991:67; Harris, 1997:80), and prospectors were quickly followed by the arrival of several hundred settlers, the establishment of sawmills, and then salmon canneries (Harris, 1997). The earliest colonial settlement in what would become Vancouver was Granville, which had only 50 colonial residents (i.e., non-Indigenous people) in 1870 CE, growing to 300 a decade later (Wynn, 1992:69). The natural harbour of Burrard Inlet was strategically important for supplying the nearby newly established colonial capital at New Westminster, and for loading lumber and spars to be shipped around the Pacific (Armitage, 2001:38–54).

Confederation of the colony of British Columbia with Canada (1871 CE) and the arrival of the transcontinental Canadian Pacific Railroad at Burrard Inlet in 1886 CE changed the trajectory of Vancouver's growth, and by 1911 CE, 120,000 new colonists had arrived (Wynn, 1992:69). During this period, the Port of Vancouver in Burrard Inlet developed into a significant international terminus. With new canning technology and ready access to a global market, many salmon canneries were established on the lower reaches of the Fraser River (Harris, 1997:93–95). At the greatest density, around 1900 CE, there were about 20 canneries along a few kilometers of the Lower Fraser River (Harris, 1992:61; Newell, 1993:16). Colonial fishing operations were exploiting local fisheries on an industrial scale that had supported significant Indigenous Coast Salish populations for millennia (Matson & Coupland, 1995). Intensive industrial development, including shipbuilding and petrochemical industries, grew significantly during World War II (1939–1945 CE) (Oke et al., 1992) and continued throughout the twentieth century. With a population of around 2.5 million in 2020 CE, metro Vancouver is still rapidly growing. The Port of Vancouver is the busiest in Canada, rapidly expanding, forecasting a 33% increase in vessel calls from 2016–2026 (https://www.portvancouver.com/about-us/faq/vessel-numbers-now-and-into-the-future/), not including ferries and recreational vessels.

We investigate the rapid, industrially-fueled growth in the area between about 1885 CE and 1920 CE, when there were few to no environmental regulations or restrictions on fisheries, as a critical period of ecological change that witnessed the collapse of several major forage fish fisheries. Further, we demonstrate that this early historical change renders related ecological baselines established in the later twentieth century misleading and inaccurate representations of the historical abundance of these species in the region.

Methods

We undertook an extensive meta-analysis of the regional ethnohistoric and scientific/regulatory literature of relevant sources within a study area defined around the Vancouver area (Supplemental Table 1). Temporally, these materials span from millennia prior to First Contact (e.g., archaeological and oral history information) to around the middle of the twentieth century (e.g., scientific and fisheries reports) and include other more recent historical summaries of twentieth-century fisheries data (e.g., Therriault et al., 2002).

Our study area in the Vancouver region was defined by both geographic focus on Burrard Inlet and cultural focus on areas of traditional TWN resource harvesting places and comprised three study sites: Burrard Inlet (and waters draining therein), the Lower Fraser River and the Salish Sea adjacent to the latter (Fig. 2). These study sites are interlinked, but there are/were considerable differences in the local resource structure in each. Burrard Inlet is a narrow fjord bounded by steep mountains to the north, low topography to the south, and connecting to the larger Salish Sea to the west. The Lower Fraser River, including the North, Middle, and South Arms, downstream from the Coquitlam River, primarily occupies a broad floodplain that, prior to diking in the late nineteenth and early twentieth centuries, would have experienced significant seasonal inundations with the spring freshet. The adjacent Eastern Salish Sea consists of a marine area with significant freshwater influx extending about 10 km west from Burrard Inlet and the mouth of the Fraser River, and is inclusive of Boundary Bay (Fig. 2).

The bulk of our research focused on forage fish abundance in the late nineteenth and early twentieth centuries because initial evidence indicated that the most significant changes in these taxa occurred early in the historic period. More specifically, beginning with pre-contact ecological baseline conditions as represented in the archaeological record, we identify and assess changes in the abundance of herring, smelt and eulachon, and where possible, anthropogenic impacts to those taxa. To understand the trajectory of ecological change from pre-contact times in we include a wide range of archaeological, historical, cartographic, scientific, ethnographic, oral history, Indigenous place names, and TWN TUS data.

We selected the range and types of documentary sources largely based on previous historical-ecological research that utilized textual and historical materials (e.g., Armstrong et al., 2017; Edmonds, 2001; Fogerty, 2001; Pauly et al., 1998, Pauly, 2019:82; Reithmaier, 2001; Swetnam et al., 1999; Vellend et al., 2013), to which we added Indigenous place names and TWN TUS information. We reviewed a range of materials for spatial and temporal coverage of the study area to highlight important and distinct information and dampen biases inherent in each type of reference.

The zooarchaeological data derived from excavated archaeological sites in the Vancouver area provide a detailed record of ancestral Coast Salish fisheries, including harvesting herring, smelt, and eulachon, over 3500 years prior to Euro-Canadian colonization. While there are many

archaeological sites of pre-contact Coast Salish settlements in the study area, only a few have been excavated and have well-reported zooarchaeological assemblages. We selected eight sites from across the study area to illustrate the range of fish that supported ancestral Coast Salish people for millennia:

- Belcarra Park/təmtəmíxʷtən (DhRr-6) (Pierson, 2011),
- Strathcona Park/Say-umiton (DhRr-18) (Lepofsky et al., 2007; Trost, 2005),
- Noon's Creek/Say-mah-mit (DhRq-1) (Pierson, 2011),
- Point Grey/ʔəlqsən (DhRt-5) (Coupland, 1991),
- Locarno Beach/qʷəʔápəłp (DhRt-6) (Madrone, 2012),
- Tsawwassen/stl'álep (DgRs-2) (Arcas Consulting Archaeologists Ltd., 1999),
- Beach Grove/Taa-na-cum (DgRs-1) (Arcas Consulting Archaeologists Ltd., 1995), and
- Glenrose/qʷəqʷəʔápəłp (DgRn-6) (Casteel, 1976; Matson, 1976a, b) (Table 1).

Zooarchaeological samples from these sites date from about 1500 BCE to 1600 CE (Table 1). The sites have been interpreted variably as year-round settlements (Morin et al., 2021a; Trost, 2005), spring settlements (Coupland, 1991; Williams, 2013), or as fall-winter-spring settlements (Matson, 1976b:304). The sites are unevenly located across our three study sites (Burrard Inlet, Eastern Salish Sea, and Lower Fraser River), but their zooarchaeological assemblages undoubtedly reflect local abundance of species that were important to Coast Salish subsistence (Fig. 3). Forage fish, especially eulachon, are probably proportionally underrepresented in zooarchaeological assemblages due to their delicate bones compared to their actual importance to Coast Salish peoples' subsistence in pre-contact times.

Oral history sources are Indigenous narratives describing the actions of past ancestors or supernatural beings, usually set in the centuries or millennia prior to First Contact that has been recorded from Indigenous people by anthropologists and others. All recorded and publicly available Indigenous oral histories within the study area were reviewed for relevant information (e.g., Bouchard & Kennedy, 1986, 2006; Carter, 1966, 1972; George, 1930, 1997; Matthews, 1955; Johnson, 2014; MacDonald et al., 1998; Maud, 1978a, b; Mortimer & George, 1981; Rozen, 1985; Suttles, 2004; Wells, 1966, 1987).

Indigenous place names include descriptions and translations of Indigenous place names. We reviewed all recorded and publicly available Indigenous place names within the study area for relevant information (e.g., MacDonald, 1992; Matthews, 1955; Maud, 1978a; McHalsie, 2001; Morin, 2015:82; Rozen, 1985; Suttles, 1996, 2004).

We reviewed a wide range of sources for relevant historical-ecological information on forage fish (e.g., Armitage, 2001; Barett-Lennard, 1969; Barman, 2005; Canada, 1916; Cole & Lockner, 1989; Drew, 2017; Duthie, 1909; Elliot, 1912; Emmerson, 1865; Grant, 1877; Harris, 1978; Lamb, 1960, 1984; Lord,

Table 1 The age of zooarchaeological samples from selected archaeological sites

Site	Location	Age of Zooarchaeological Samples (BCE/CE)	Reference
Belcarra/ təmtəmíxʷtən (DhRr-6)	Burrard Inlet	750 BCE – 1600 CE	Morin et al. (2018), Pierson (2011)
Strathcona/ Say-umiton (DhRr-18)	Burrard Inlet	750 – 1600 CE	Morin et al. (2018), Lepofsky et al. (2007)
Noon's Creek/ Say-mah-mit (DhRq-1)	Burrard Inlet	50 BCE – 600 CE	Morin et al. (2018), Pierson (2011)
Locarno Beach/ qʷəʔápəłp (DhRt-6)	Burrard Inlet	1400 BCE – 400 CE	Williams (2013)
Point Grey/ ʔəlqsən (DhRt-5)	Eastern Salish Sea	300 BCE – 200 CE	Coupland (1991)
Tsawwassen/ Stl'álep (DgRs-2)	Eastern Salish Sea	500 – 800 CE	Arcas Consulting Archaeologists Ltd. (1999)
Beach Grove/ Taa-na-cum (DgRs-1)	Eastern Salish Sea	1500 BCE – 1200 BCE	Arcas Consulting Archaeologists Ltd. (1995)
Glenrose/ qʷəqʷəʔápəłp (DgRn-6)	Lower Fraser River	350 BCE – 50 BCE	Matson (1976a, b)

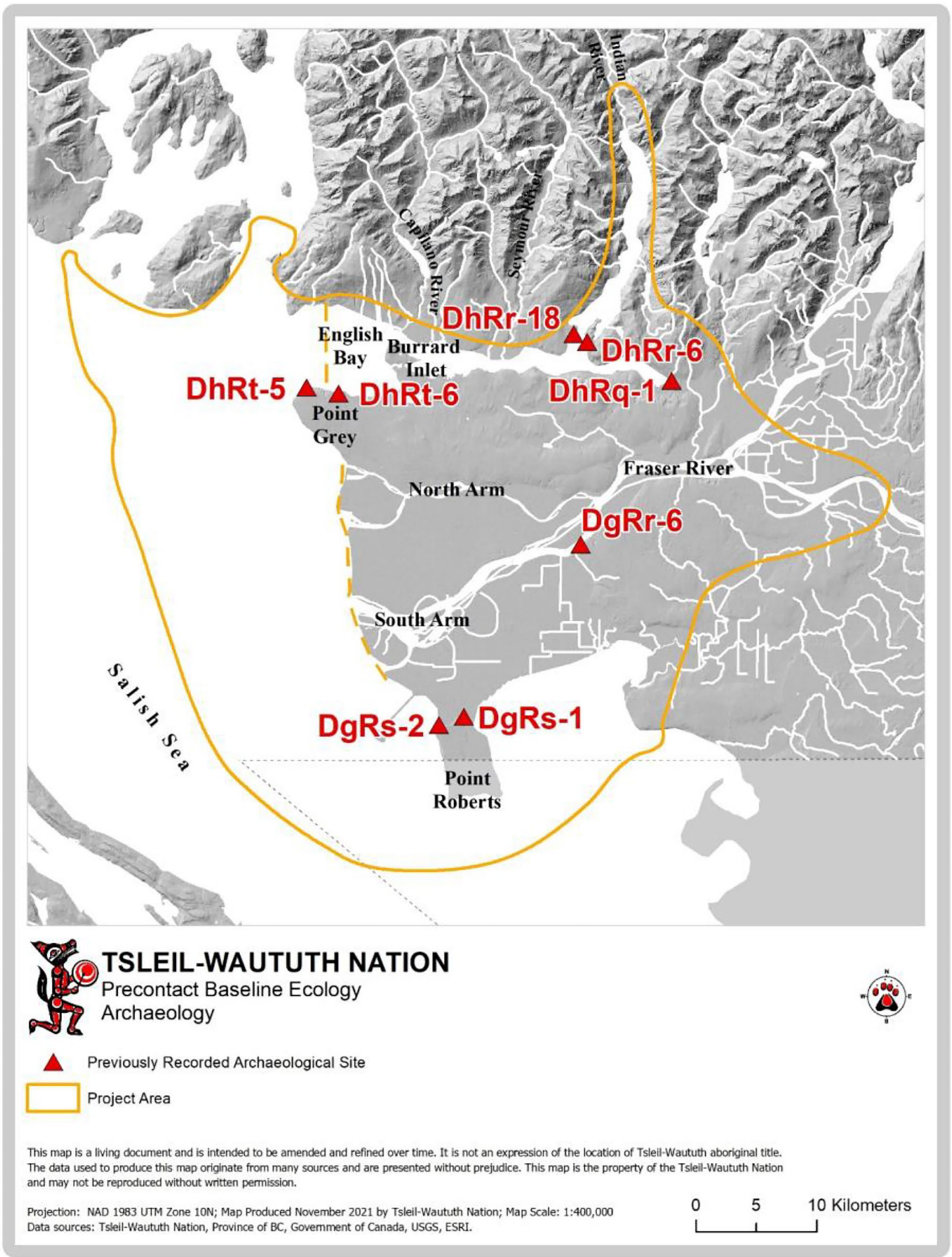

Fig. 3 Map of archaeological sites discussed in text

1866; MacDonald et al., 1998; MacLachlan, 1998; Matthews, 1932, 1955; Mayne, 1862; Moberly, 1885; Newcomb, 1923; Pidcock, 1862; Puget, 1792; Safarik & Safarik, 2012; Simpson, 1847; Vancouver, 1798; Wagner, 1933; Walden, 1947; Willis, 1861). Brief encounters First Contact between Coast Salish people and Europeans comprise the earliest historical records in the study area: in 1791 CE at Point Roberts (Wagner, 1933:187), in 1792 CE in Burrard Inlet (Lamb, 1984:581; Vancouver, 1798:300), and 1808 CE on the Lower Fraser River (Lamb, 1960:111). In 1827 CE, Fort Langley's founding launched a continuous Euro-Canadian presence in the study area with associated textual records left by Hudson's Bay Company (HBC) officials (MacLachlan, 1998). Materials described here as historical sources include published and unpublished records of first-hand (primary) observations and depictions of the ecology of the study area and (secondary) historic sources with many first-hand observations.

Historical cartographic sources include published and unpublished maps of the study area produced since 1791 CE. Modern place names in cartographic sources occasionally reflect locally abundant species or other relevant ecological information. The major strength of cartographic sources is that the name or description is likely accurately located, and there is no reason to suspect the information is biased. For example, Sturgeon Bank, located off the mouth of the Fraser River, was so named by Captain Vancouver because "…of our having purchased of the natives some excellent fish of that kind, weighing from fourteen to two hundred pounds each" (Akrigg & Akrigg, 1973:165; Vancouver, 1798:314).

Scientific and regulatory sources include reports, publications, notes, and data collected for scientific investigation or regulatory management of fisheries. There is extensive interaction between scientific and regulatory sources, as newly founded regulatory bodies trained thousands of kilometres away attempted to manage the marine fisheries of the study area (e.g., Thompson, 1917). Documentary evidence associated with commercial fisheries management in the study area begins in the early 1880s CE and includes landings of commercially important species, the number of boats involved in local fisheries, the value of their nets, and, in some cases, estimates of local settler harvests (e.g., Department of Fisheries, 1885, 1886, 1887, 1888, 1889). References derived from scientific investigation begin around 1910 CE and include descriptions of local habitat, local fisheries, and prospects for commercial expansion (e.g., Thompson, 1917). We reviewed scientific/regulatory materials mainly dated prior to 1930 CE, and only a smattering of scientific/regulatory materials dating to more recent times (mainly historical reviews or summaries) (e.g., Argue et al., 1990; British Columbia, 1908, 1910, 1915, 1918; Department of Fisheries, 1885, 1886, 1887, 1888, 1889, 1890, 1891, 1893, 1894; Department of Marine and Fisheries, 1895, 1897, 1899, 1900, 1901; Department of Environment, 1971; Fisheries Branch, 1917; Levy, 1985; Thompson, 1913, 1917).

Ethnographic sources include descriptions of historical Indigenous lifeways and cultures, usually recorded by an anthropologist. The earliest ethnographic sources in the area date to the late nineteenth century, but most ethnographic sources date to after about 1930 CE. Ethnographic documentation of Coast Salish lifeways (published books, reports, papers, field notes, and interviews with Indigenous informants) often included information relevant to the marine and riverine ecology of the study area, such as descriptions of the range of prey species, locations of harvested species, and the range of tools and traps to harvest them. We reviewed a wide range of ethnographic materials for relevant historical ecological information on forage fish (e.g., Barnett, 1935, 1936, 1955; Bouchard & Kennedy, 1976, 1986; Duff, 1950; George & Joe, 1983; Jenness, 1955; Matthews, 1955; Maud, 1978a, b; Suttles, N.d., 1998).

TUS and associated documents have been undertaken to document ongoing Indigenous land use and resource-harvesting activities. TUS became common in British Columbia in the late 1990s in relation to the Crown consultation process with First Nations groups. The TWN TUS data (we did not approach groups other than TWN to share their TUS data for this study) were collected from about 1998 to 2011 CE, and largely describe activities undertaken by TWN people after 1950 CE when more than half a million people already lived the Vancouver area (Tsleil-Waututh Nation, 1998, 2000, 2011). Other ethnographic or historical documents often contain TUS information (e.g., Barnett, 1955; Bouchard & Kennedy, 1986; Matthews, 1955; Rozen, 1985; Suttles, 2004).

To allow for ready quantification of observed resources by period and GIS mapping of the distribution (spatial and temporal) of observed references, we entered information into a spreadsheet to record the reference, the resource, the verbatim relevant citation with the associated page number, the identity of the research participant, the time frame that the informant was describing, the location of the observed resource, the UTM coordinates for each observed reference, and any additional notes regarding negative impacts to the resource in question. The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request (data availability statement, DAS).

Results

Starting in pre-contact times, forage fish appear to have been very abundant and comprised a significant portion of past Coast Salish diets, in many cases rivalling salmon. The documentary evidence from the early period of colonization of the Vancouver area, from around 1885 to 1915 CE, similarly identifies very rich forage fisheries, followed by sequential of collapses of taxa, beginning with herring in

Burrard Inlet in 1885 CE, eulachon in Fraser River by 1899 CE, and smelt in the Eastern Salish Sea in 1912 CE. In each of these cases, the reduction in taxa abundance approaches or exceeds 99% and occurred at least 50 years prior to local baseline ecological studies. These fish, while formerly central to ancestral TWN subsistence, are nearly absent in the TWN TUS that describe harvesting activities in the second half of the twentieth century. Below, we summarize the fish remains recovered from the archaeological sites to characterize both traditional local Coast Salish subsistence and local ecological abundance, then describe the specific literature that tracks the historical trajectory of herring, smelt, and eulachon fisheries.

Pre-Contact Coast Salish Forage Fish Fisheries

Archaeological research in the Coast Salish region indicates heavy reliance on marine/riverine resources began at least by about 1500 BCE, and supported large, relatively permanent settlements of ancestral Coast Salish people (Borden, 1970; Burley, 1980; Carlson et al., 2017; Charlton, 1980; Clark, 2013; Coupland, 1991; Lepofsky et al., 2007; Matson & Coupland, 1995; Matson, 1976b; Morin et al., 2018). Evidence of pre-contact ancestral Coast Salish subsistence is robust and indicates that marine or anadromous fish, especially salmon, forage fish, and flatfish, were by far the most important resources, with local variation depending on ecological conditions (see e.g., Carlson et al., 2017; Casteel, 1976; Chisholm et al., 1983; Coupland, 1991; Ewonus et al., 2011; Grier et al., 2013; Hanson, 1991; Lepofsky et al., 2007; Matson, 1992; Morin et al., 2021a, b; Pierson, 2011; Schwarcz et al., 2014). The zooarchaeological data from the eight archaeological sites provide a detailed record of ancestral Coast Salish fisheries and insight into the pre-contact marine ecological conditions of the region.

Fish remains recovered from the archaeological sites indicate that some combination of forage fish and salmon comprise the two most abundant taxa in all eight sites and, thus, a large portion of pre-contact Coast Salish diets. Herring is the most abundant taxon in five of the sites and is only present as a trace at Glenrose, located ~ 20 km up the Fraser River. Salmon is the most abundant taxon in only two sites (Belcarra and Glenrose), and smelt is the most abundant taxon at Locarno Beach (Table 2). Another forage fish completely absent from the ethnohistoric and scientific literature review, Northern Anchovy (*Engraulis mordax*), is present in low-to-moderate quantities in five of the sites, especially at sites in Burrard Inlet. Other fish, including rockfish, flatfish, cod, and sturgeon, comprise a small proportion of zooarchaeological assemblages (Table 2, Fig. 4).

In the Burrard Inlet study site, herring, smelt, and anchovy comprise large proportions of zooarchaeological assemblages, and eulachon is present only in low frequencies (Lepofsky et al., 2007:202; Madrone, 2012:44; Pierson, 2011:25–29) (Table 2). This trend varies considerably among sites, however, and smelt is abundant at only a single site (Locarno Beach), where it comprises most of the fish (Madrone, 2012:44) (Table 2). This pattern largely reflects the various local spawning places of these forage fish across local beaches, and in the case of eulachon, up the rivers in Burrard Inlet. Alternative explanations of this heterogenous pattern of pre-contact forage fish use, such as changing dietary preferences and shifts in harvesting technology, are not convincing.

In the Eastern Salish Sea study site, herring are the most abundant taxon in all the zooarchaeological assemblages (Coupland, 1991, Arcas Consulting Archaeologists Ltd., 1995, 1999) (Table 2). Smelt and eulachon are represented in very low frequencies, and anchovy is reported in low frequencies from only one site (Point Grey) (Table 2). The common dominance of herring is interpreted as reflecting the local abundance of spawning herring in those areas.

The zooarchaeological assemblage at the single archaeological site in the Lower Fraser study site, Glenrose, is dominated by salmon (96.9%), with only a trace of herring (0.3%) and no other reported forage fish. This scarcity of all forage fish, and all other fish here, probably reflects its location on the south bank of the Fraser River and a focus on harvesting salmon there.

This summary of pre-contact zooarchaeological assemblages identifies the importance of forage fish to local pre-contact Coast Salish subsistence. Collectively, these forage fish likely rivalled salmonids in importance to past diets here. Of these forage fish, herring were the most abundant and the most regularly harvested, while a relative emphasis on the other species – smelt, eulachon, and anchovy was much more variable. This pattern is not unexpected, as the importance of forage fish to pre-contact Coast Salish and other Northwest Coast peoples' subsistence has become increasingly recognized by archaeologists (Butler & Campbell, 2004; Lepofsky et al., 2007; McKechnie et al., 2014). Given historical records of abundance, eulachon was expected to occur in greater frequencies in these zooarchaeological assemblages than observed, and, given its absence in the ethnohistoric and regulatory literature, the relative abundance of anchovy was unanticipated. Having provided this pre-contact background of Coast Salish forage fish fisheries in the study area, the following sections shift to a discussion of the relevant ethnohistoric and regulatory literature describing the history of the collapse of herring, smelt, and eulachon stocks and fisheries.

Table 2 Comparison of regional archaeological sites by fish fauna

Archaeological Site	Salmon % of Fish NISP (NISP)	Herring % of Fish NISP (NISP)	Eulachon % of Fish NISP (NISP)	Anchovy % of Fish NISP (NISP)	Smelt % of Fish NISP (NISP)	Other Fish % Fish NISP (NISP)	Total Fish NISP	Reference
Burrard Inlet								
Belcarra/ təmtəmíxʷtən (DhRr-6)	39.2% (856)	30.8% (613)	0.2% (5)	17.3% (378)	0.3% (6)	12.2% (266)	2183	Pierson (2011)
Strathcona/ Say-umiton (DhRr-18)	17.3% (813)	55.4% (2656)	1.9% (91)	15.1% (724)	1.6% (78)	8.72% (417)	4797	Lepofsky et al. (2007)
Noon's Creek/ Say-mah-mit (DhRq-1)	28.8% (602)	40.6% (848)	10.8% (226)	12.5% (261)	1.0% (20)	6.4% (133)	2090	Pierson (2011) (Column sample)
Locarno Beach/ qʷəʔápəɬp (DhRt-6)	13.9% (86)	8.1% (50)	0% (0)	2.1% (13)	65.4% (404)	10.5% (65)	618	Madrone (2012) (East column sample)
East Salish Sea								
Point Grey/ ʔəlqsən (DhRt-5)	0.8% (45)	82.0% (4451)	0.6% (35)	11.8% (643)	1.6% (89)	3.02% (166)	5429	Coupland (1991) (Column sample)
Tsawwassen/ Stl'álep (DgRs-2)	27% (n/a)	59% (n/a)	0% (0)	0% (0)	0% (0)	14% (n/a)	(n/a)	Arcas Consulting Archaeologists Ltd. (1999) (Tsawwassen VI)
Beach Grove/ Taa-na-cum (DgRs-1)	27.9% (780)	35.9% (1005)	0.03% (1)	0% (0)	0% (0)	36.1% (1011)	2797	Arcas Consulting Archaeologists Ltd. (1995) (Blocks I, II, III, and IV)
Fraser River								
Glenrose/ qʷəqʷəʔápəɬp (DgRn-6)	96.6% (570)	0.3% (2)	0.0% (0)	0.0% (0)	0.0% (0)	3.1% (18)	590	Casteel (1976) (Marpole component only, Unit 1)

Herring

References to herring were relatively infrequent in the literature (n = 60), and most occur in the early historical and regulatory literature (95%) and only rarely in TWN TUS data (5%). Herring were the earliest forage fish to be severely negatively impacted. However, because the local economic value of herring to the settler economy was never great, this collapse has been far less recognized than contemporaneous collapses of Fraser River salmon stocks. The historical record indicates an initial collapse in Burrard Inlet east of First Narrows, then a progressive shift westward, followed by sequential collapses in English Bay, then west of Point Grey. Several historical references describe a rich herring fishery within Inner Burrard Inlet, Vancouver Harbour, and Coal Harbour (Barman, 2005:62, 78; Department of Fisheries, 1888:246; Matthews, 1955:52, 143). The herring fishery east of First Narrows had collapsed entirely by 1885 CE (Department of Fisheries, 1885:259, 1888:246; Matthews, 1955:239). In eastern Burrard Inlet and the eastern Salish Sea off Point Grey, herring populations were also seasonally abundant, but herring fisheries there had also failed by about 1915 CE (Fisheries Branch, 1917:261).

In the later half of the nineteenth century, Indigenous people harvested herring with purse seines (Armitage, 2001:93; Matthews, 1933:143), although the volumes are unknown. Within about 15 years of Euro-Canadian settlement on Burrard Inlet in the late nineteenth century, the preferred method for fishing herring was with dynamite. In 1875 CE, George Dawson (a geologist) recorded the following observations on a wharf Vancouver Harbour:

> Witnessed the method of killing fish by dynamite. Cartridge fitted with fuse and after being fired thrown off wharf. Explosion dull heavy sound, but not much commotion of water, immediately followed by the appearance of thousands of herring and other small fish jump-

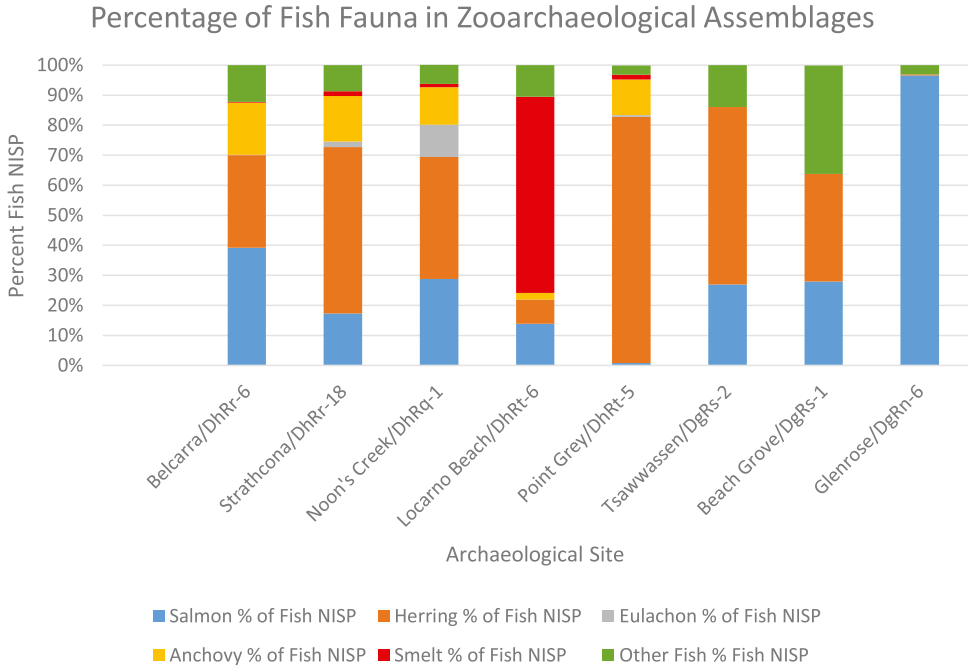

Fig. 4 Relative proportion of fish fauna by the archaeological site

> ing above the surface. Not in the immediate vicinity of the discharge but in a circle surrounding it, and as if trying to escape from it. In a few minutes hundreds of dead fish begin to slowly rise to the surface and can be secured from a boat. (Cole & Lockner, 1989:116)

Fishing with dynamite was not the only stressor on herring in Burrard Inlet. The earliest record of commercial herring harvests in the area dates to 1877 CE in New Westminster (Carrothers, 1941:109; Ketchen et al., 1983:1099). Around 1881 CE, herring were being harvested on a large scale in Burrard Inlet, although exact volumes are unknown, and rendered into oil used for lubricating skid rows in forestry (Armitage, 2001:93; Carrothers, 1941:109; Matthews, 1933:133). A floating oil processing vessel, called Spratt's Oilery (1881–85 CE), rendered herring into oil and dumped the resulting waste directly into the Coal Harbour area of Burrard Inlet (Armitage, 2001:93; Matthews, 1933:133, 2011:165, 1955:239), which, according to TWN elders contributed to the collapse of these fisheries. One of the few historical records quantifying herring landings describes 7260 L of herring oil produced at Spratt's Oilery in 1884 CE (Department of Fisheries, 1885:264–265). If herring meat is approximately 10% oil (Moss, 2015:644), then Spratt's Oilery must have received more than 75,000 kg of herring.

After 1884 CE, herring did not return to Inner Burrard Inlet in large quantities to justify harvests for oil production. However, in 1884 CE, fisheries records indicate that a small herring fleet of 11 boats and nets worth 2,500 dollars (equivalent to approximately $70,000 in 2021 Canadian dollars) registered in Coal Harbour, and one herring seine registered Burrard Inlet were located there in anticipation of a rich herring run (Department of Fisheries, 1885:262, 263). In addition to the fleet supplying Spratt's Oilery, there was a small non-commercial fishery for local consumption of 680 kg of herring (probably not including Indigenous harvests) (Department of Fisheries, 1885:263). In 1885 CE, a single herring seine with $2,500 worth of nets harvested 3,800 kg of herring in Burrard Inlet, likely in English Bay (Department of Fisheries, 1886:294). In 1886 CE, Spratt's Oilery burned down, was not rebuilt, and no other operation was developed to replace it (Carrothers, 1941:109; Department of Fisheries, 1887:250). Only about 450 kg of herring were caught in Burrard Inlet for local consumption in 1886 CE (Department of Fisheries, 1887:274).

After 1887 CE, there are only three TWN TUS references to harvesting herring and herring spawn dating to the 1930s and 1940s CE, and there are no records of any herring harvests east of First Narrows. Interviews with a now-deceased TWN elder recount how his parents (who would have been born in the 1930s CE) told him stories of harvesting herring roe from hemlock and cedar boughs in Burrard Inlet (Tsleil-Waututh Nation, 2011). This elder indicated that the herring never returned after a small fish farm was built in the Indian Arm, probably in the late 1970s CE.

Fishery officials noted this dramatic loss of herring but did not place blame on fishery practices: "through some unknown cause, the herring, although plentiful in the Gulf of Georgia, did not enter the Narrows at Burrard Inlet as usual, in sufficient quantities to justify the working of Mr. Spratt's oil and scrap manufactury" (Department of Fisheries, 1885:259), and

"since the increase in the shipping traffic this fish [herring] have almost deserted Burrard Inlet, and only a few can now be caught with a seine where the supply formerly seemed to be inexhaustible" (Department of Fisheries, 1888:246). Other contemporary observers noted that Spratt's practice of dumping of processed herring meal into the water drove the herring from Inner Burrard Inlet (Matthews, 1955:239), also noted TWN members. While the practice of fishing with dynamite undoubtedly contributed to the demise of herring in Inner Burrard Inlet, early fisheries officials were instead concerned with the considerable waste in using herring for industrial purposes rather than bait: "That the great destruction of herring now practised to supply a few crude oileries on the coast and elsewhere should be prevented by departmental enactments and thus avoid the too great and rapid depletion of an important factor as bait for carrying on the deep-sea fisheries of the BC coast" (Canada, Sessional Papers, 1893, cited in Carrothers, 1941:110).

By 1887 CE, in response to the collapse of the herring fishery east of First Narrows, the local herring fishery shifted west to English Bay in Burrard Inlet, and a herring fishery based in New Westminster, but likely fishing near Tsawwassen was established (Department of Fisheries, 1888:260). While the herring fishery in English Bay appears to have been quite rich, it was never described as of the same abundance as that east of First Narrows. In 1887 CE, herring landings from English Bay were about 12,700 kg; by 1888 CE, they increased to 23,100 kg; in 1887 CE, those at New Westminster were 2,700 kg (Department of Fisheries, 1888:260; Department of Fisheries, 1889:281). By 1889 CE, the herring fishery appears to have shifted again to the west of Point Grey (Department of Fisheries, 1890:300). It is not certain if this was in response to a collapse of herring populations in English Bay, but it is likely. The Point Grey herring fishery was the first to use gillnets around 1905 CE (Carrothers, 1941:111), likely increasing herring landings but decreasing their stocks. The herring fishery off Point Grey continued until it collapsed around 1914–15 CE (Fisheries Branch, 1917:261). While the commercial herring fishery was gone from west of Point Grey by 1915 CE, some herring must have still returned there, as local injuries from dynamite used in herring fishing were still reported as late as the 1930s CE (Armitage, 2001:170). As late as 1973 CE, beach seine and hydroacoustic surveys of Vancouver Harbour estimated 1000–2000 tons of herring in late August (Nelles, 1978 cited in MacDonald & Chang, 1993:65).

The westward annihilation of herring, beginning in 1885 CE in Coal Harbour, is well-documented and a stark example of modern fisheries mismanagement. Fishing with dynamite and dumping offal into spawning areas likely accelerated this process and did unknown harm to other local species. In the late nineteenth century, herring were seasonally abundant in Burrard Inlet, especially the Coal Harbour area and English Bay. These early historic descriptions would likely apply equally to pre-contact times.

Smelt

References to smelt were common in our literature review (n = 78), but there were none in the TWN TUS data. Smelt appear to have been seasonally abundant along the south shore of Burrard Inlet, especially Coal Harbour, English Bay, Spanish Banks, and False Creek. Available references describe an earlier Indigenous fishery (late nineteenth century), followed by a sporadic settler fishery, and then after about 1911 CE, a marked reduction of smelt abundance.

The number of ethnographic and historic references describing Indigenous smelt fisheries in the study area indicates their importance as a staple for local Coast Salish people (Matthews, 2011:48). The smelt were recorded at First Contact with Europeans, led by George Vancouver in Burrard Inlet. In June of 1792 CE, Vancouver's party was met near First Narrows by a party of Indigenous people in canoes coming from the direction of Capilano River who offered them fish "resembling the smelt" that may have been smelt or herring (Lamb, 1984:581). However, Peter Puget (1792:21) (a member of Vancouver's party) described them as smelt. The earliest known sketch of the Vancouver area, dating to 1861 CE, represents a scene of the south shore of Burrard Inlet at Kitsilano Beach, with Indigenous people harvesting smelt with beach seines (Matthews, 1887) (Fig. 6). Matthews describes the scene: "one end of the net is held to the land; the other end is encircled around to enmesh the myriads of smelts, while Indian women squat before their lodges awaiting the catch, to be dried for winter food." Numerous references to abundant smelt from both Indigenous and settler sources identify the Kitsilano Beach and Spanish Banks as the premier smelt fisheries in the area, where they numbered in the millions. Other reported smelt fisheries located at Horseshoe Bay, Jericho Beach, Locarno Beach, Second Beach, Steveston, the lower three kilometers of the Fraser River, and just west of First Narrows (Department of Fisheries, 1886:242; Matthews, 2011:13–18, 28,31; Suttles, N.d.:1). The large Indigenous fish trap in False Creek was reportedly used to harvest smelt and flounder (Matthews, 2011:15).

The Department of Fisheries (1887:274) reported a modest commercial smelt fishery in the study area by 1886 CE, with 454 kg of smelt reported from canneries at New Westminster (probably harvested near the mouth of the Fraser River) and 909 kg reported from Burrard Inlet. The following year, it reported 3,636 kg of smelt harvested from Burrard Inlet, probably outer Burrard Inlet (Department of Fisheries, 1889:281). Therraiult et al. (2002:26) report that commercial catches of

smelt in Burrard Inlet peaked in 1911 CE, with 114,000 kg landed, and have steadily declined after that (Fig. 5). As late as 1918 CE, local settlers could still harvest large quantities of smelt at Kitsilano Beach using garden rakes (Matthews, 1955:256). However, by the 1930s CE, the commercial smelt fishery off Point Grey was reported as "destroyed" by commercial fishermen (Safarik & Safarik, 2012:180). Comparing the 1930s CE smelt landings, when the fishery was thought of as destroyed, with those in the latter half of the twentieth century illustrates how low smelt stocks had already fallen (Fig. 5). The absence of smelt in the TWN TUS data perhaps indicates that after about 1930 CE, populations were too low to warrant harvesting. By 2000 CE, landings of smelt in Burrard Inlet totalled 51 kg (Therraiult et al., 2002:14), marking a reduction from ~ 114,600 kg landed in Burrard Inlet (exclusive of Indigenous fisheries) in 1911 CE (Therraiult et al., 2002:26) - about 99.96%.

The first declines of smelt after 1911 CE were probably due to overfishing and later declines to pollution and habitat loss. The first decade of the 20th century witnessed the establishment of industry (mills, refineries) and unfettered pollution in areas of former smelt habitat (Oke et al., 1992:162; Therraiult et al., 2002:13). The addition of vast volumes of dredged sand at Kitsilano Beach, Locarno Beach, and Jericho Beach on top of the coarser natural beach substrate preferred by smelt, very likely negatively affected smelt spawning (Levy, 1985:14). Recent research has reflected concern over the sustainability of the current recreational smelt fishery in Burrard Inlet (Therraiult et al., 2002). However, historical evidence indicates that these modern smelt populations are at a fraction of their former levels.

Eulachon

Eulachon was relatively rarely identified in the literature review (n = 35), with references essentially, but not entirely, restricted to the lower Fraser River. Notably, eulachon was reported only five times in the TWN TUS data. Evidence indicates that eulachon were formerly seasonally highly abundant on the lower Fraser River but also reported from Burrard Inlet.

Early historical descriptions of Fraser River eulachon indicate that these small fish were seasonally hyper-abundant. The Fort Langley Journals, for example, describe eulachon in the Fraser River in 1828 CE and the Indigenous eulachon fishery (MacLachlan, 1998:60–61). In the late nineteenth century, the eulachon returns were described as "vast" and "immense" (Department of Fisheries, 1898:lix). The earliest reported commercial landings of eulachon at New Westminster (Department of Fisheries, 1885:264) are about 4,500 kg in 1884 CE. In 1898 CE, eulachon landings at New Westminster had increased to about 1,136,000 kg, and this appears to have been a peak (Department of Fisheries, 1899:228). Eulachon harvests in Burrard Inlet were much more modest by comparison - in 1884 and 1885 CE, 1,360 kg and 2,270 kg for "residents at Vancouver and Port Moody and neighbourhood of Burrard Inlet, for home consumption," respectively (probably not including Indigenous harvests) (Department of Fisheries, 1886:274). It is not clear where in Burrard Inlet or its tributaries this eulachon fishery was. There is ethnographic evidence of eulachon in Indian River (Bouchard & Kennedy, 1986:334), and archaeological evidence of eulachon at Noon's Creek (Pierson, 2011), both draining into Burrard Inlet.

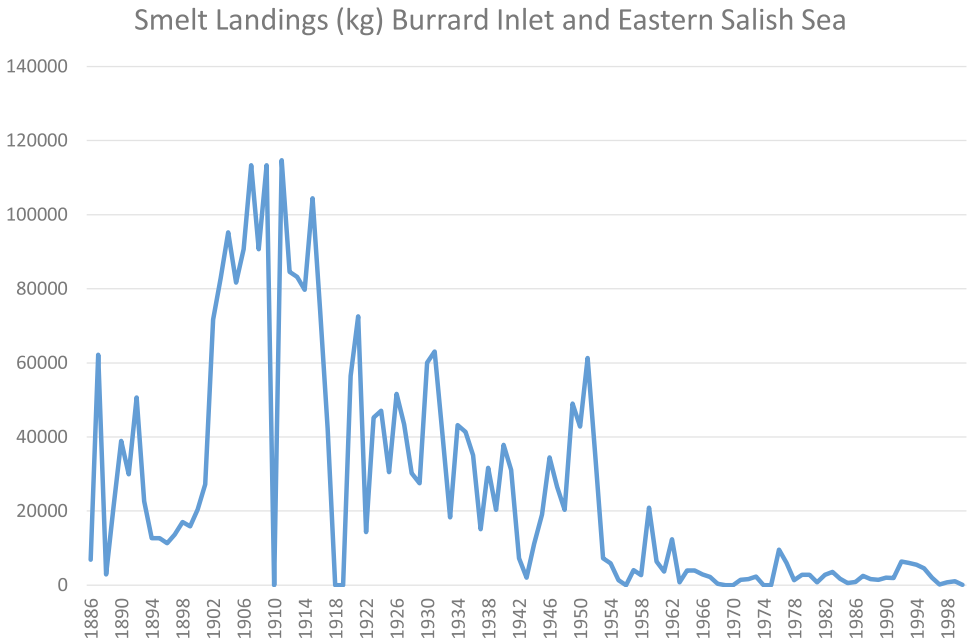

Fig. 5 Smelt landings in Burrard Inlet and Eastern Salish Sea study sites, data from Therraiult et al. (2002:26–28)

Fig. 6 The earliest known sketch of the Vancouver area, depicting Coast Salish people harvesting smelt (Willis, 1861, Vancouver Archives BE.N.14.P.42). The location is the Kitsilano area of Vancouver, looking east

Decreases in Fraser River eulachon returns were noted as early as 1887 CE: "These fish [eulachon] appear to be decreasing in the Fraser River, whether from overfishing or other causes, I am unable to say; but I think the large amount of traffic on the river by stern wheel steamers has a tendency to keep them away" (Department of Fisheries, 1888:238). In 1890 CE, the Fraser River eulachon fishery was described as a failure, and noted that returns were decreasing annually (Department of Fisheries, 1891:182). As noted, landings of Fraser River eulachon peaked in 1898 CE and decreased thereafter (Fig. 7). By the late nineteenth century eulachon are reported only in Burrard Inlet and Indian River, and the rarity of eulachon in TWN TUS data suggests a continued decline so that they were absent or very rare in Burrard Inlet by the 1930s CE.

Around 1940 CE recent historical declines (1921–1939 CE) of eulachon were identified (COSEWIC, 2011; McHugh, 1941; Moody & Pitcher, 2010:30). In the following decades, eulachon returns appeared to be increasing (Moody & Pitcher, 2010:30; Ricker et al., 1954), but by 1957 CE, eulachon were noted as absent over a large portion of their spawning area on the Fraser River (Moody & Pitcher, 2010:31) (Fig. 7). Commercial landings after 2000 CE have been very low, totalling 5760 kg in 2002 CE and 440 kg in 2004 CE (COSEWIC, 2011:54), and Fraser River eulachon are known to have suffered at least a 98% decline in abundance since 2000 CE (COSWEIC, 2011:xii): "Recent runs have been so poor that no eulachon have been captured from any of these fishing sectors [commercial, recreational, Indigenous]" (Moody & Pitcher, 2010:28), a stark contrast to early historic and ethnographic accounts of hyper-abundant returns. Given a decline of about 95% of the eulachon stock during the twentieth century (1,136,000 kg in 1898 CE, and 5760 kg in 2002 CE), and additional 98% decline since 2000 CE, the current Fraser River eulachon stocks must be far less than 1% of their early nineteenth century and pre-contact levels.

Summary

The results of our meta-analysis of archaeological, ethnohistoric, and scientific/regulatory information indicate significant and early reductions in the abundance of forage fish that were once staples of local pre-contact Coast Salish people in the study area. It is notable that anchovy stocks were not encountered in the literature review despite their prevalence in pre-contact local Coast Salish archaeological sites (Lepofsky et al., 2007; Table 2). The data indicate a significant reduction of herring (1885 CE), eulachon (after 1898 CE), and smelt (after 1911 CE) in the order of 99%, well-prior to extensive scientific documentation.

Discussion

Based on our data, it is evident that within a few decades of initial Euro-Canadian settlement of the Vancouver area, the Coast Salish communities who had inhabited the area for millennia witnessed a massive transformation of their home waters, including the loss of forage fish that, along with salmon, had comprised a significant portion of their subsistence and economic base, representing a profound change to the local ecology. Given this history of 3,000 years of intensive Indigenous harvesting supporting local populations of thousands of people, the sudden collapses in forage fish stocks within a few decades of industrial scale colonial

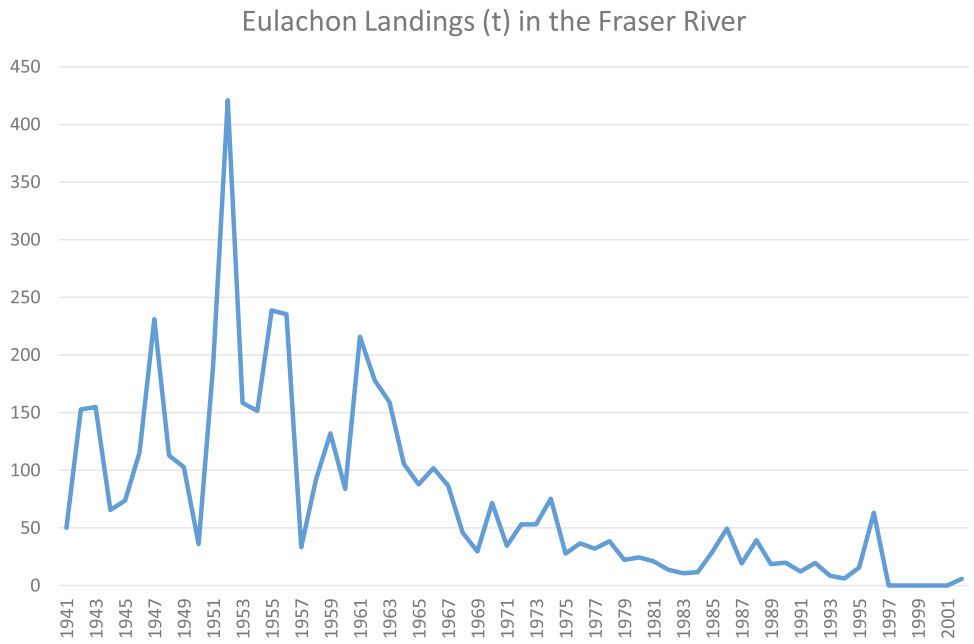

Fig. 7 Eulachon landings on the Fraser River 1941–2002, data from Hay et al. (2003:23). Note peak landings of eulachon reported in 1952 CE are less than 40% landings reported in 1898 (Department of Fisheries, 1899:228)

fisheries strongly indicate they were driven by local anthropogenic impacts rather than climate changes or other natural processes. Anthropogenic impacts to these stocks by over-fishing, poor fishery practices, habitat loss, increased shipping, and pollution, as observed by eyewitnesses in the 1880s CE (Cole and Lockner, 1989:116; Matthews, 1955:239), contributed to these collapses.

We found that these early historic negative impacts have largely been unappreciated in the broader scientific literature. A near-complete absence of discussion of historical herring abundance in Burrard Inlet is perhaps the most obvious omission in modern ecological descriptions. Despite Moody and Pitcher's (2010:29–31) historical review of eulachon fisheries, and Therriault et al.'s (2002) historical review of smelt fisheries, the implication of these significant documented reductions in abundance (~99%) are not broadly acknowledged. Modern (i.e., post ~ 1970 CE) local ecological descriptions and fisheries stock assessments describing baseline conditions differ significantly from early historic and pre-contact conditions. More recent assessments in the later twentieth and early twenty-first centuries describe increasingly degraded ecological conditions, shifting the presumed baseline conditions to an even less productive state.

Ecosystem-wide effects of the collapse of the forage fish would have had significant negative impacts on species in higher trophic levels because forage fish comprise an important link in the food chain between producers and consumers (Hay & McCarter, 2013; Surma et al., 2018). Chinook and coho salmon, dogfish, sea gulls, waterfowl, seals, and sea lions all congregate in abundance and feed on herring during their runs, and in the past Coast Salish people harvested across this entire food chain (Hay & McCarter, 2013; Monks, 1987). Sturgeon, seals, and waterfowl all fed on eulachon during their runs (Department of Marine and Fisheries, 1899:lviii; Moody & Pitcher, 2010:124), all of which were important to local Coast Salish diets (Monks, 1987). According to Suttles (1998:182–183): "sturgeon may have rivalled salmon in importance" in the diets of Coast Salish people on the Lower Fraser River. In sum, a reduction of these forage fish of approximately 99% would result in a corresponding collapse in species at higher trophic levels that prey upon them.

The major implications of these findings are, first, that modern descriptions of baseline marine ecological conditions in the Vancouver area certainly reflect already severely negatively impacted environments. Current Canadian environmental regulations use these ecological baselines to assess impacts of major industrial and infrastructure projects. In our experience, these assessments invariably identify limited ecological impacts but no cumulative effects on resources, and projected impacts on are characterized as within local year-to-year stochastic variability that may be offset by future planned habitat enhancement measures. Given that our data indicate that key forage fish species have undergone a ~ 99% reduction in abundance over the last ~ 150 years, any additional negative effects to these resources is clearly cumulative. It is only from recent shifted baselines for mid-late 20th century stock assessments that such additional impacts can be assessed as not cumulative.

The lack of historical understanding of marine ecosystems limits the capacity of government regulators to make meaningful and positive changes to policy, activity, and industry structure. Without longer-term baselines restoration targets will calculated on already depleted ecosystems rather

than long-term historical and resilient systems. Colonization significantly negatively impacted environmental states, due to both a sudden increase in population and shifts in resource harvesting and use that threaten the future availability of such resources. Urban development, industrial activity, and industrialized harvesting activities have relatively recently shifted the ecological baselines for conservation and management planning.

Second, it should be acknowledged that the collapse of forage fish populations and the corresponding ecosystem-wide effects was and is experienced by local Indigenous populations as a crisis to their historical physical and spiritual dependence almost entirely upon local marine resources. Current ecological conditions have precluded harvesting many of their former staples for more than a century, and currently allow for only small and decreasing quantities of salmon and crab, impacting not only their diet but also their ability to conduct most of their cultural and ceremonial events that are still central to the TWN community. Consequently, ecological reconstruction and habitat enhancement efforts are major priorities for TWN and have been focused on salmonids and clams. Surma et al. (2018) provide a more accurate understanding of the historical ecological conditions of the study area and highlight the restoration of forage fish habitat as a key link in local food webs between producers and predators that support a range of other important traditional Coast Salish staple species.

Coast Salish peoples are often presented with Canadian Environmental Assessment reports claiming that the construction and operation of new infrastructure/industry will not impact their traditional resource harvesting practices, again based on recent (i.e., late twentieth century) baseline ecological conditions and current Indigenous harvesting and land use activities. For example, the absence of local Indigenous harvests of species such as herring and eulachon is cited as evidence of "no impacts" to such harvesting practices, despite contrary historical evidence of their importance.

Conclusions

In the nearly 230 years since First Contact between Indigenous Coast Salish and Europeans in the Vancouver area, the local aquatic ecosystems have undergone a series of profound changes resulting from overfishing, poor fishery practices, pollution, and habitat destruction. The extent and timing of these changes have not been well-documented and are not widely appreciated within the recent scientific literature. A major issue underlying this misunderstanding of the historic conditions of the marine ecology of Vancouver area is the SBS, whereby each generation of researchers assumes that recent observed ecological conditions are historic baseline conditions (Pauly, 1995). To gain a better understanding of the history of ecological changes in forage fish from pre-contact baseline ecological conditions, and to assess the scope and magnitude of negative impacts to key species, we undertook an extensive review of historic, archival, ethnographic, TUS and other relevant materials, and contrasted our findings with pre-contact archaeological evidence.

The archaeological record indicates that forage fish, especially herring, were a significant part of pre-contact Coast Salish peoples' diet in the Vancouver area, likely rivalling salmon in importance. Eulachon was less abundant in the archaeological record than anticipated, and anchovy was far more abundant than anticipated. Collectively, these forage fish were intensively harvested by ancestral Coast Salish people in this region for more than 3000 years.

Several keystone species that were harvested in very large quantities in pre-contact times had become nearly absent in early historic times, many generations before scientific and ecological descriptions. Examination of the early fishery records and supplemental historical documents revealed early peaks in landings of herring, smelt and eulachon, with sharp decreases in the early twentieth century, leading to at least a 99% reduction in stocks by the early twenty-first century. Because of the importance of forage fish in supporting higher trophic levels, the successive collapses of herring (1885 CE), eulachon (1899 CE) and smelt (1930s CE) may have been the most significant impacts to the entire marine ecosystem. While the relative importance of overfishing, poor fisheries practices, pollution, and habitat destruction varies for each of these forage fish, collectively they have completely devastated fisheries that had supported dense Indigenous populations for millennia.

Our findings have important implications for modern local ecological restoration efforts and understanding of the impacts of development on local Indigenous peoples. While the historic reduction in salmon abundance is generally well-recognized, and salmon habitat enhancement measures are common, the profound discrepancy between modern and early historic forage fish abundance has not been widely acknowledged, and comparable habitat enhancement measures are much less common. Because forage fish populations, which are keystone species, have probably undergone the greatest reduction in historic abundance, their restoration would support species that prey on them, including salmonids. Efforts towards re-establishing the pre-contact ecological richness of the study area will require significant investment in enhancing herring, smelt, and eulachon abundance, and are of profound importance to TWN and other local Coast Salish peoples because they above all have experienced the impact of the historic collapse of their most important food sources and corresponding impacts on all aspects of their traditional culture.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10745-023-00398-w.

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Data Availability The data collected as a result of this literature review is available upon request to the authors. The TWN TUS data is available with permission from TWN.

Declarations

Informed Consent Not applicable – this research did not undertake interviews or testing of human participants.

Conflict of Interest The authors report no conflict of interest.

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