The Sablefish (*Anoplopoma fimbria*) of Čḯxwicən: Socioenvironmental Lessons From an Unusually Abundant Species

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The sablefish (Anoplopoma fimbria) of Ĭxʷicians: Socioenvironmental lessons from an unusually abundant species

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A B S T R A C T

We analyzed sablefish (Anoplopoma fimbria) remains from Ĭxʷicians (pronounced ch-WHEET-son), a 2700 year-old ancestral village of the Lower Elwha Klallam Tribe in northwest Washington state, U.S.A., to improve understanding of how this species was used by Native American/First Nations peoples in the past. Though sablefish are abundant at Ĭxʷicians, and limited ethnographic accounts indicate they were highly prized in northwestern North America, their remains are rare in regional archaeology. We present a body-size regression model for estimating the fork length (FL) of archaeologically represented sablefish and determining which habitats they were captured from (i.e. shallow, nearshore waters as juveniles or deepwater, offshore sites as adults). FL estimates for sablefish remains from Ĭxʷicians indicate the site occupants exclusively targeted inshore juveniles. Comparisons of sablefish abundances over time show juvenile sablefish were reliably and sustainably harvested over the duration of the site’s occupation despite major environmental perturbation from regional climate change and tectonic disturbances. However, patterns of sablefish use differ in two Ĭxʷician households, suggesting access to and consumption of sablefish was socially mediated.

1. Introduction

Analysis of archaeological fishbone from Ĭxʷicians (pronounced ch-WHEET-son), a large Native American village on the coast of Washington State, U.S.A. (Fig. 1), shows that sablefish (Anoplopoma fimbria, also commonly marketed as black cod), is the third most abundant fish taxon represented at the site (3209 NISP out of a total 44,763 NISP). Considering that sablefish are scarce or absent from all other archaeological sites in northwestern North America (Nims and Butler, 2018), we were initially perplexed that the species is so abundant at Ĭxʷicians. Now that we know more about the species, we seek to understand why it is not more common elsewhere. Today, sablefish occupies nearly every North Pacific habitat over the course of its life span, from the extreme depths of continental slopes to inshore waters, where young-of-the-year are easily caught by hand-jigging (Echave et al., 2013). The species is also extremely nutritious (U.S. Department of Agriculture, 2014) and we expect sablefish would have been sought after wherever they were available.

Ethnographic and historic evidence for sablefish capture in the region is lacking, with only a few exceptions. Available records show that adult sablefish were especially prized on Haida Gwaii (Fig. 1) where Haida fished for them with specialized bentwood hooks (Blackman, 1990; Hobler, 1978; Swan, 1887). Further evidence for sablefish use among Haida was recorded in a story told by John Sky (in Swanton, 1905) that includes the expression, “Does the black cod stick you here?” According to Swanton (1905, p. 225), the question refers to the exclusive availability of ‘black cod’ on the west coast of Haida Gwaii, which was so highly regarded that visitors, including the story’s main character, would delay departure from the region. Arima and Dewhirst (1990, p. 397) mention that groups of Nuu-chah-nulth and Ditidaht on the west coast of Vancouver Island (Fig. 1) captured ‘sablefish’ and ‘lingcod’ with lures and harpoons or dipnets from canoes. Finally, James Swan (1887) noted in the late nineteenth century that sablefish were highly valued by peoples living on the Strait of Juan de Fuca (Fig. 1), and that it was a common bycatch in European and Native American/First Nations commercial fisheries that was occasionally taken in large volumes. Swan (1887) also states that Native American/First Nations peoples along the Strait of Juan de Fuca only desired mature sablefish, which are typically captured at depths of 100 m to 1400 m and grow to over a meter in length (Head et al., 2014; Love, 2011; Pearson and Shaw, 2004). Thus, adults were pursued with long-line fishing methods as luxury items for chiefs, but only infrequently
variability in juvenile sable
Another important factor to consider is the high degree of spatial variations in juvenile sable abundance observed in southeast Alaska found at John Baptist Bay (Rutecki and Varosi, 1997a). Why sable are only consistently present in large numbers at one location, St. John Baptist Bay (Rutecki and Varosi, 1997a) is unknown, but Coutré (2014) suggests that sable might be entrained in specific places as larvae. As sablefish occupy different habitats at particular stages of their life history, we aimed to improve our understanding of the ecological contexts of sablefish capture in the past by studying the population structures of archaeological sablefish. Here, we present a method for estimating the body-size of sablefish from the size of their vertebrae and apply it to the Cix*ican collection to explore the ecological contexts of sablefish capture. We also examine the patterns in sablefish abundances over time at Cix*ican and in two separate households from the site to explore the socioenvironmental factors that affect sablefish representation. Finally, we apply insights from Cix*ican to the question of sablefish’s widespread scarcity in northwest North American archaeology.

2. Sablefish life history

Sablefish make two ontogenetic migrations during their early life history. First, larvae hatch from eggs on continental slopes in February or March and then migrate to the shoreline along the surface of the ocean during their first summer, developing into juvenile fish along the way (Kendall and Matarese, 1987; Mason et al., 1983; McFarlane and Beamish, 1983; Wing, 1997). Annual migrations of juveniles arrive in nearshore and inshore waters by September or October, where they reside for one or two years. Second, sablefish leave inshore waters after their second summer for the continental slopes and move progressively deeper as they mature and grow larger (Courtney and Rutecki, 2011; Maloney and Sigler, 2008; Rutecki and Varosi, 1997a, 1997b). These two migrations effectively separate sablefish life history into three distinct habitat regimes: offshore epipelagic (i.e. inhabiting the oceanic zone illuminated by sunlight), inshore demersal (i.e. bottom-dwelling), and offshore demersal.

Because sablefish body-size and growth rates are closely related to age, with rapid growth in the first few years of life followed by slow or zero growth after reaching maturity (Echave et al., 2012; Hanselman et al., 2015; Head et al., 2014), sablefish life-stage and habitat regime can be identified by body-size alone (Maloney and Sigler, 2008; Rutecki and Varosi, 1997b). Based on studies from southeast Alaska to California, juveniles arriving in inshore waters typically measure between 20 cm and 30 cm length (Bell and Gharrett, 1945; Edson, 1954) with average lengths of 21 cm to 23 cm in southeast Alaska (Rutecki and Varosi, 1997a). By the end of their first summer, when sablefish begin migrating to offshore waters, sablefish in the same region grow to average lengths of 35 cm to 39 cm (Rutecki and Varosi, 1997b, 1997a). From these observations, we classify any sablefish measuring between 20 cm and 40 cm as inshore demersal juveniles, with smaller fish falling into the offshore epipelagic category (Table 1). Though some juveniles measuring up to 60 cm may reside in inshore waters for an additional year or two (Rutecki and Varosi, 1997a), we classify any larger sablefish as offshore demersal.
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atlas and other vertebra types and used size-frequencies for the former
variation. Instead, we calculated separate regression models for the
vertebrae – centrum size is consistent for abdominal vertebrae, but not for caudal
vertebral column. Our observations of sable
focus on the atlas and abdominal vertebrae alone.
dramatic decreases in size towards the caudal end of the vertebral
elements of sable
used vertebrae for our regressions because these are the only skeletal
3.1. Sable

Table 1
Sablefish life stages by habitat regime and body-size.

| Life stage | Habitat regime | Fork length (cm) | Citation |
|------------|----------------|-----------------|----------|
| Egg        | Offshore pelagic | n/a             | Kendall and Matarese (1987) |
| Larvae     | Offshore pelagic | < 3.5           | Rutecki and Varosi (1997a, 1997b) |
| Offshore   | epipelagic      | 3.5–20          |          |
| Juvenile   | Inshore demersal | 20–40           |          |
| Offshore   | demersal        | 40–54           |          |
| Adult      | Offshore demersal | > 54           | Head et al. (2014) |

*a Length at which 50% of sablefish reach maturity.

3. Methods and materials

3.1. Sablefish body-size regression

To estimate sablefish body-size, we calculated linear regression models relating fork length (FL) to the height of vertebral centra. We
used vertebrae for our regressions because these are the only skeletal
elements of sablefish represented in substantial numbers at Čixįcatonic, but this approach comes with two potential issues. First, if vertebrae
from some fish survive in higher proportions than others they will be
disproportionately represented in size-frequency distributions. We
could control for this problem by estimating body-size with the atlas
alone, but only 86 atlas specimens were identified among the 3209
sablefish specimens in the Čixįcatonic fishbone collection (2.7% NISP_sablefish). This sample is large enough to provide an overall pattern
of sablefish size frequencies, but it is too small to examine intra-site
variation. Instead, we calculated separate regression models for the
atlas and other vertebra types and used size-frequencies for the former
to test whether there are any biases in the latter.

Second, teleost vertebral columns exhibit extensive morphological
variability within individual skeletons, and the dimensions of the vertebral centrum are not consistent across all vertebrae in any individual.
In other words, the size of any given vertebra could be a function of
both its allometric relationship to body-size and its position in the vertebral column. Our observations of sablefish vertebrae suggest that
centrum size is consistent for abdominal vertebrae, but not for caudal vertebrae – vertebrae that possess a haemal arch (Fig. 2) – which shows
dramatic decreases in size towards the caudal end of the vertebral column. Therefore, we exclude caudal vertebrae from our analysis and
focus on the atlas and abdominal vertebrae alone.

Our reference sample of modern sablefish consisted of 11 individual
fish. While minimum sample sizes of 30 to 40 individuals are preferred when performing regression, acceptable models of this type have been
produced in the past with as few as 12 reference specimens (Orchard, 2001, pp. 69, 71; Reitz et al., 1987, Table 3). One sablefish was
collected from St. John Baptist Bay by Dana Hanselman (Alaska Fisheries
Science Center, National Oceanic and Atmospheric Administration),
and an additional 10 unprovenienced individuals were provided by Dan
Kamikawa (Northwest Fisheries Science Center, NOAA). FL in the
reference sample ranged from 32 cm to 60 cm (x = 44 cm) (Table 2).
Prior to collecting our vertebral measurements, Butler prepared two
sablefish skeletons (PSU 13-2-1 and PSU 13-2-2) by warm-water ma-
ceration, and Nims extracted abdominal vertebrae from the remaining
sablefish after baking them under several layers of aluminum foil at
175 °C for 30 min.

Nims used Mitutoyo CD-6 CX digital calipers to record the max-
imum height of each vertebral centrum (Fig. 2; Table 2; Supplementary
Table 1). Measurements for the atlas were collected three times and
then averaged. Measurements for abdominal vertebrae were collected
once, and then averaged across all abdominal vertebrae from each in-
dividual. All outlier heights were re-measured to check for measure-
ment error. Comparing the heights of abdominal vertebrae across the
vertebral column shows that variability is very low across all indi-
dividuals (Fig. 3; Table 2). Based on these observations, we are con-
fident that average abdominal centrum height provides an accurate
measure for regression analysis.

Using R version 3.4.2, we created linear regression models com-
paring FL to the atlas centrum height and average abdominal centrum
height (Table 3; Fig. 4). For comparison, Nims also calculated models
comparing FL to measures of centrum width and length. All six models
show statistically significant (p < 0.05) and practically significant
(high R² values) relationships between FL and centrum dimensions, but
as regression models based on centrum height provided the best fit
(Table 3) we only used these when estimating the FL of Čixįcatonic sa-
befish specimens.

One limitation of these models is that our reference set of modern
sablefish only represents a fraction of the juvenile size-classes that are
of interest; our smallest reference fish has a FL of 32 cm, but sablefish
measure around 20 cm when they end their shoreward migration. If
there is a change in the allometric relationship between vertebral size
and body-size between lengths of about 20 cm and 32 cm, our regres-
sion models would make inaccurate FL predictions for smaller juve-
niles, potentially leading to incorrect assessments of habitat use.
Fortunately, there is no reason to expect that this relationship would
change over the juvenile life-stage, and our reference set shows no
evidence that the relationship changes between the adult and juvenile
life-stages. Therefore, we confidently assume that our model can ac-
curately predict FL from sablefish smaller than 32 cm, though in the
future we hope to expand the sample size of our reference set to include
smaller juveniles, especially those smaller than 20 cm FL.

3.2. Čixįcatonic materials

The Čixįcatonic faunal collection comes from a large excavation pro-
ject carried out by Larson Anthropological Archaeological Services
(LAAS) and LEKT members in 2004 (Reetz et al., 2006). All excavated
matrix was collected in 10 L buckets and wet-screened through nested
1" (25.6 mm), 1/2" (12.8 mm), and 1/4" (6.4 mm) mesh. At least one
10 L bucket from each micro-stratum identified in the field was also
screened through 1/8" (3.2 mm) mesh and designated a ‘complete’
("C") bucket. The fishbone collection used in this study was analyzed
during a large-scale zooarchaeological and georegional analysis initi-
ated by Butler, Kristine Bovy (University of Rhode Island), Sarah
Campbell (Western Washington University [WWU]), Mike Etner
(WWU), and Sarah Sterling (Portland State University) that focused on
animal remains recovered from two plankhouse structures, and extru-
mural activity and midden areas at Čixįcatonic (for a full history of the
Čixįcatonic mitigation project, see Butler et al., 2018a, this issue; and
for overall faunal analysis and sampling, see Butler et al., 2018b, this issue).

Butler directed analysis of the fishbone assemblage at PSU from
2012 to 2015 following QC/QA protocols that are consistent with
Driver’s (2011) recommendations. PSU master’s students Kathryn
Mohlenhoff, Anthony Hofkamp, Shoshana Rosenberg, and Nims iden-
tified fish remains from “C” buckets (and other sample types), and
Butler verified and often adjusted all initial identifications under
magnification. For a full account of fishbone identification methods and
protocols, see Butler et al. (2018c). To evaluate the reproducibility of
the Čixįcatonic fishbone identifications, Nims and Butler (2017) con-
ducted a blind reanalysis of 14 “C” buckets (140 L) from three stages of
the project and found that our results are highly reproducible.

The analyzed fishbone from Čixįcatonic represents seven chron-
ological zones (CZs) of activity spanning the last 2150 years (Fig. 5;
Campbell et al., 2018, this issue). In this study, we compare patterns of
sablefish representation between CZ’s (Table 4) – and to general pat-
terns in regional environmental history (Fig. 5) – to explore whether the
climate shifts and tectonic events discussed by Hutchinson et al. (2018, this issue) affected catches of sablefish. Here, we assume that local at-
mospheric and marine temperatures are correlated, and this assumption

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is supported by long-term reconstructions of oceanic sea surface temperatures (SST) at global and ocean-basin scales (McGregor et al., 2015). McGregor et al.’s synthesis of SST records for the past 2000 years shows a cooling trend in Pacific Ocean waters from 1850 to 1450 BP, followed by a warming period with peak temperatures around 850 BP, and another cooling phase that lasted from 650 to 50 BP. As these trends closely match local reconstructions for atmospheric trends, we use changes in atmospheric temperatures as a proxy for marine SST. We also contrast patterns of sablefish representation in two households to explore whether sablefish abundances reflect social differences. Excavations at ĺįxʷič reveals remains from two separate plankhouses in Area A1 and Area A4 of the site (Fig. 6). The house in Area A4 was first established during CZ 4 (Fig. 5), and two distinct floor deposits (Floor 1 and Floor 2) date to this period of occupation. Subsequent floor levels from this house date to CZ 5 (Floor 3) and CZ 6 (Floor 4) (Campbell et al., 2018, this issue). The house in Area A1 was first established during CZ 5, after the Area A4 household formed (Fig. 5), and it also contains floor deposits that date to CZ 5 (Floor 1) and CZ 6 (Floor 2). Given the contemporaneous occupations, we compare sablefish use between the two households for CZ 5 and CZ 6 (Table 5).

Nims measured the centrum height of all sablefish atlases and abdominal vertebrae in the ĺįxʷič fishbone collection with at least one intact centrum face. All vertebrae were recorded three times, and then averaged (Supplementary Table 2). If there was noticeable disagreement between the three measurements for any specimen, Nims

![Fig. 2. Rostral and lateral aspects of sablefish vertebrae and the dimensions used in our body-size regression models: H = height, W = width, L = length. We present separate regression models for the atlas (a) and abdominal vertebral (b, c). No models were developed for caudal vertebra (d).](image)

| Accession number | FL (cm) | Atlas height (mm) | Abdominal vertebrae |
|------------------|---------|------------------|---------------------|
| PSU 13-2-1       | 34.8    | 4.34             | 26                  |
| PSU 13-2-2       | 37.4    | 4.71             | 26                  |
| PSU 15-1-1       | 37.0    | 4.86             | 27                  |
| PSU 15-1-2       | 56.0    | 7.18             | 27                  |
| PSU 15-1-3       | 45.3    | 5.87             | 28                  |
| PSU 15-1-4       | 60.0    | 8.70             | 23                  |
| PSU 15-1-5       | 45.0    | 6.02             | 25                  |
| PSU 15-1-6       | 41.3    | 5.40             | 25                  |
| PSU 15-1-7       | 32.0    | 3.97             | 25                  |
| PSU 15-1-8       | 34.5    | 4.66             | 28                  |
| PSU 15-1-9       | 35.5    | 4.57             | 26                  |

| Number measured | Average height (mm) | Min. | Max. | Std. Dev. (mm) | CV (%) |
|-----------------|---------------------|------|------|----------------|--------|
| 26              | 4.25                | 4.14 | 4.46 | 0.09           | 2.1    |
| 26              | 4.67                | 4.50 | 4.88 | 0.10           | 2.1    |
| 27              | 4.63                | 4.42 | 4.84 | 0.13           | 2.8    |
| 27              | 6.65                | 6.32 | 6.93 | 0.17           | 2.6    |
| 28              | 5.69                | 5.56 | 5.81 | 0.08           | 1.4    |
| 23              | 8.02                | 7.83 | 8.46 | 0.18           | 2.2    |
| 25              | 6.12                | 5.96 | 6.38 | 0.09           | 1.5    |
| 25              | 5.23                | 5.07 | 5.37 | 0.08           | 1.5    |
| 25              | 3.92                | 3.76 | 4.05 | 0.06           | 1.5    |
| 28              | 4.53                | 4.36 | 4.81 | 0.12           | 2.6    |
| 26              | 4.50                | 4.33 | 4.68 | 0.09           | 2.0    |
discarded the values and repeated the measurement. We calculated FL estimates from the average of the three trials using the linear model appropriate for the given element with R version 3.4.2.

4. Results

4.1. Sablefish size-frequency distributions

The FL estimates for all measurable sablefish vertebrae from Čišćenica fall into the demersal stage of juvenile sablefish life history between 20 cm and 40 cm FL (Fig. 7; Table 1). A total of 41 atlas

Table 3
Summary of linear regression models calculated for sablefish body-size estimation. Models shown in bold provide the best fit based on $R^2$ values. (“Abd.” = abdominal).

| Dependent variable | Independent variable | Coefficient | Intercept | df | $F$ | $p$ | $R^2$ |
|--------------------|----------------------|-------------|-----------|----|-----|-----|-------|
| Fork length        | Atlas height         | 64.408      | 64.603    | 1, 9 | 269.5 | < 0.001 | 0.967 |
|                    | Atlas width          | 54.534      | 81.854    | 1, 9 | 114.6 | < 0.001 | 0.927 |
|                    | Atlas length         | 80.749      | 92.919    | 1, 9 | 106.3 | < 0.001 | 0.921 |
|                    | Abd. vertebra height | 72.819      | 31.746    | 1, 9 | 216.3 | < 0.001 | 0.960 |
|                    | Abd. vertebra width  | 63.393      | 71.022    | 1, 9 | 138.7 | < 0.001 | 0.939 |
|                    | Abd. vertebra length | 71.472      | 101.316   | 1, 9 | 72.66 | < 0.001 | 0.889 |

Table 4
Sample size for all fish specimens in NISP and volume of “C” buckets analyzed (L) for each CZ at Čišćenica.

| CZ  | Sample size (NISP) | Volume (L) |
|-----|--------------------|------------|
| CZ 7 | 841                | 130        |
| CZ 6 | 29,140             | 1280       |
| CZ 5 | 8815               | 1010       |
| CZ 4 | 3226               | 590        |
| CZ 3 | 1040               | 670        |
| CZ 2 | 274                | 370        |
| CZ 1 | 32                 | 280        |
| Total| 43,663             | 4330       |

Fig. 3. Heights of abdominal vertebral centra from modern sablefish reference specimens.

Fig. 4. Linear regression models for sablefish fork length and (A) height of atlas vertebral centrum, and (B) average height of abdominal centrum.

Fig. 5. Chronology of the Čišćenica fishbone assemblages, household occupation, and major environmental events (Hutchinson et al., 2018, this issue). LAIA = Late Antique Little Ice Age; MWP = Medieval Warm Period; LIA = Little Ice Age.
specimens and 1074 abdominal vertebrae were intact enough to measure, with a remaining 2023 vertebral specimens that were either fragmented, crushed, or identified as caudal vertebrae.

As individual sablefish have approximately 26 abdominal vertebrae each (Supplementary Table 1), we compared the FL estimates calculated from the atlas to those of the abdominal vertebrae to check whether the abdominal vertebrae size-distributions are biased by differential survivorship of vertebrae from different size-classes. We used Welch’s unequal variances t-test to compare the mean FL estimates from atlases (mean FL = 28.1 ± 1.9 cm) and abdominal vertebrae (mean FL = 27.7 ± 2.7 cm); Welch’s t-test is more robust than Student’s t-test of independent samples when samples have unequal variances or sample sizes. The test results show there is no statistical difference between the two vertebral type samples (t = 1.13, df = 46.51, p = 0.264), and the difference of 0.4 cm in mean FL has no practical significance (Cohen’s d = 0.129; see Wolverton et al., 2016 for more on practical significance).

Combining atlas and abdominal vertebra FL estimates into a single size-frequency distribution shows a strongly unimodal distribution in each (Supplementary Table 1).
the sablefish catch at Číxwícan (Table 6; Fig. 8). The mean FL of 27.7 ± 2.6 cm suggests sablefish were captured in the period between fall, when juveniles first arrive inshore, and their second summer, when southeast Alaskan sablefish approach average lengths of 30 cm (Rutecki and Varosi, 1997a). The same pattern is evident across all CZ's that have a minimum sample size of 29 NISP, which show < 1 cm of variation in mean FL for all sablefish captured across 1500 years of Číxwícan’s occupation (Fig. 9; Table 6).

| CZ   | Sample size (NISP) | Mean FL (cm) | Standard deviation |
|------|--------------------|--------------|--------------------|
| CZ 7 | 29                 | 27.8         | 2.9                |
| CZ 6 | 532                | 27.4         | 2.6                |
| CZ 5 | 282                | 28.0         | 2.6                |
| CZ 4 | 186                | 28.2         | 2.6                |
| CZ 3 | 49                 | 28.2         | 2.2                |
| CZ 2 | 5                  | 27.5         | 1.6                |
| NPAa | 32                 | 27.2         | 2.5                |
| Total| 1115               | 27.7         | 2.6                |

* Not assigned to CZ.

4.2. Spatio-temporal variation in sablefish abundance

Sablefish relative abundance varies moderately throughout the occupation of Číxwícan (Fig. 10). Sablefish is ranked as the sixth most common fish taxon in CZ 1, and then falls to seventh most common in CZ 2, though its proportional representation does not change. From CZ 3, sablefish rank-order increases to the third most common fish and then alternates between second and third most abundant in the remaining four CZ’s. While herring (Clupea pallasii) clearly dominate the Číxwícan fishbone record, these distributions show that juvenile sablefish – along with flatfishes (Pleuronectiformes), salmonoids (Oncorhynchus sp.), staghorn sculpin (Leptocottus armatus), and dogfish shark (Squalus suckleyi) – were a key and reliable fish species for 2150 years (Fig. 10).

Comparing this pattern with regional histories of climate trends and earthquake events (Fig. 5) shows these processes had little to no long-term effect on sablefish catches at Číxwícan. Current research on sablefish population dynamics has revealed complex relationships between year-class strength and environmental factors (Echave et al., 2012; McFarlane et al., 1997; Shotwell et al., 2014; Sogard, 2011). On one hand, growth rates in larval and early juvenile-stage sablefish increase with sea surface temperature (SST), enhancing year-class strength (McFarlane et al., 1997; Sogard, 2011). However, Shotwell et al. (2014) concluded that increases in primary productivity associated with cooler SSTs are a more important control on sablefish recruitment. Therefore, we assume that cooler periods would enhance sablefish year-class strength and encounter rates. Using atmospheric trends as a proxy for SST (see above), sablefish abundance might be expected to increase at Číxwícan during the Late Antique Little Ice Age (~1600–1250 cal BP in this region [after Hutchinson et al., 2018, this issue]) and the Little Ice Age (~750–250 cal BP) (Fig. 5). These cool periods overlap with every CZ at Číxwícan except CZ 1, making it difficult to compare changes in these assemblages to changes in climate.
regime. However, the absence of any noticeable change during CZ 4 and CZ 5, which overlap more with the Medieval Warm Period (~1250–750 cal BP) than either cool period, suggests changes in climate did not appreciably affect human capture rates of juvenile sablefish.

Meanwhile, there is no a priori reason to suspect that sablefish populations would be affected by earthquake or tsunami events for more than a season. As adults reside and spawn offshore, any short-term disruptions to inshore environments could only affect a single year-class of juveniles. Tectonic events could affect sablefish catch sizes indirectly if the fishing gear or watercraft necessary for fishing in waters 20 m to 60 m deep were lost or destroyed in a tsunami, but this would only have a long-term effect in the event that people did not replace their equipment and stopped fishing from boats. While there is clear evidence of variation in occupation intensity at Ħixʷ on following earthquake event “U” (Hutchinson et al., 2018, this issue), the consistency in sablefish representation over this period shows that village inhabitants were able to procure juvenile sablefish at the same rates as before (Fig. 10).

Despite the overall consistency in sablefish relative abundance from CZ 4 to CZ 7 when the aggregated assemblage is considered (Fig. 10), there are differences in sablefish representation over the occupation of the two houses associated with Areas A1 and A4 of Ħixʷ (Fig. 11), suggesting social factors mediated fish use. Butler et al. (2018b, this issue) have examined all animal classes to explore whether households were autonomous or communal in resource use. They predict households that operate more communally – sharing gear or access to harvest areas or captured fish – would generate faunal deposits that are more similar relative to households that operate autonomously. In CZ 5, Butler et al. (2018b, this issue) found that fish use was relatively consistent between households, suggesting a communal social structure. In CZ 6, the pattern changes, with stark differences in fish representation between houses, suggesting a more autonomous social structure.

The sablefish record between households and CZs is consistent with this broader pattern in fish representation. In the earlier CZ 5, sablefish remains are modestly represented in both houses (Fig. 11). In CZ 6, sablefish representation differs greatly between households: sablefish is ranked second after herring in the Area A4 house, but it is ranked 10th in the Area A1 house. Butler et al. (2018b, this issue) analysis found that the two households also vary greatly during CZ 6 in representation of herring (A4: high; A1: low), staghorn sculpin (A4: low; A1: high), and salmon (A4: high; A1: low). Overall, the record shows that the households operated much more independently in the later time period. Given the ethnohistoric link of sablefish to prestige and gifting, higher abundances at Area A4 indicate occupants of this household may have had privileged access rights to sablefish or ownership of fishing grounds where young-of-the-year congregated. While the specific social factors involved remain uncertain, the contemporaneity and shared locality of the two households demonstrates these patterns are not linked to environmental drivers.

5. Discussion and conclusions

Our reconstructed sablefish body-size distributions reveal that Ħixʷ’s inhabitants fished exclusively for inshore demersal juveniles that today inhabit bays and inlets at depths of 20 m to 60 m (Fig. 8; Table 1). There is a clear unimodal distribution in sablefish FL estimates that suggest they were largely captured between late fall and spring. These juveniles are one of the most abundant fishes among a group of fish taxa that are consistently well-represented in each Ħixʷ fish-bone assemblage, and they provided a reliable resource through long-term climate shifts and short-term socio-environmental disruptions caused by tectonic events (Fig. 10).

These patterns provide an intriguing contrast with available ethnohistoric information about traditional sablefish use, which largely relate to mature sablefish. Swan’s (1887) observations specifically highlighted the importance of adult sablefish in the Salish Sea and cited their depth as a limiting factor in sablefish consumption. Discussions of sablefish at Haida Gwaii also imply that sablefish were primarily captured as adults with long-line trawls measuring up to 350 m in length (Hobler, 1978; Swan, 1887). However, Arima and Dewhirst’s (1990) account of fishing for sablefish with lures from canoes may indicate that sablefish were being captured as juveniles from western Vancouver Island as lures would only be effective for attracting demersal fishes in relatively shallow waters, which would not be inhabited by adults. Considering the ethnohistoric and the archaeological evidence together, it is clear that Native American/First Nations peoples in northwestern North America took sablefish using a variety of methods that intersected with a number of stages in sablefish life history. Importantly, our work highlights problems with over-reliance on ethnographic records in interpreting archaeological assemblages (for other examples, see Moss, 1993; Orchard and Wigen, 2016).

Regarding the social significance of sablefish, the evidence from Ħixʷ is consistent with Swan’s (1887) assertion that sablefish were a prized resource. Though the Ħixʷ catch is entirely composed of juveniles, and Swan (1887) argued that only mature sablefish were highly regarded by peoples living on the shores of the Strait of Juan de Fuca, sablefish are well represented throughout the site’s occupation (Fig. 10). We also observed marked differences in sablefish abundance that suggest household members associated with the Area A4 household may have had privileged access to sablefish. Differential access could arise directly through ownership of fishing grounds that sablefish
particular favor, or indirectly through greater access to watercraft, necessary fishing gear, labor, or other resources. Alternatively, if Swan's (1887) observation that sablefish were a chiefly luxury held true at Čxʷ, the higher frequencies of sablefish in Area A4 may reflect higher rates of gifting and/or tribute to the house's inhabitants.

While we are not in a position to answer our original question about why sablefish are so scarce in northwest North American archaeology, the insights from Čxʷ provide much needed context that can help guide future research on this topic. Importantly, the consistency in sablefish abundance at Čxʷ indicates the species can be productively and sustainably harvested at local scales for millennia, despite major shifts in climate and tectonic disruption. This suggests the absence of sablefish is probably not related to environmental perturbations, as sablefish and their juveniles are apparently able to tolerate a wide range of marine conditions. But if juvenile populations were as variable in the past as they are today, environmental factors could still play a role in determining the archaeological distributions of sablefish remains through their controls on year-class-strength and influencing where sablefish congregate. Unfortunately, these relationships remain poorly understood.

Our research also confirms our assumption that, at least in some contexts, sablefish were considered an attractive resource and some people may have had privileged access to the species. This could lead to high degrees of intra-site variation in sablefish deposition, affecting our ability to recognize sablefish archaeologically at sites where time and budget constraints prevent the implementation of an intensive sampling-strategy. However, sablefish at Čxʷ are widely distributed throughout the site, and the number of sablefish remains identified from Area A1 alone greatly outnumber the total number of sablefish remains recorded at all other northwestern North American archaeological sites despite the marked differences in relative abundance that we documented between the two houses. We doubt that intra-site variation in sablefish frequencies could be so extreme that sablefish would only be recovered from a single context, and it seems unlikely that intra-site variability in sablefish distribution accounts for the rarity of sablefish in most archaeological sites.

Finally, though the archaeological record presents an uninterrupted history of sablefish procurement by the inhabitants of Čxʷ, juvenile sablefish are not known to congregate in or around Čxʷ today. Most juvenile sablefish studies have focused their efforts on regions north of Vancouver Island (Kennedy and Smith, 1972; Mason et al., 1983; McFarlane and Beamish, 1983; Rutecki and Varosi, 1997a). It is not clear when juvenile sablefish stopped congregating in the vicinity of Čxʷ, or why they are no longer abundant, but future work on these questions could help resolve the factors that lead juveniles to their preferred nurseries. Combining such information with reconstructions of coastal environmental conditions could help predict where sablefish would or would not have congregated in the past, allowing us to test hypotheses about whether the archaeological scarcity of sablefish is related to the distribution of sablefish populations in the past.

Like other focused studies of individual fish taxa (e.g. herring - McKechnie et al., 2014; halibut - Orchard and Wigen, 2016; lampreys - Smith and Butler, 2008), we found that paying close attention to particular species like sablefish can deepen our understanding of, and our appreciation for, the people who skillfully managed these food webs in the past.

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