



# Investigating the complexities of sustainable fishing at a prehistoric village on western Vancouver Island, British Columbia, Canada

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## Summary

Zooarchaeological data provide direct evidence of long-term human resource utilization relevant to the modern study of sustainability and conservation. On the northwest coast of North America, prehistoric aboriginal communities relied heavily on nearshore marine fish species, many of which have life history characteristics that make them vulnerable to overexploitation. This study examines temporal trends in the abundance and distribution of nearshore fish from skeletal remains recovered from three separate areas of a prehistoric coastal village on the west coast of Vancouver Island (ca. 1800–250 yr BP). Over the course of 1500 years, site inhabitants from these contemporaneously occupied areas regularly utilized *Sebastes* spp. (rockfish), with varying impacts on abundance and total length. Contrasting temporal trends in *Sebastes* spp. total length in separate village areas suggest different consequences to prehistoric harvesting practices, differences that can be linked to ethnographic and archaeological evidence of lineage-based territories. These long-term zooarchaeological data provide unique insights into the context and challenges of sustainable resource use in prehistory and can inform contemporary conservation efforts focused on similar species in this modern-day marine protected area.

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## Introduction

The overexploitation and subsequent decline of common-property resources is a frequent outcome of modern attempts at resource management, particularly among marine fisheries (Ostrom,

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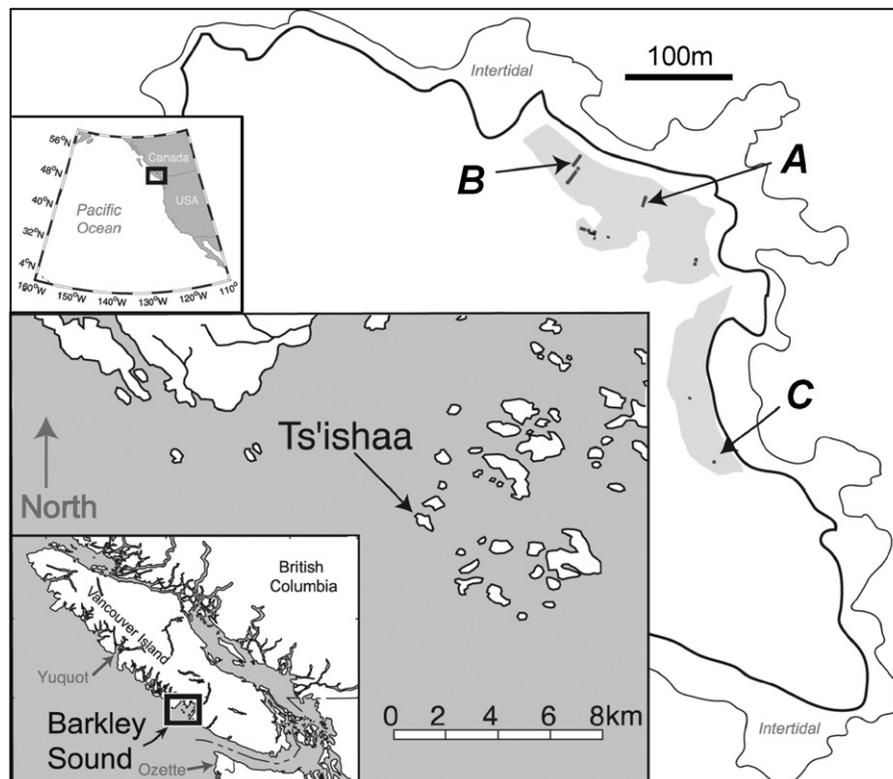
1990; Pauly et al., 2002). Recent efforts directed at conservation and ecosystem-based management recognize the importance of evaluating the historic legacy of human impacts on marine ecosystems for establishing benchmarks for conservation goals (Jackson et al., 2001; Steneck et al., 2002). Managers and conservation scientists have also incorporated the harvesting practices and traditional ecological knowledge (TEK) of indigenous peoples into strategies for the restoration of ecological systems (Berkes, Colding, & Folke, 2000; Pitcher, 2001). However, very little is known about the historical development and long-term effectiveness of traditional resource harvesting practices or the circumstances that might have led to emergence and refinement of TEK. In contrast, zooarchaeological data provide direct evidence of the traditional use of natural resources over long time scales and provide a novel dimension through which conservation scientists can investigate sustainability and conservation (Frazier, 2007; Lauwerier & Plug, 2004; Lyman & Cannon, 2004).

In this paper, I examine a 1500-year history of fishing at a coastal village in Barkley Sound, Vancouver Island, British Columbia, Canada (Fig. 1).

The extensive archaeological evidence of prehistoric occupation and resource use at this site provides an opportunity to evaluate the long-term human impact on marine fisheries and link it to contemporary management efforts directed towards the conservation of these same fishery resources. Trends in abundance and total length estimates are used to argue that ancient inhabitants from separate areas of a single village community impacted local populations of *Sebastes* spp. (Cuvier, 1829) in varying ways. These results provide insights into the complexities of resource management in a prehistoric context and illustrate the utility of integrating zooarchaeological data with contemporary marine conservation efforts.

### Cultural and archaeological context

Aboriginal populations have occupied the western coast of Canada for at least 10,000 years, and the west coast of Vancouver Island, for at least the past 5000 years (McMillan, 1999). These ancient human populations intensively utilized the marine environment as evidenced by the numerous shell



**Figure 1.** Ts'ishaa village site map (Site numbers DfSi 16&17) showing the extent of shell midden deposits (shaded) and the locations of excavation units (black squares and rectangles); letters indicate areas (A, B, and C) associated with traditional lineage groups discussed in the text. Insets show: general location of the Broken Group of Islands within Barkley Sound and Vancouver Island on the west coast of North America. Also shown are the village locations of Yuquot (Fig. 2) and Ozette discussed in Etnier (2007).

midden habitation sites found throughout the northwest coast (Ames & Maschner, 1999). Shell middens are mounded cultural sediments predominantly composed of food detritus (i.e., bones and shells), cooking debris, architectural features, and other artefacts. These typically occur along semi-protected marine shorelines with boat access as the majority of travel was by canoe (Mackie, 2001). Due to the alkalinity of the shell-rich matrix of shell midden sediments, vertebrate skeletal remains preserve exceptionally well, despite being exposed to the wet coastal climate and acidic forest soils (Erlandson, 2001). These abundant, non-fossilized skeletal remains offer direct evidence of a diverse variety of mammals, birds, and fishes consumed by prehistoric inhabitants over the past several millennia.

At the time of European contact (AD 1774), aboriginal communities on the western shores of Vancouver Island occupied a densely populated coastline with strongly defined territorial boundaries (McMillan, 1999). The prehistoric population of Barkley Sound is estimated to have been more than 8500 people, based on the presence of 30–40 large, village-sized shell midden sites and historic accounts from the early contact era (Clayton, 2000, p. 146; Haggarty & Inglis, 1985; McMillan & St. Claire, 2005, p. 34). At least five autonomous tribal groups belonging to the Nuu-chah-nulth linguistic group inhabited Barkley Sound during the 19th century, but considerably more had existed prior to historic-era tribal amalgamations and introduced diseases (St. Claire, 1991). Each autonomous tribal group maintained territories containing a principal village location and a network of smaller habitation sites from which they acquired resources. Chiefs were charged with overseeing and controlling access to territories and resources, and their authority was ultimately recognized by the community at large (Marshall, 2000). Drucker (1951, p. 247) noted:

The Nootkans [Nuu-chah-nulth] carried the concept of ownership to an incredible extreme. Not only rivers and fishing places close at hand, but the waters of the sea for miles offshore, the land, the houses, carvings on a house post, the right to marry in a certain way or the right to omit part of an ordinary marriage ceremony, names, songs, dances, medicines, and rituals, all were privately owned property.

Historic accounts of Nuu-chah-nulth communities in the 18th and 19th centuries indicate that people depended primarily on the marine environment for food (Folan, 1984). Fishing was a frequent activity conducted by the majority of community inhabi-

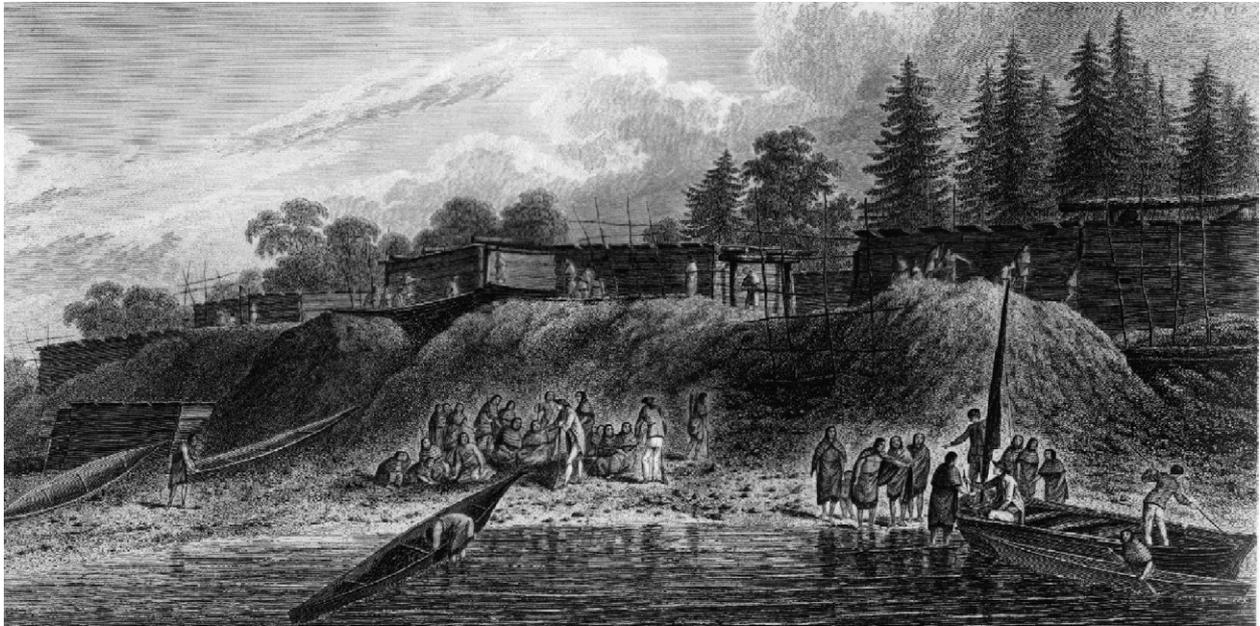
tants (Sapir & Swadesh, 1955, p. 30). Larger demersal (bottom dwelling) fish, particularly *Sebastes* spp. (rockfish), were caught by hook and line or basket traps from dugout canoes, while mid-water schooling fish were captured with rakes, dipnets or weirs, in addition to hook and line. The collection and distribution of fishery resources was sanctioned by chiefs, who were also entitled to a portion of the catch (Drucker, 1951, p. 272). Food was always consumed in the presence of others (Drucker, 1951, p. 388) and disposal of food waste regularly occurred in the immediate vicinity of households (Sproat, 1868, p. 33); producing large quantities of shell midden deposits (Fig. 2).

Nearshore fishing was conducted year-round (weather permitting) and could be readily performed a short distance offshore with widely available technology. Demersal fishes, particularly *Sebastes* spp., were probably caught and consumed by individuals or small family groups. In contrast, other important marine fishes such as *Clupea pallasii* Valenciennes, 1847 (herring), *Engraulis mordax* Girard, 1854 (anchovy), and *Oncorhynchus* spp. Suckley, 1861 (salmon) which aggregate seasonally in large schools, were harvested collectively and stored for later consumption (Sapir & Swadesh, 1955, p. 29).

### Contemporary ecological context

The waters off the western coast of Vancouver Island comprise an extremely productive marine ecosystem (Ware & Thomson, 2005) that has undergone substantial human impacts, particularly over the past two centuries, most notably, the extirpation of *Enhydra lutris* Linnaeus, 1758 (sea otters) during the early maritime fur trade (ca. AD 1785–1805), the international harvest of *Callorhinus ursinus* Linnaeus, 1758 (Northern Fur Seals) (ca. AD 1820–1910), and modern commercial whaling (ca. AD 1908–1967) (Crockford, Frederick, & Wigen, 2002; Gibson, 1992; Gregor, Nichol, Ford, Ellis, & Trites, 2000). Intense commercial and recreational fishing pressure, as well as habitat alteration, during the late 20th century has greatly impacted coastal fish populations, many of which are now recognized as vulnerable or endangered (Berkeley, Hixon, Larson, & Love, 2004).

In just the past quarter century, the average length of demersal fish caught off the US Pacific Coast has decreased by 45%, and the majority of fish populations currently exhibit unsustainable or sharply negative rates of growth (Levin, Holmes, Piner, & Harvey, 2006). This dramatic decline demonstrates the coast-wide influence of human



**Figure 2.** An engraving by John Webber depicting a contact-era (ca. AD 1778) Nuu-chah-nulth village (Yuquot) in Nootka Sound on western Vancouver Island. The large shell midden landforms located in front of the houses are comparable to the shell midden deposits at Ts'ishaa in Barkley Sound. Image used with the kind permission of the Captain Cook Society (Essex, UK).

exploitation on marine ecosystems, and has created a compelling scientific basis for reducing harvest quotas and establishing marine protected areas. However, there is little available data to evaluate either the short- or long-term effectiveness of these recent conservation efforts (Sale et al., 2005).

*Sebastes* is a speciose genus with 35 species documented in British Columbia (Hart, 1973) that comprise a significant proportion of both the commercial and recreational catches in the province (Beamish, Benson, Sweeting, & Neville, 2004). Non-migratory and long-lived, many *Sebastes* spp. reach ages of 50–200 years (Munk, 2001), life history characteristics that make them particularly vulnerable to overexploitation (Berkeley & Chapman et al., 2004; Berkeley, Hixon, Larson, & Love, 2004). Most *Sebastes* are semi-sedentary and occupy high-relief rocky outcrops and kelp beds (Love, Yoklavich, & Thorsteinson, 2002), a habitat that is widely distributed in the vicinity of the study site (Lee & Bourne, 1977). Larger individuals are generally found in deeper waters (Murie, Parkyn, Clapp, & Krause, 1994). The inshore (hook and line) recreational catch in British Columbia is dominated by six species of *Sebastes*: *S. caurinus* Richardson, 1844; *S. flavidus*, Ayres, 1862; *S. melanops* Girard, 1856; *S. maliger* (Jordan & Gilbert, 1880); *S. nebulosus* Ayres, 1854; and

*S. nigrocinctus* Ayres, 1859 (Department of Fisheries & Oceans, 2000). Due to their preference for structured habitat (e.g., rocky crevices, kelp forests, shipwrecks), inshore *Sebastes* are rarely caught in nets (White, 2003).

Recent recognition that *Sebastes* spp. populations are severely depleted (Levin et al., 2006) has led to the implementation of Rockfish Conservation Areas along the coast of British Columbia (Department of Fisheries & Oceans, 2006). The Broken Group Islands surrounding the study site has been managed as a 'no-take' Rockfish Conservation Area since 2002. Ongoing underwater biological monitoring conducted near the study site notes that despite the productive habitat, there is low rockfish abundance, suggesting that in their current state, *Sebastes* spp. "will not sustain high levels of fishing" (Holmes & Tomascik, 2003, p. 123).

### Ts'ishaa site context

The zooarchaeological data presented in this paper come from excavations at a prehistoric coastal village in Barkley Sound, British Columbia, situated on a small island (~17 ha) in an exposed archipelago on the southwest coast of Vancouver Island within the boundary of Pacific Rim National

Park Reserve (Fig. 1). Archaeological excavations at the site were undertaken as a collaborative research project funded by Parks Canada and the Tseshaht First Nation (McMillan & St. Claire, 2005). Three seasons of excavation (1999–2001) by a team of archaeologists, Tseshaht First Nation members, and volunteers examined ~220 cubic metres of prehistoric cultural deposits dispersed throughout the northeast portion of the island.

The site contains shell midden deposits that stretch over 300 m along the northeastern portion of Benson Island, more than 3 m deep in many locations (Fig. 2). Faunal remains described in this paper come from archaeological excavations conducted in three specific areas of the site (A, B, and C) which are the ethnographically identified locations of Tseshaht lineage groups (*ushtakimilh*, McMillan & St. Claire, 2005). Each lineage group can trace their respective ancestry to the 'original' inhabitants of the village (McMillan & St. Claire, 2005, p. 9). These three excavation areas are approximately 75–100 m apart (Fig. 1).

Ethnographic accounts describe sequential periods of population expansion which correspond to the establishment of individual lineage groups going back numerous generations (McMillan & St. Claire, 2005, p. 9). Each new group was granted permission to establish households in separate areas of the village and to harvest resources within defined territories. The oldest, and founding, lineage group, located in the centre of the village (area A), held the highest status and authority, while groups established later (areas B and C) held lesser status with peripheral territories. Although membership and leadership of household lineages changed over time, the physical locations as well as the resource harvesting rights and associated territories were relatively stable (Marshall, 2000; St. Claire, 1991). A conservative estimate of the pre-contact (<AD 1774) village population is between 400 and 500 people (McMillan & St. Claire, 2005, p. 23).

Ts'ishaa Village site has evidence of human occupation spanning the past 5000 years (McMillan & St. Claire, 2005). However, cultural deposits older than 3000 years are restricted to an elevated terrace ~8–10 m above present day sea level, features that are not specifically identified in the historic accounts of the village. Material younger than 2000 years is concentrated along the modern shoreline in deep deposits approximately 1–4 m above sea level (Fig. 2). The analysis in this paper focuses on the last 1500 years of occupation, the period most securely related to archaeological evidence and ethnohistoric accounts of the village.

## Materials and methods

### Recovery and identification

Shell midden deposits were excavated by hand in  $2 \times 2$  m units, by removing 10 cm vertical excavation levels that controlled for separate stratigraphic contexts. Where cultural deposits were deeper than 2 m, contiguous  $2 \times 2$  m units were excavated as trenches. Sediments were screened through 6.3 mm wire mesh; skeletal remains of all fishes, birds, and mammals were collected for subsequent analysis. Additional faunal remains (primarily fish) were recovered from ~ $20 \times 10$  cm columns of sediment removed from the sidewalls of excavation units. Column samples were washed and screened through 3.2 mm mesh, and subsequently sorted and identified in the laboratory (McKechnie, 2005). Faunal remains from column samples, although based on a considerably smaller volume of sediment (139 litres), provide an additional proxy for assessing the relative abundance and density of small fish remains in the deposits.

The large volume of excavated deposits –  $220 \text{ m}^3$  – together with the high density of faunal remains, produced many more skeletal specimens than could be realistically examined. Thus, only a portion of the recovered materials was selected for identification and analysis. For the present study, faunal remains were examined from 19.8 cubic metres of cultural sediments excavated from four excavation units (two units from area B and one unit each from areas A and C), representing a total of 49 excavation levels. Faunal material from an additional 139 litres of sediment were examined; these derived from a total of 34 column sample levels removed from the side walls of the excavation units in the three areas. Details on examined volumes of sediment from both the excavation unit and the column sample assemblages are shown in Tables 1 and 2.

Identification to genus or species was attempted for all skeletal elements with the aid of a binocular dissecting microscope ( $6.3\text{--}40\times$ ) and the extensive comparative collections at the Zooarchaeology Laboratory, Department of Anthropology, University of Victoria, British Columbia, Canada. Osteological and provenience data were recorded for each skeletal specimen, and the results were quantified to the number of identified specimens (NISP, Grayson, 1984). Only identified fish remains are presented in this paper; further analysis and description of vertebrate taxa is reported in Frederick and Crockford (2005) and McKechnie (2005, 2007).

**Table 1.** Number of identified fish specimens (NISP) from the excavation unit assemblage (6.3 mm mesh) in areas A, B, and C, ordered alphabetically by fish taxa and by temporal/archaeological period. Also shown is the examined volume in cubic metres and the number and mean total length of measured *Sebastes* spp. elements (1 standard deviation shown in parentheses).

Fish taxa	Area A					Area B				Area C			Total NISP
	1800–1500	1500–1000	1000–750	750–250	Total	1500–1000	1000–750	750–250	Total	1000–750	750–250	Total	
<i>Clupea pallasii</i>	4	5	21	39	69	54	57	23	134	33	13	46	249
Cottidae						4	1		5	3	1	4	9
<i>Damalichthys vacca</i>	6	2	2	75	85	36	93	16	145	1	7	8	238
<i>Embiotica lateralis</i>	3		3	9	15	10	75	3	88				103
Embiotocidae	16	25	7	35	83	55	189	3	247	58	34	92	422
<i>Engraulis mordax</i>							1		1	1		1	2
<i>Eopsetta jordani</i>		13			13	200	343	36	579	10		10	602
<i>Gadus macrocephalus</i>	10				10	4	3		7				17
<i>Hemilepidotus hemilepidotus</i>		1		3	4	24	41	8	73	5	2	7	84
<i>Hemilepidotus</i> sp.										17	17	34	34
<i>Hexagrammos</i> sp.	135	48	19	104	306	258	663	115	1036	202	257	459	1801
<i>Hippoglossus stenolepis</i>	92	4	5	6	107	20	34		54	11	1	12	173
<i>Hydrolagus colliei</i>	13	40	2	2	57	58	83	12	153	25	1	26	236
<i>Lepidopsetta bilineata</i>						6	17		23				23
<i>Leptocottus armatus</i>		1			1								1
<i>Merluccius productus</i>		42			42	110	252	32	394	44	2	46	482
<i>Oncorhynchus</i> sp.	14	27	6	11	58	57	85	102	244	60	335	395	697
<i>Ophiodon elongatus</i>	648	37		31	716	131	234	95	460	78	441	519	1695
<i>Parophrys vetulus</i>							2		2				2
<i>Pleuronectiformes</i>		7			7	33	7	4	44	9		9	60
<i>Porichthys notatus</i>	1	6			7	16	11	1	28	2		2	37
<i>Raja</i> sp.		1			1					5		5	6
<i>Scorpaenichthys marmoratus</i>	28	5	9	7	49	68	95	19	182	45	125	170	401
<i>Sebastes</i> sp.	581	1187	73	29	1870	3190	8325	317	11832	739	302	1041	14743
<i>Squalus acanthias</i>	43	5		14	62	68	92	13	173	71	17	88	323
<i>Theragra chalcogramma</i>										2		2	2
<i>Thunnus thynnus</i>	5	1			6		10	3	13				19
Total NISP	1599	1457	147	365	3568	4402	10,713	802	15,917	1421	1555	2976	22461
Examined volume (m <sup>3</sup> )	2.0	1.6	1.2	3.2	8.0	3.2	4.0	2.0	9.2	0.8	1.6	2.4	19.6
Mean <i>Sebastes</i> total length cm	41.4	34.4	35.3	28.9	35.3	33.8	35.1	37.2	35.1	36.7	34.5	36.1	352
(SD)	(1.2)	(5.7)	(7.7)	(5.4)	(8.5)	(7.5)	(7.1)	(8.2)	(7.6)	(8.7)	(5.8)	(8.1)	(7.8)
Measured <i>Sebastes</i> (n)	73	226	16	5	320	563	815	336	1714	178	63	241	2275

**Table 2.** Number of identified fish specimens (NISP) from the column sample assemblage (3.2 mm mesh) in areas A, B, and C, ordered alphabetically by fish taxa and by temporal/archaeological period; examined volume shown in litres

Fish taxa	Area A					Area B				Area C			Total NISP
	1800–1500	1500–1000	1000–750	750–250	Total	1500–1000	1000–750	750–250	Total	1000–750	750–250	Total	
<i>Anoplopoma fimbria</i>	1	13			14	3	5		8				22
<i>Clupea pallasii</i>	214	532	205	145	1096	1026	136	242	1404	111	338	449	2949
Cottidae	1				1						1	1	2
<i>Cymatogaster gracilis</i>								1	1				1
<i>Damalichthys vacca</i>		1			1		4		4				5
<i>Embiotica lateralis</i>										1		1	1
Embiotocidae	14	19	6	5	44	15	36	10	61	7	1	8	113
<i>Engraulis mordax</i>	11	28	112	24	175	37	728	4	769	216	30	246	1190
<i>Eopsetta jordani</i>		1	1		2		1		1				3
<i>Gadus macrocephalus</i>	1				1								1
<i>Hemilepidotus hemilepidotus</i>		6	1		7	1	2		3	2		2	12
<i>Hexagrammos</i> sp.	40	43	29	17	129	34	58	29	121	19	69	88	338
<i>Hippoglossus stenolepis</i>		11	2	1	14		4		4	2		2	20
<i>Hydrolagus colliei</i>	3	2			5	1	2		3				8
<i>Lepidopsetta bilineata</i>							1		1				1
<i>Merluccius productus</i>	4		1	1	6		25		25	6		6	37
<i>Oncorhynchus</i> sp.	22	5	15	1	43	6	35	16	57	15	50	65	165
<i>Ophiodon elongatus</i>	7	2		2	11	2	8	4	14		2	2	27
<i>Platichthys stellatus</i>							2		2				2
Pleuronectiformes	1	2			3		7		7	1		1	11
<i>Porichthys notatus</i>	1	16		1	18		3		3				21
<i>Raja</i> sp.		1			1								1
<i>Scorpaenichthys marmoratus</i>	1	1			2	4	2		6	1	2	3	11
<i>Sebastes</i> sp.	115	144	75	1	335	35	301	2	338	52	12	64	737
<i>Squalus acanthias</i>	1	10	7	2	20	1	22	2	25	2	1	3	48
Total NISP	437	837	454	200	1928	1165	1382	310	2857	435	506	941	5726
Examined volume (litres)	18.75	18.75	18.75	18.75	75	16	12	12	40	14	10	24	139

Due to their morphological similarity, it is not possible to confidently distinguish skeletal elements among *Sebastes* species (Cannon, 1987; Frederick & Crockford, 2005). However, given the relatively small estimated total lengths of the archaeological specimens (see results below), it is assumed that the *Sebastes* involved are predominantly the six common inshore species regularly observed in the study area today (see discussion above).

### Ts'ishaa site chronology

Eighteen radiocarbon dates from archaeological deposits in areas A, B, and C vary between ca. 1870 and 220 calibrated years BP (Table 3). Four periods of village occupation (ca. 1800–1500, 1500–1000, 1000–750, and 750–250 cal year BP) are distinguished on the basis of at least three radiocarbon dates from each area. The oldest, area A, spans all four temporal periods, while areas B and C are younger, spanning 1500–250 and 1000–250 cal year BP, respectively. This occupation sequence corresponds to ethnohistoric accounts of the ancient expansion of the village (McMillan & St. Claire, 2005).

### Abundance estimates

Estimates of abundance are based on three calculations: the relative abundance of identified

skeletal specimens of a particular taxon in relation to the total number of identified specimens (%NISP); the percentage of archaeological contexts in which a certain taxon is found (ubiquity); and number of identified specimens per litre (NISP/litre). Each of these three measures is provided for both the excavation unit and column sample assemblages. While these measures may be subject to a variety of taphonomic factors and quantitative biases (Grayson, 1984), their combined use provides stronger evidence for documenting temporal trends in the relative abundance of taxa of interest. Minimum numbers of individuals are not calculated.

### Total length estimates

All total length (TL) estimates for archaeological *Sebastes* are derived from one of 26 allometric regression formulae, each of which is based on measurements on one of 12 cranial or vertebral elements (Orchard, 2003). As many as three separate measurements for certain skeletal elements are possible because of the fragmentary nature of archaeological specimens. The regression formulae are based on measurements of 35 contemporary *Sebastes* specimens representing 16 different species which were pooled for this analysis. Each of the 26 linear regression equations has an  $R^2$  value of at least 0.769 (mean  $R^2 = 0.854$ ; 1 SD = 0.04; see Orchard, 2003, p. 109).

**Table 3.** Radiocarbon dates associated with deposits in areas A, B, and C of Ts'ishaa Village. Radiocarbon ages for charcoal have been converted from  $^{14}\text{C}$  ages into calibrated years before present (cal year BP) using the calibration curve of Reimer et al. (2004); bone samples of *Callorhinus ursinus* (Northern Fur Seal) were calibrated with a  $\Delta R$  of  $250 \pm 25$  year using the calibration curve of Hughen et al. (2004).

Area	Lab number	$^{14}\text{C}$ age	2 sigma range (cal year BP)	Material	$\text{d}^{13}\text{C}$	Level/layer	Depth (cm)
A	CAMS-85647	$895 \pm 30$	420–220	Fur seal	–14.1	4A	30–40
A	Beta-134655	$1490 \pm 60$	1520–1300	Charcoal	–25	25C	220–230
A	CAMS-85646	$2235 \pm 35$	1670–1420	Fur seal	–15.3	37G	360–370
A	Beta-134656	$1800 \pm 60$	1870–1570	Charcoal	–25	37G	350–370
B	CAMS-97191	$350 \pm 45$	500–310	Charcoal	–25	3B	20–30
B	CAMS-97192	$475 \pm 35$	550–480	Charcoal	–25	3B	20–30
B	CAMS-85651	$1145 \pm 30$	600–450	Fur seal	–14.4	5C	40–50
B	CAMS-85649	$1470 \pm 30$	870–680	Fur seal	–14.4	7C	60–70
B	CAMS-85650	$1545 \pm 30$	920–740	Fur seal	–14.6	7C	60–70
B	CAMS-97203	$1385 \pm 35$	1350–1260	Charcoal	–25	20D	190–200
B	CAMS-97204	$1300 \pm 35$	1290–1180	Charcoal	–25	20D	190–200
B	CAMS-85648	$1595 \pm 35$	980–770	Fur seal	–13.4	21D	210–220
B	CAMS-97198	$1230 \pm 35$	1260–1070	Charcoal	–25	30D	290–300
B	CAMS-97197	$1310 \pm 35$	1290–1180	Charcoal	–25	30D	290–300
B	Beta-147074	$1230 \pm 90$	1300–970	Charcoal	–25	30D	300
C	UCIAMS-23517	$325 \pm 15$	460–310	Charcoal	–25.1	6A	32–42
C	UCIAMS-23518	$345 \pm 15$	480–320	Charcoal	–29.2	12A	93–96
C	Beta-134657	$970 \pm 60$	980–740	Charcoal	–25	24C	210–213

A total of 2275 archaeological *Sebastes* elements were measured for this study, involving all measurable elements from the three excavation areas despite the possibility of measuring multiple elements of the same individual. Measurements do not include specimens recovered from column samples due to the comparatively small sample size of measurable elements. Temporal and spatial trends in total length are evaluated for each of the three areas using one-way analysis of variance (ANOVA) with *post hoc* tests where equality of variance between groups is not assumed (Norusis, 2000, p. 263). Total length estimations for archaeological *Sebastes* were compared to a sample of 487 *Sebastes* of multiple species caught in the modern recreational fishery in Barkley Sound in 2003 and 2004 (DFO management area 23, Department of Fisheries & Oceans, 2007) using Student's *T* test where equal variances are not assumed.

## Results

The excavation unit assemblage yielded a total of 23,211 identified skeletal specimens (NISP), 97.7% of which are fish remains (NISP = 22,461, Table 1). In comparison, marine mammals (NISP = 425), birds (NISP = 241), and land mammals (NISP = 85) make up only 1.8%, 1.0%, and 0.4%, respectively, of the overall assemblage. The column sample assemblage contains 5732 identified skeletal specimens, 99.9% of which are fish (NISP = 5726, Table 2). While these numbers do not translate directly into the relative abundance of individual animals or meat weights, the overwhelming dominance of fish in both assemblages indicates the high degree to which fishery resources were relied upon by site inhabitants.

## Abundance

*Sebastes* spp. is the most abundant taxon in the excavation unit assemblage (65.6% of the total NISP), is present in 96% of the 49 examined excavation unit levels, and is the most abundant (%NISP) taxon in each of the three areas (Table 1). In the column sample assemblage (Table 2), *Sebastes* is the third most abundant taxon (12.9% NISP), behind *C. pallasi* (51.5% NISP) and *E. mordax* (20.8% NISP). The abundance of the last two named species is due to the high numbers of small schooling fish recovered in smaller screen sizes (McKechnie, 2005). *Sebastes* is present in the majority (86%) of the 34 examined levels in the column sample assemblage.

During the last two periods of occupation (1000–750 and 750–250 BP) similar temporal trends

occur in all three areas, with declines in both abundance (%NISP) and density (NISP/litre) of *Sebastes*; however, there are differences between the three areas (Fig. 3). In area A, the location of the oldest lineage group, these decreases occur during the last three periods of occupation (1500 to 250 BP), and are preceded by increases in all values except column abundance. In contrast, area B peaks in both abundance and density during 1000–750 BP.

## *Sebastes* total length

Mean total length (35.2 cm, SE $\pm$ 1.6,  $n = 2272$ ) does not differ significantly among the three areas (*post hoc* ANOVA,  $p = 0.960$ – $0.166$ ), indicating that occupants in each area caught a similar size-range of *Sebastes*. However, there are different temporal trends in average total length for these separate but contemporaneously occupied areas (Fig. 3). In area A there is a significant decrease in total length over time (ANOVA,  $p \leq 0.010$ ), while in area B there is a significant *increase* in length (ANOVA,  $p = 0.003$ ). In area C, length decreases but not significantly (ANOVA,  $p = 0.79$ ). The mean total length of the archaeological assemblage is significantly smaller than in the modern recreational fishery in Barkley Sound (Fig. 4).

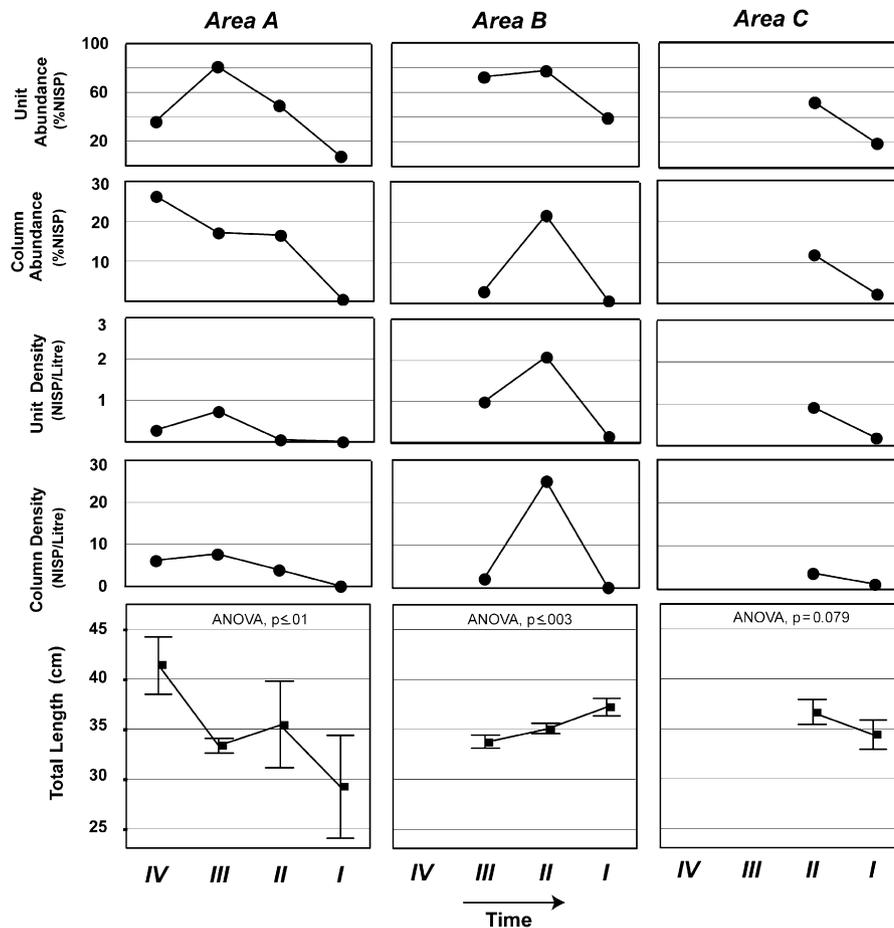
## Discussion

Fishing was central to Ts'ishaa Village for over 1500 years, and *Sebastes* spp. were a focal component of the fishery as demonstrated by their abundance, ubiquity and density in three contemporaneously occupied village areas. Consistent, long-term exploitation of widely available resources is also observed for other fish and marine mammal species at the site (McKechnie, 2005).

The large volume of midden deposits and the ethnographic history of the village indicate that prehistoric inhabitants had the capacity to over-exploit local *Sebastes* populations. Contrasting trends in total length for areas A and B, subject to the same environmental conditions, suggest human-induced fishing impacts. However, several other factors may also account for, or contribute to, the observed trends in *Sebastes* abundance and length, and are discussed in turn below.

## Climatic change

Significant changes occurred in the marine environment of Barkley Sound during the period



**Figure 3.** Temporal trends in *Sebastes* spp. relative abundance (%NISP), density (NISP/litre) and total length, for excavation units and column samples for each of the three areas (A, B, and C). Vertical error bars indicate 95% confidence intervals for total length estimates with ANOVA results shown. Time periods: IV = 1800–1500; III = 1500–1000; II = 1000–750; and I = 750–250 cal yr BP.

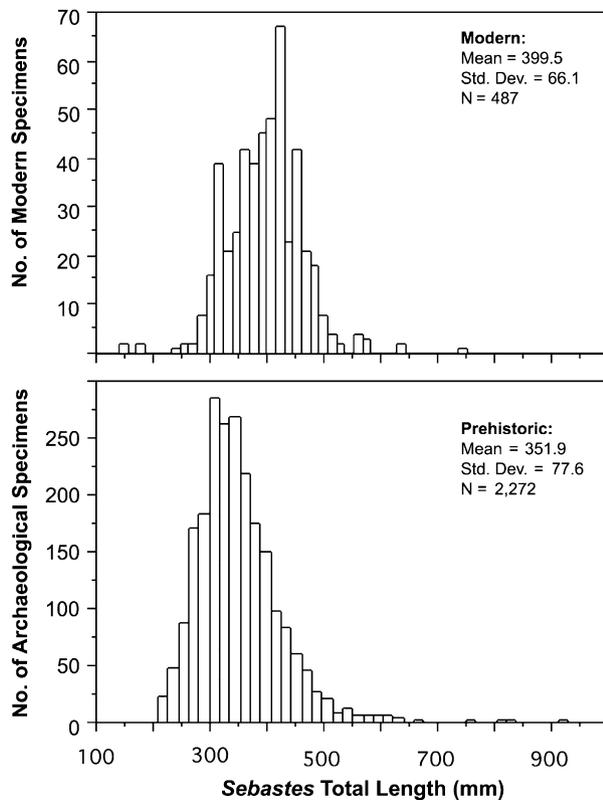
under consideration. Paleoecological data indicate increased marine upwelling between ca. 1450 and 1050 cal yr BP and a period of lower marine productivity during the past 500 years (Dallimore, Thomson, & Bertram, 2005; Hay et al., 2007; Wright, Dallimore, Thomson, Patterson, & Ware, 2005). These changes had the potential to alter *Sebastes* recruitment and population dynamics (Laidig, Chess, & Howard, 2007).

Paleoecological data indicate that *Sebastes* spp. do not appear to have undergone major fluctuations in abundance during the past 4000 years near Barkley Sound (Wright et al., 2005, p. 376). However, changes in the marine environment may have affected different *Sebastes* species in different ways, depending on their vulnerability or resilience to climatic changes. Different trends in length could also be explained by preferential targeting of species by residents in different areas of the village. However, species identifications of archaeological remains are not currently available.

Future research using ancient DNA to determine species identifications may help resolve this issue.

### Archaeological sampling

Limitations in sampling is another factors which may complicate interpretation of the observed similarities and differences in trends between areas. Due to the considerable logistics and expense of staging a large-scale excavation project in a remote locale, it was only possible to excavate and identify fauna from a limited number of areas within Ts'ishaa. If additional excavations were conducted in other areas of the site or in other village sites in the region, more complex or contrary patterns may emerge. Similarly, an increased sample of skeletal elements from the same locations could alter temporal trends of total length distributions. Sample size in this study was limited by the low abundance, and hence low



**Figure 4.** Frequency histograms: top – total lengths for modern *Sebastes* caught in the recreational fishery in Barkley Sound (Department of Fisheries & Oceans 2007); bottom – estimates of total lengths from archaeological specimens from areas A, B, and C in Ts’ishaa Village. *T*-test between two unequal samples  $t = -13.65$ , d.f. = 800.54,  $p < 0.01$ .

availability of measurable *Sebastes* elements during the final period of occupation in area A ( $n = 5$ ). The fact that measurements were only taken on specimens recovered from 6.3mm mesh further introduces a size-selective bias, as smaller sized *Sebastes* recovered in smaller mesh sizes were not included in the analysis (McKechnie 2005, p. 50). Thus, although the data reported here involve a considerable sample of identified skeletal remains associated with numerous radiocarbon dates, further identification and measurement of fauna from additional excavation levels is warranted to confirm the trends reported herein.

### Fishing territories and harvest pressure

Differing trends in total length observed in separate but contemporaneous areas may reflect different levels of fishing pressure specific to individual areas. The temporal declines in relative abundance and total length for area A suggest over-

harvesting of preferred prey (cf. Grayson, 2001). In contrast, area B shows a significant increase in length over three contemporaneous temporal periods and a higher overall density of *Sebastes* than any other area (Fig. 4). These results conform to ethnohistoric accounts of the village which identify these separate areas as household locations associated with defined territories and specific lineages who inherited their harvesting privileges from previous generations (McMillan & St. Claire, 2005). Hence, fishing practices – and impacts – could have differed between areas.

As fishery declines are often met with increases in harvesting effort (Walters, 1986), a possible explanation for the differing trends in *Sebastes* lengths in areas A and B is different responses to (human-induced) declines in the availability of inshore fish (cf. Leach & Davidson, 2001). The increase in length in area B may reflect the local depletion of *Sebastes* from shallow water followed by the increased targeting of deeper, offshore areas where larger-sized fish tend to be more prevalent (Murie et al., 1994). Area B is located at the north-western edge of the village deposits, closest to a deep-water channel north of the site where larger *Sebastes* are likely more abundant (Fig. 1). The high overall density (NISP/litre) of *Sebastes* in the area B (Fig. 3) suggests a more intense use occurred in this portion of the village.

Different fishing strategies and locations may have been used by different lineage groups. For instance, baited basket traps or hook and line fishing may not have been equally appropriate in different areas with different fishing conditions (e.g., prevalence of kelp, proximity to shore, water depth, currents, etc.). Area A, the oldest portion of the village, faces northeast towards the more protected and shallower waters encompassed by the Broken Group Islands (Fig. 1). This semi-protected cluster of islands, reefs, and channels contains productive *Sebastes* habitat that was likely a preferred fishing location, for it is navigable in most weather conditions. This area is also within the current 'Rockfish Conservation Area' boundary. This may have resulted in this location being subject to the greatest cumulative fishing pressure. On the other hand, ethnographic accounts of this founding lineage group also emphasize how the leaders of this high status household were renowned sea mammal hunters and whalers (McMillan & St. Claire, 2005), factors which may have contributed to the reduced importance of *Sebastes* use in this area.

Radiocarbon and ethnographic evidence support the interpretation that area C was established only after overcrowding in the rest of the village

(McMillan & St. Claire, 2005, p. 9). *Sebastes* from this area show a decrease in total length, as well as decreases in abundance and density (Fig. 3), suggesting that inhabitants in this relatively young area of the village exhibited a negative impact on the rockfish populations they exploited, over a relatively short period of occupancy.

The decline in abundance and density of *Sebastes* in all three areas during the final period of occupation (750–250 BP) indicates decreased use of this previously important fishery resource throughout the village (Fig. 3). Simultaneously, areas B and C show marked increases in the abundance and density of *Oncorhynchus* spp. (salmon), and area C also shows increases in *Ophiodon elongatus*, Girard, 1854 (lingcod) and *Scorpaenichthys marmoratus* Ayres, 1854 (cabezon) in the excavation unit assemblage (Table 1). In area A, however, reduced *Sebastes* abundance is associated with increases in the abundance of *Rhacochilus vacca*, Girard, 1855, Embiotocidae (perch) and *Hexagrammos* spp. (greenling) in the excavation unit assemblage. These changes suggest different responses throughout the village to declines in *Sebastes*.

### Implications for conservation

Despite recently documented coast-wide declines in *Sebastes* body size and abundance (Levin et al., 2006), mean total length in the modern recreational catch from Barkley Sound is significantly larger than in the archaeological assemblage, representing some 1500 years of continual exploitation (Fig. 4). This comparison has considerable relevance to contemporary issues of fisheries management.

Older female *Sebastes* have up to 10 times the reproductive output (larval abundance and survival) than younger fish (Berkeley, & Chapman et al., 2004), which exposes the futility of minimum-size limits to conserve or sustain inshore fish populations (Birkeland & Dayton, 2005). Considering the increased commercial and recreational fishing effort in recent decades and the fact that *Sebastes* have high catch and release mortality (Department of Fisheries & Oceans, 2000), it is not surprising that many populations are facing human-induced population crises (Levin et al., 2006).

Irrespective of possible conservation intentions of aboriginal fishers (cf. Hunn, Johnson, Russell, & Thornton, 2003), there is clear ecological relevance in targeting smaller-sized *Sebastes* which have less reproductive potential than larger (and older) fish. Visual comparison with a generic level *Sebastes*

growth curve suggests that the majority of specimens from the archaeological assemblage are younger than 20 years (Helser, Stewart, & Lai, 2007, p. 476). Targeting smaller (and younger) fish would facilitate a higher overall catch rate without removing reproductively potent older fish, and it also allows younger fish to recruit to a productive (and regularly fished) habitat more readily. Since a responsibility of aboriginal group leaders was to successfully manage the harvesting of resources within defined territories by controlling access and amounts captured (Drucker, 1951; Trosper, 2002), such harvesting practices would have direct benefits to both leaders and the village inhabitants as a whole. However, even if such prehistoric management practices were in place, they do not appear to have fully mitigated *Sebastes* depletion over the long-term, particularly in the oldest area of the village (area A).

### Conclusion

Aboriginal inhabitants at Ts'ishaa Village successfully sustained a marine fishery for at least 1500 years. Assuming 20 years per human generation, this represents ~75 generations of direct human participation in the Barkley Sound marine ecosystem. This stands in marked contrast to the dramatic and potentially catastrophic fishery declines witnessed during the past 40 years throughout the Pacific Coast of North America. Although the ecological impacts of modern fishing are dramatically greater than in the past, so too are the human populations who are now facing the long-term consequences (Pauly, Watson, & Alder, 2005).

Similarly, but on a much smaller scale, the social and economic circumstances faced by the ancient inhabitants of Ts'ishaa appear to have successfully confronted the consequences of intensively utilizing vulnerable resources over the long-term. However, differing trends in *Sebastes* length from separate locations within this ancient village suggests that various resource management practices occurred within this single village community. If so, these differing approaches to fishing may provide a context in which TEK was generated or called upon (cf. Turner & Birkes, 2006). By examining the archaeological and cultural context of this ancient fishing community, this study suggests it is possible to rediscover and reapply some of those principals and practices towards the restoration of currently impacted marine ecosystems.

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