2015

Saffron Cod (Eleginus gracilis) in North Pacific Archaeology

Megan A. Partlow

Eric Munk

SAFFRON COD (*ELEGINUS GRACILIS*) IN NORTH PACIFIC ARCHAEOLOGY

Megan A. Partlow
Department of Anthropology, Central Washington University, Ellensburg, WA 98926; partlow@kvalley.com

Eric Munk
Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic Atmospheric Administration, Kodiak, AK 99615; retired; emunk@gci.net

ABSTRACT

Saffron cod (*Eleginus gracilis*) is a marine species often found in shallow, brackish water in the Bering Sea, although it can occur as far southeast as Sitka, Alaska. Recently, we identified saffron cod remains in two ca. 500-year-old Afognak Island midden assemblages from the Kodiak Archipelago. We developed regression formulae to relate bone measurements to total length using thirty-five modern saffron cod specimens. The archaeological saffron cod remains appear to be from mature adults, measuring 22–45 cm in total length, and likely caught from shore during spawning. Saffron cod may have been an important winter resource for Alutiiq people living near the mouths of freshwater rivers. It is also possible that saffron cod were caught in late summer or fall during salmon fishing.

Detailed faunal analyses and the use of fine screens at a variety of archaeological sites have demonstrated a rich diversity of subsistence resources used by eastern North Pacific peoples in prehistory. The ethnohistoric record has clearly documented the importance of fish, especially Pacific salmon (*Oncorhynchus* spp.) and Pacific cod (*Gadus macrocephalus*), to native peoples living from the Aleutians south to the Washington coast (Birket-Smith 1953; Crowell and Laktonen 2001:176; Davydov 1977; De Laguna 1972, 1990a, 1990b; Holmberg 1985; Jochelson 2002:51; Langdon 1979; Lukin 2001; Mishler 2001; Oberg 1973; Turner 1886:89–90). Thousands of fish bones recovered from shell middens attest to the importance of salmon and Pacific cod to the prehistoric inhabitants (Cannon 1991; Knecht and Davis 2008; Maschner 1997; Partlow 2006; Partlow and Kopperl 2011; West 2009). However, there is increasing awareness both of the need to look at a variety of site types when characterizing a prehistoric regional economy (Cannon 1996; Cannon et al. 2011) and that differences in faunal assemblages may be explained simply by differences in local abundance and availability (Moss 2012). Analyses of fish remains from other types of fish, including herring (*Clupea pallasii*; Moss et al. 2011), anchovy (*Engraulis mordax*; McKechnie 2005), greenling (*Hexagrammus* spp.; Savinetsky et al. 2012), rockfish (*Sebastes* spp.; McKechnie 2007), starry flounder (*Platichthys stellatus*; Trost et al. 2011), sculpin (family Cottidae; Trost et al. 2011), and halibut (*Hippoglossus stenolepsis*; Moss 2008), have drawn attention to the importance of a wide range of fish species to the prehistoric inhabitants of the region. Nearshore fishes (e.g., greenlings, sculpins, starry flounders), in particular, may have been critical subsistence resources harvestable from shore when dangerous weather curtailed offshore fishing or when other resources were unavailable.

Recently, another nearshore species, saffron cod (*Eleginus gracilis*), has been identified in the Alaska archaeological record (Crockford 2012; McKinney 2013; Partlow and Kopperl 2011; Savinetsky et al. 2012). The goal of this paper is to provide regional archaeologists with more information about this recently documented species and its potential to inform us about the past. Specifically, we discuss its biology, the ethnographic and archaeological records, and provide information on identification and size estimation. With this discussion, we hope to start to address the role of saffron cod in the prehistoric economies of people living at these sites and to provide useful tools for future research in the region.

BIOLOGY AND MODERN USE

Saffron cod (*Eleginus gracilis*) is a cold-water nearshore marine species belonging to the cod order Gadiformes and cod family Gadidae (Mecklenburg et al. 2002:293). It is closely related to Pacific navaga (*Eleginus nawaga*), which has a different geographic distribution. Today, *E. nawaga* occurs primarily along the northern coast of Russia in the White, Barents, and Kara seas of the Arctic Ocean (Carr et al. 1999:20; Cohen et al. 1990:37), whereas *E. gracilis* has a more easterly and much wider distribution (Fig. 1). Saffron cod are abundant north of Siberia in the Chukchi and Bering seas, north and east along the arctic coasts of Alaska and Canada from the Beaufort Sea to the Coronation Gulf region, and can be found as far south as the Yellow Sea in the western North Pacific Ocean and Sitka, Alaska, in the eastern North Pacific (Bond and Erickson 1993; Cohen et al. 1990:35; Hopky and Ratynski 1983; Mecklenburg et al. 2002:293). Saffron cod have been commercially fished for over a century in the western portion of its range from the Chukchi Peninsula south to the Korean coast (Wolotira 1985). Commercial fishing of this species usually occurs during late fall and winter using hoop and pound nets set beneath shorefast ice (Wolotira 1985:26, 28). Although never commercially fished in Alaska waters, saffron cod are abundant north of the Alaska Peninsula today (Sutton and Steinacher 2012:79).

A shallow-water (< 60 m) fish, saffron cod are commonly found in brackish water and the lower reaches of coastal rivers (Mecklenburg et al. 2002:293; Wolotira 1985:17). They mature in their second or third year. In the western North Pacific, at three years of age, saffron cod average between 19 and 35 cm in total length (Wolotira 1985:24), although adults can reach 55 cm total length (Mecklenburg et al. 2002:293; Wolotira 1985:8). Although they spend the winter inshore and the summer somewhat offshore, they do not have extensive seasonal migrations (Wolotira 1985:7–8). Saffron cod move into shallower (< 30 m), often ice-covered, waters near river mouths, inlets, and into bays in the Bering and Chukchi seas in autumn and early winter for spawning (Lowry et al. 1983; Morrow 1980). For example, in parts of the Bering Sea, saffron cod have been found in large numbers in nearshore waters (≤ 30 m) starting in September and October (Lowry et al. 1983).

Far less is known about saffron cod in the eastern North Pacific. Juvenile saffron cod have been found in nearshore environments from spring to fall in Prince William Sound and the Kodiak Archipelago, where most

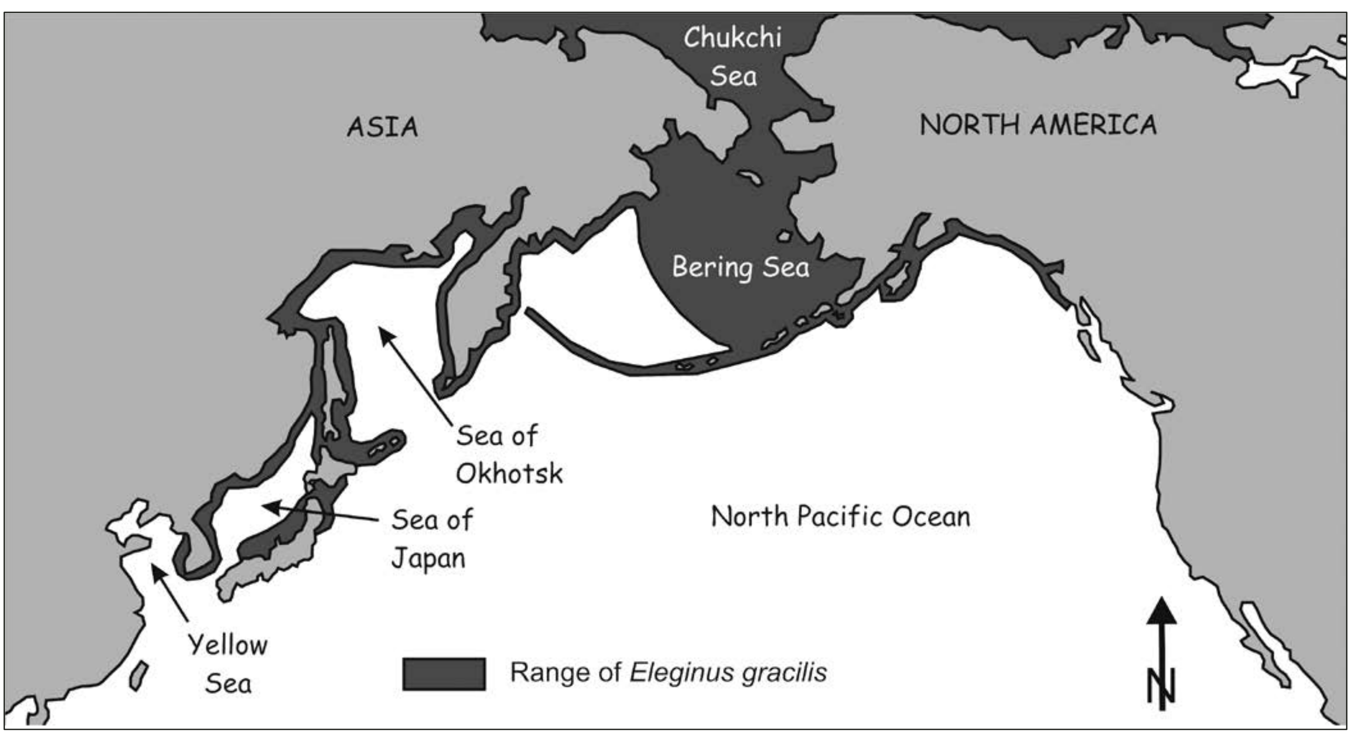

Figure 1. Modern range of saffron cod, adapted from National Oceanic and Atmospheric Administration (2007).

are associated with eelgrass habitat (Johnson et al. 2009; Johnson et al. 2010; Laurel et al. 2007). It is likely that adult saffron cod move nearshore during fall and winter for spawning. They have been caught with hook and line from shore in 1–5 m of water in summer and fall on Kodiak Island by one of us (Munk) for the last seven years. Most of the fish used for size estimation in this paper were obtained this way in 2007.

Other cod family species in the North Pacific include Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcograma*), and Pacific tomcod (*Microgadus proximus*). The first two species are very abundant, can grow to be quite large (Pacific cod can reach total lengths of over a meter), and are the target of commercial fisheries (Cohen et al. 1990; Mecklenburg et al. 2002). Both are widely distributed: Pacific cod range from southern California north and west through the Aleutians and south to the Yellow Sea (Cohen et al. 1990:42); walleye pollock range from central California north and west through the Aleutians and south to the Sea of Okhotsk (Cohen et al. 1990:74). By contrast, Pacific tomcod is much smaller (maximum total length of 37 cm, but usually smaller), less widely distributed (from central California north and east to the eastern Aleutians), and not commercially targeted (Cohen et al. 1990:58; Mecklenburg et al. 2002).

Saffron cod and Pacific navaga are most closely related to Pacific tomcod (*Microgadus proximus*). In fact, recent genetic studies have suggested that these two members of the genus *Eleginus* should be subsumed into the genus *Microgadus*; saffron cod would become *Microgadus gracilis* (Carr et al. 1999; Coulson et al. 2006; Owens 2015). Given this close relationship, it should not be surprising that saffron cod are sometimes confusingly referred to as "tomcod" in local parlance (Soong et al. 2008:32).

OSTEOLOGY

Saffron cod skeletal elements are distinct from other gadids in a number of ways and several elements can be readily identified in archaeological assemblages. The most apparent are expanded parapophyses of the precaudal vertebrae, which do not occur in other Alaska gadids (Mecklenburg et al. 2002:293). Saffron cod have these flaring ventral processes with distinct pockets on the ventral sides typically expressed on all precaudal vertebrae as well as the first three to five caudal vertebrae (Fig. 2), based on a sample of seven comparative skeletons from Kodiak Island.

Other elements are not so easily assigned to species and require a good reference collection. With such a collection, we found it possible to distinguish saffron cod from other

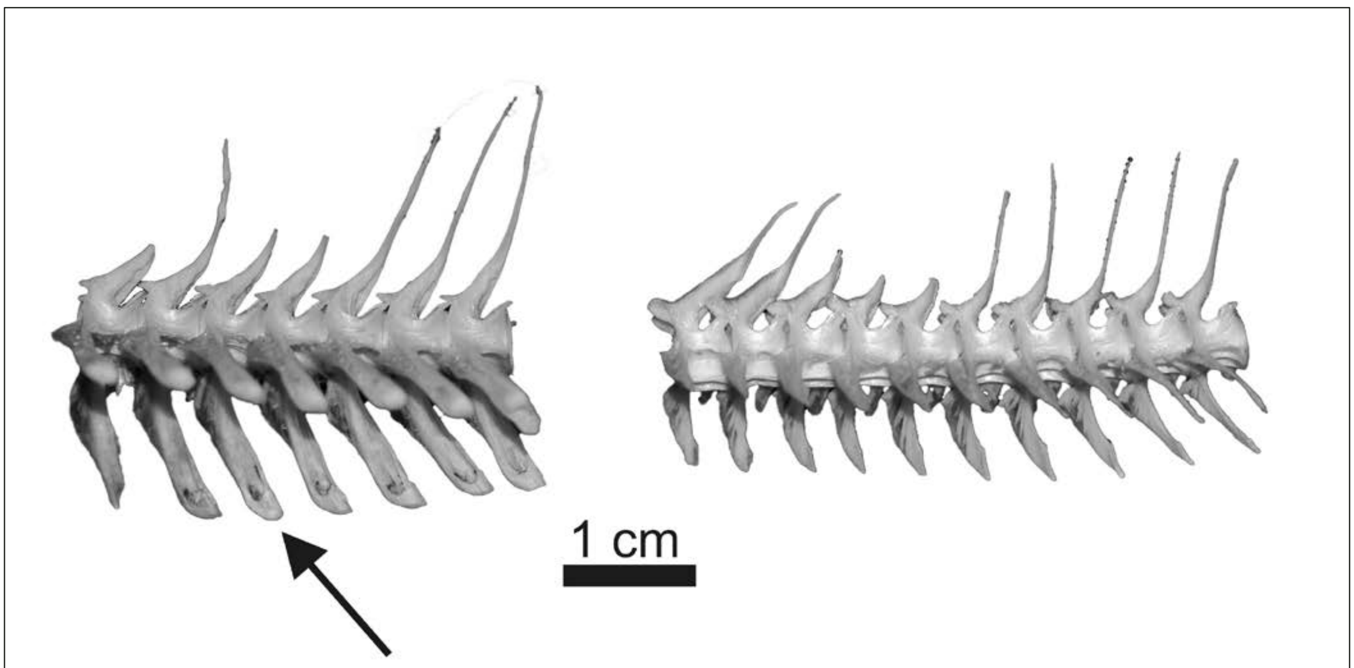

Figure 2. Saffron cod (left) and Pacific cod (right) articulated precaudal vertebrae. Note expanded parapophyses on saffron cod. Arrow indicates a parapophysis. Specimens PL-357 (left) and PL-154 (right).

cod species from the following skeletal elements: articular, basioccipital, dentary, epihyal, maxilla, parasphenoid, premaxilla, quadrate, and vomer. Figure 3 shows a diagnostic characteristic for each of the five most distinctive elements that can be used to differentiate between saffron cod and Pacific cod. This figure shows a small Pacific cod specimen comparable in size to the saffron cod in order to highlight their differences. This comparison was thought to be helpful since Pacific cod is so common in North Pacific archaeological assemblages (Partlow and Kopperl 2011). Saffron cod can also be distinguished from walleye pollock and tomcod based on these elements. An atlas describing distinguishing osteological characteristics for all the cod family species is beyond the scope of this article.

Cod family sagittal otoliths also vary by species. Harvey et al. (2000) provide photographs of otoliths from many North Pacific species, including gadids. The Pacific cod and walleye pollock otoliths are quite different from

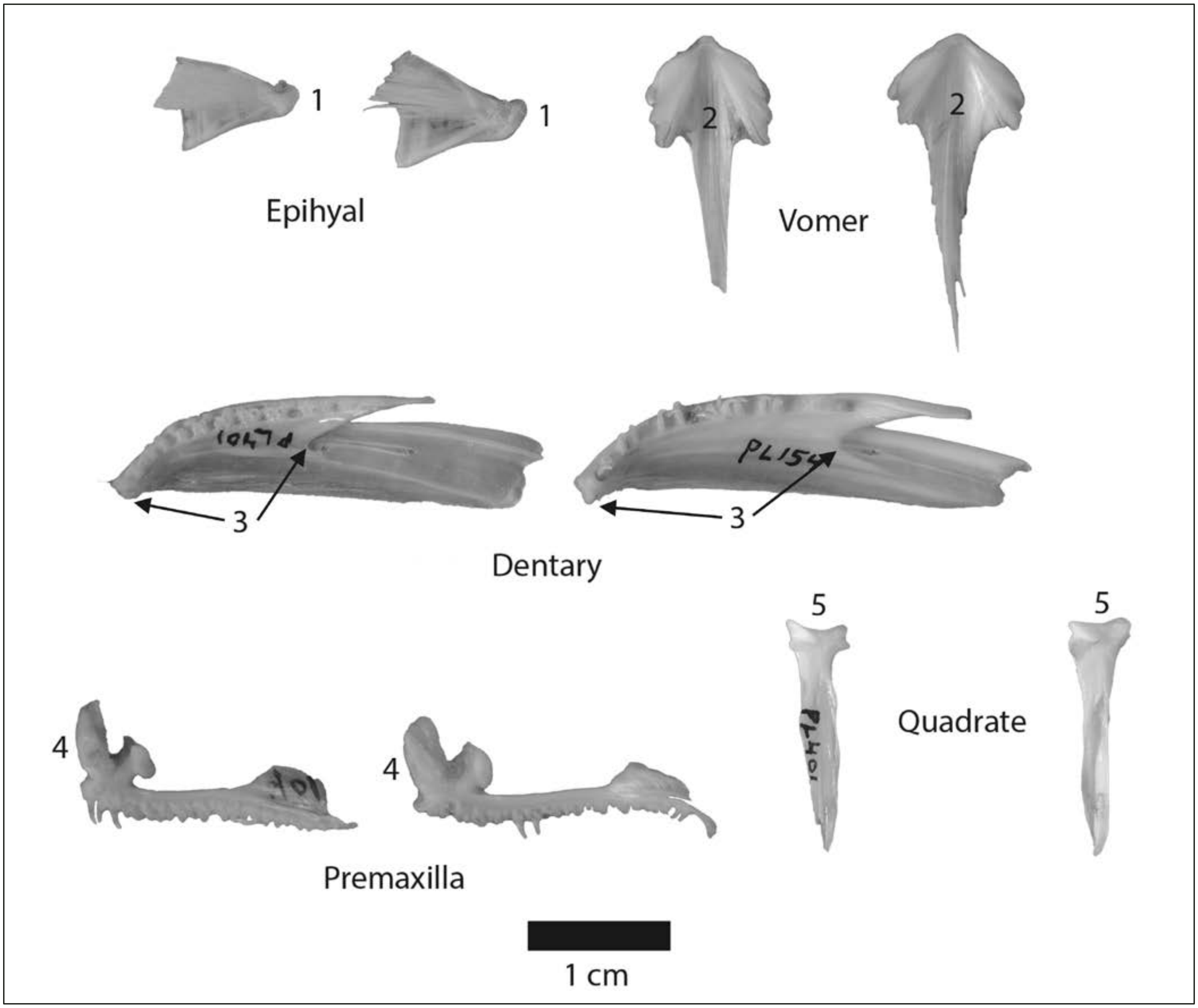

Figure 3. Pairs of the five elements from a comparative saffron cod (left of each pair) and Pacific cod (right), each showing an example distinguishing characteristic. Epihyal: the posterior process (1) is narrower in saffron cod. Vomer: the dorsal (nontoothed surface) has a narrower upside-down V-shaped cleft (2) in saffron cod. Dentary: the anterior-posterior diameter from the symphysis to the interior-posterior incision (3) is shorter in saffron cod. Premaxilla: the ascending process (4) is narrower and taller in saffron cod. Quadrate: the articulation (5) is more concave in saffron cod. All elements shown are right side. Saffron cod elements from specimen PL-401 (total length 35 cm) and Pacific cod elements from PL-154 (total length 30 cm).

saffron cod in these photographs and our comparative collection. However, the saffron cod and tomcod otoliths are quite similar, and the senior author did not feel comfortable separating them. All gadid otoliths are large compared to other North Pacific fishes, and saffron cod are no exception. For example, a comparative saffron cod (PL-401) with a total length of 35 cm has an otolith 18 mm long. Although otoliths are not bone, they are similar to shell and generally preserve well in shell middens (West 2009).

ETHNOGRAPHY

Finding saffron cod in the ethnographic and ethnohistoric record is complicated by the fact that observers may not have distinguished this species from other species of the cod family. The possibility that the term "cod" in the ethnohistoric literature may mean more than just Pacific cod has been suggested by several researchers working on the eastern North Pacific coast (e.g., Hanson 1995; Suttles 1990; Yarborough 2000). Using this idea, Sepez (2008:123) reconciles the presence of Pacific tomcod (*Microgadus proximus*) remains at the Ozette site in Washington with its absence in lists of subsistence resources used by contemporary Makah by arguing that Pacific tomcod were not distinguished from Pacific cod in surveys.

Despite this difficulty, there are accounts that specifically refer to saffron cod. For example, Turner (1886:90-92) referred to "*Tilesia gracilis*" (an obsolete scientific name for saffron cod) and wrote that it was called tomcod or *vakhnya* by people living on Unalaska Island in the Aleutians and in the Norton Sound region. Jochelson (1905:526) noted that "tom-cod (*Eleginus navaga*)" was used by the Koryak of the Kamchatka Peninsula in the late 1800s. While the species name given by Jochelson would refer to Pacific navaga today, it clearly refers to saffron cod based on current interpretations of the ranges of these two species.

Ethnographic accounts demonstrate that saffron cod were likely food fishes for many native peoples living along the Chukchi and Bering seas of Siberia and Alaska. In Siberia, they were caught with weighted nets in summer and through the ice with hook and line in winter and spring by the coastal Chukchi (Antropova and Kuznetsova 1964:809), as well as being used by the Koryak (Jochelson 1905:526). In Alaska there is a similar pattern. In the Seward Peninsula region, they were harvested as food for sled dogs as well as people in the late 1800s (Nelson 1983:16, 183, 267). Inupiaq men, women, and children caught "tomcod" ca. 1900 by jigging through the sea ice close to shore (Smith and Smith 2001:296, 300). Today in the same region, saffron cod, still locally known as tomcod, are an important subsistence resource, prized for their livers and caught by jigging through the ice or by gillnets in open water (Jones 2006; Soong et al. 2008:32, 52; Sutton and Steinacher 2012:79). Nome residents often catch as much as three to five 55-gallon-drums worth of saffron cod in one set, using beach seines as the fish move into shallow estuaries and lagoons in October. After freeze-up they jig or use dip nets through ice to catch them in estuaries less than five feet deep (Sutton and Steinacher 2012:79).

Farther south, in the Yukon-Kuskokwim region, Yupik women traditionally caught large numbers of "tomcod" (which were likely saffron cod, see Brazil et al. 2011:26) using dipnets along sloughs and rivers in late summer and fall (Fienup-Riordan 2007:269). In winter, Yupik men and women would catch "tomcod" by dipnetting or jigging through the ice (Fienup-Riordan 2007:270, 274; Turner 1886:90–92).

Although the southern range for saffron cod extends today through the Kodiak Archipelago and down to Baranof Island in the North Pacific (Mecklenburg et al. 2002:293), the ethnohistoric records in these areas make no mention of fishing for small codfishes like those farther north. The only codfish activities described are deep-sea fishing for "cod," interpreted here as Pacific cod (e.g., Davydov 1977; de Laguna 1972; Emmons 1991; Gideon 1989; Holmberg 1985; Oberg 1973). It is possible that compared to other resources (like Pacific cod and salmon), saffron cod were not as abundant and therefore few native peoples harvested it. On the other hand, the ethnohistoric record can be a less than comprehensive account of subsistence resources used historically by eastern North Pacific peoples (Gobalet et al. 2004; Hanson 1995; Moss 1993; Sepez 2008; Suttles 1990). In addition to the possible confusion on species identification mentioned above, differences in sex/gender, age, and experience in the division of labor between the observer and the observed people (e.g., Frink 2009), as well as the status of a particular resource (e.g., Moss 1993) may limit the discussion of certain resources in the literature. Of course, the ethnohistoric record can never be a complete record of every prehistoric subsistence resource ever utilized by people. Discovering how and why subsistence economies changed over time is a prime reason why the prehistoric faunal record is so important.

ARCHAEOLOGY

There are few published reports of saffron cod from archaeological sites. Sites with identified saffron cod remains include Settlement Point (AFG-015) and AFG-012 on Afognak Island in the Kodiak Archipelago, Mink Island (XMK-030) on the Alaska Peninsula, Tutiakoff (ADK-171) in the Aleutians, and Peschanyi One in the Amur Bay region of the Russian Far East (Fig. 4). Table 1 lists these sites with their radiocarbon ages, the number of saffron cod remains, the number of fish remains identified to the cod family (family Gadidae), and the number of fish remains identified to family level or a more specific level of taxonomic inclusion. The sites in the Aleutians, along the Alaska Peninsula, and Kodiak Archipelago are noteworthy because of saffron cod's absence from the ethnohistoric literature for these areas.

The AFG-012 and Settlement Point (AFG-015) archaeological sites are located on southern Afognak Island in the Kodiak Archipelago. Both sites are shoreline pithouse settlements dating to the late prehistoric Koniag Tradition, ancestral to the present-day Alutiiq people inhabiting the archipelago (Clark 1974; Fitzhugh 2003). The fish sample for AFG-012 was generated by 1996 test excavations by Partlow (2000), while the Settlement Point sample was generated by 1994–1996 excavations under the direction of Rick Knecht and Patrick Saltonstall (Saltonstall 1997)[1]. Both fish samples were derived from ⅛" (3.2 mm) screened site matrix and were identified by Partlow (2000; Partlow and Kopperl 2011). Identification of cod remains beyond the family level at these two sites was completed only recently, after acquiring comparative saffron cod in 2009. The elements identified as saffron cod at the two Afognak Island sites include the articular, basioccipital, dentary, epihyal, maxilla, parasphenoid, premaxilla, quadrate, vomer, and precaudal vertebra.

Saffron cod were found to make up about 21% (n = 1,438) of the identified fish remains (n = 6,980) at the AFG-012 site (Table 1), located near the mouth of the Afognak River. By contrast, saffron cod make up only 2% (n = 366) of the fish remains identified to at least the level of family (n = 19,883) recovered from the Settlement Point site (Table 1), located farther away from the Afognak River. The difference in saffron cod abundance at these two Afognak Island sites could possibly be due to preservation bias against smaller fishes. Although this has not been explicitly tested, it seems unlikely given the general lack of any apparent weathering on any fish elements. Instead, we propose that the greater abundance of saffron cod at the AFG-012 site than at Settlement Point is likely due to the

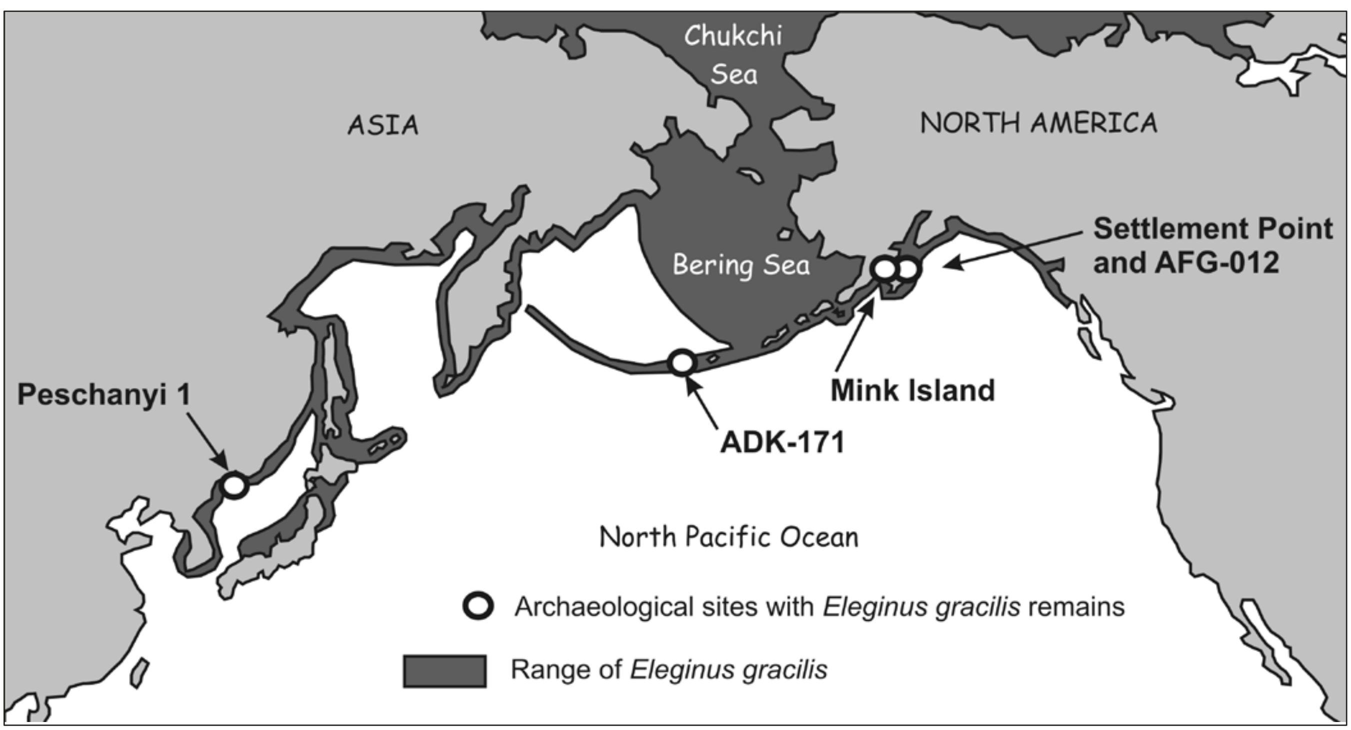

Figure 4. Modern range of saffron cod and known archaeological sites with saffron cod remains. Base map adapted from NOAA (2007).

Table 1. Reported saffron cod assemblages with number of identified specimen (NISP) counts.

Site	Age (uncal)[1]	Date (cal)[2]	Saffron Cod (*Eleginus gracilis*)	Cod Family (Gadidae)[3]	Non-Gadid Fishes[4]	Total Fish[4]	References
AFG-012	280 ± 60; 310 ± 40; 420 ± 60; 450 ± 60	AD 1409–1795	1,438	4,469	2,511	6,980	Partlow 2000 (dates); Partlow and Kopperl 2011 (fish)
Settlement Point (AFG-015)	300 ± 50; 330 ± 60; 340 ± 60; 350 ± 70; 390 ± 50; 440 ± 50; 450 ± 50; 570 ± 60; 620 ± 50	AD 1297–1650	366	7,132	12,751	19,883	Partlow 2000 (dates); Partlow and Kopperl 2011 (fish)
Mink Island (XMK-030), House Feature 5 midden	400 ± 60; 720 ± 60	AD 1225–1621	742	1,690	3,329	5,019	Hutchinson and Crowell 2006 (dates); McKinney 2013 (fish)
Mink Island (XML-030), UMIII	1510 ± 90; 1590 ± 40; 1620 ± 60; 1650 ± 70	AD 263–625	3	845	692	1,537	Hutchinson and Crowell 2006 (dates); McKinney 2013 (fish)
Tutiakoff (ADK-171)	6620 ± 115; 6620 ± 140; 6770 ± 100	5751–5394 BC	454	3,430	4,984	8,414	Krylovich 2009 (fish); Savinetsky et al. 2012 (dates)

1. All radiocarbon dates are from charcoal except the Tutiakoff dates, which are from marine fish and mammal bone collagen.

2. Calendrical ages are 1σ age ranges calibrated with CALIB 7.0.2 (Stuiver and Reimer 1993; Stuiver et al. 2014) using the IntCal 13.14c dataset (Reimer et al. 2013).

3. Includes saffron cod remains, plus Pacific cod, walleye pollock, Pacific tomcod, and other cod remains identified to the family level.

4. Identified to taxonomic family, genus, or species.

site's location near a prime saffron cod spawning area. The Afognak River was recorded in the late nineteenth century as emptying into an estuary thick with eelgrass at the head of Afognak Bay (Bean 1891:186). Eelgrass provides good juvenile saffron cod habitat (Johnson et al. 2009; Johnson et al. 2010; Laurel et al. 2007). Adult saffron cod are known to spawn in brackish water near river mouths, like the mouth of the Afognak River (Mecklenburg et al. 2002:293; Wolotira 1985:17).

The Mink Island site is located within a group of small islands near Amalik Bay, off the Pacific side of the Alaska Peninsula, along Shelikof Strait. The site consists of two components: the Lower Midden and the Upper Midden. Excavations of the site were conducted from 1997 to 2000 under the direction of Jeanne Schaaf of the National Park Service (Hilton 2002). The Lower Midden was excavated using ¼" (6.4 mm) screens, while the Upper Midden was excavated using ⅛" (3.2 mm) and 1⁄16" (1.6 mm) screens (McKinney 2013:91–94). Saffron cod remains were recovered from the midden associated with House Feature 5 in the Upper Midden. House Feature 5 radiocarbon dates place it within the late prehistoric Kukak Mound Phase of the Thule Tradition (Hutchinson and Crowell 2006:App. B; McKinney 2013:Table 4.1, 4.3). Saffron cod remains from the midden of House Feature 5 made up about 14% (n = 742) of the fish remains identified to the level of family, genus, or species (n = 5,019) (Table 1). Another three saffron cod remains were recovered from Upper Midden III, which dates to the Kukak Beach Phase of the Norton Tradition (McKinney 2013:Table 4.1, 4.3, Appendix J.1). These comprise less than 1% of fish remains identified to any larger group (Table 1).

The Tutiakoff site is located on Adak Island on the western end of the Aleutian Archipelago. Dating to ca. 5000 BC, this site is considerably older than the Afognak Island and Mink Island sites, is the oldest known site from the Central Aleutians, and is associated with the Late Anangula Phase (Wilmerding and Hatfield 2012:212, 223). The fish sample for Tutiakoff was recovered using 3 mm (~⅛") mesh during 1999 and 2005 excavations by the Western Aleutian Archaeological and Paleobiological Project under the direction of the Laboratory of Historical Ecology at the Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences (Crockford 2012:Table 6.9; Krylovich 2009; Savinetsky et al. 2012). Saffron cod made up 5% (*n* = 454) of the fish remains identified to the family level or better (*n* = 8,414) (Table 1).

Only one site from the western North Pacific was found to have saffron cod identifications reported in English. This is the Peschanyi One site from the Amur region of the Russian Far East (Gudkov et al. 2005). Gudkov et al. (2005:295) do not quantify the fish identifications, only noting that the proportion of navaga "was rather considerable." Although no details are provided, Kuzmin (2008:5) notes that saffron cod remains have been found in other western North Pacific assemblages as well.

SIZE ESTIMATION

There is a long history of using regressions to estimate live fish size from archaeological bones (e.g., Betts et al. 2014; Butler 1996; Casteel 1974; Greenspan 1998; Leach and Davidson 2001; Losey et al. 2008; Noe-Nygaard 1983; Orchard 2003; Rick and Erlandson 2008; Rojo 1986; Smith 1995; Zohar et al. 1997). Besides contribution to the diet, fish size has the potential to address fish capture method, season, and location (Bailey et al. 2008:218; Betts et al. 2014; Butler 1996; Greenspan 1998). Changes in fish size through time may be evidence of climate change, hunting pressure, or trophic cascade effects (Betts et al. 2014; Rick and Erlandson 2008).

To estimate the length of the saffron cod recovered from the Afognak sites, we produced a series of regression equations designed to estimate the total length of saffron cod from selected archaeological remains. Although regression equations exist for estimating the lengths of saffron cod from otolith length (for the Bering and Chukchi seas; Frost and Lowry 1981; Harvey et al. 2000), and from otolith width or "depth" (for the Sea of Japan; Gudkov et al. 2005), no length regressions exist for more commonly preserved saffron cod elements, particularly for cranial elements in populations from the eastern North Pacific. In addition, although Orchard (2003) has created regressions for Pacific cod, his regressions may be problematic for saffron cod, which are not only smaller overall but also have smaller heads relative to those of Pacific cod (as implied by the Latin name *Gadus macrocephalus*). For our study, one of us (Munk) obtained thirty-five saffron cod[2] using hook and line and a beach seine from shore on Kodiak Island and Long Island in August and September 2007. Total lengths of these fish at capture ranged from 173 to 421 mm. No fish age estimates were made. After boiling and cleaning the skeletons, dimensions were taken on five elements using digital calipers to the hundredth of a millimeter, using Orchard's (2003) measurement points on Pacific cod. A total of seven measurements were taken on five elements (dentary #2, epihyal #2, premaxilla #2, premaxilla #3, quadrate #3, vomer #1, and vomer #2), chosen from Orchard's list based on the relative abundance of these elements in the Kodiak area assemblages, the ease in distinguishing saffron cod from Pacific cod and Pacific tomcod for these elements, and the ease of measurement on broken or bent elements. Regression formulae were created using the least squares method to relate each bone measurement length with live total length.

Table 2 presents seven separate univariate linear regression equations generated for five saffron cod elements. These measurements were highly correlated with total

Table 2. Linear regressions for five saffron cod elements, developed from thirty-five whole Kodiak fish;* n *= 35 for each element.

Element	Orchard Measurement	m	b	r-squared
Dentary	#2	122.65	40.25	0.945
Epihyal	#1	45.32	−6.76	0.971
Premaxilla	#2	54.98	−12.72	0.954
Premaxilla	#3	76.91	−21.63	0.958
Quadrate	#3	79.96	29.91	0.957
Vomer	#1	42.46	−7.89	0.978
Vomer	#2	72.18	17.13	0.963

Note: Regression in the form of $y = mx + b$, with y = total fish length and x = skeletal measurement.

length; coefficients of determination (r^2) values range from 0.945 to 0.978. As expected, the new species-specific regressions perform better than Orchard's (2003:Table 6.7) Pacific cod regressions in estimating size of comparative saffron cod skeletons. Although Orchard's regressions estimate fork lengths, and our regressions estimate total lengths, fork length and total length in a saffron cod are virtually the same. The saffron cod regressions predicted total lengths within 2 cm of the actual total lengths of the comparative fishes in 236 out of 245 cases (96%), whereas the Pacific cod regressions were equally successful only in 70 of 245 cases (29%), often underestimating the actual lengths by 5–11 cm.

Zooarchaeologists use regressions like these to generate estimated fish-length frequency distributions. A number of different methods for quantifying distributions have been published in the literature. These include using multiple measurements on both rights and lefts of multiple elements (e.g., Losey et al. 2008), one measurement on both rights and lefts of multiple elements (e.g., Greenspan 1998; Leach 1997), and one measurement on both rights and lefts of one element (e.g., Butler 1996; Gudkov et al., 2005). Here we use the data for a single measurement locus on both left and right sides of a single paired element, after Butler (1996).

Our regression formulae were used on selected saffron cod remains from the two Afognak Island archaeological sites to generate estimated fish-length frequency distributions. The saffron cod remains recovered from the two sites appear to be from adult fish, although the Settlement Point fish tend to be smaller than the AFG-012 fish. If we use only a single measurement on a single element, the greatest number of estimated total lengths for both sites was obtained using the maximum height of the symphysis (Orchard measurement #2) on both right and left dentaries (Tables 3, 4; Fig. 5). As Figure 5 shows, the saffron cod recovered from the Settlement Point site tend to be shorter than those recovered from the AFG-012 site and the means reflect this: the mean for Settlement Point is 297 mm total length, while the mean for AFG-012 is 332 mm total length (see also Tables 3 and 4).

These saffron cod total length estimates are smaller than the Pacific cod total length estimates for these two sites, as one might expect due to the different maximum size attained by these species. Pacific cod from the AFG-012 site range from 57 to 68 cm fork length, while the Pacific cod from the Settlement Point site range from 46 to 80 cm fork length (Partlow and Kopperl 2011:Table 12.4). In fact, the majority of the saffron cod are smaller than the smallest Pacific cod (estimated 36 cm fork

Table 3. AFG-012 saffron cod estimated total lengths (mm).

Element Measurement	*n*	Minimum	Maximum	Mean	Standard Deviation
Dentary #2	55	229	456	332	50
Epihyal #1	16	283	462	357	42
Premaxilla #2	51	242	486	344	54
Premaxilla #3	50	257	500	364	57
Quadrate #3	47	242	478	360	54
Vomer #1	22	276	467	359	49
Vomer #2	22	286	419	326	31

Table 4. Settlement Point (AFG-015) saffron cod estimated total lengths (mm).

Element Measurement	n	Minimum	Maximum	Mean	Standard Deviation
Dentary #2	60	208	393	297	48
Epihyal #1	5	224	401	306	84
Premaxilla #2	26	229	386	315	47
Premaxilla #3	27	218	435	329	56
Quadrate #3	16	235	435	329	53
Vomer #1	9	283	471	359	59
Vomer #2	9	273	379	328	32

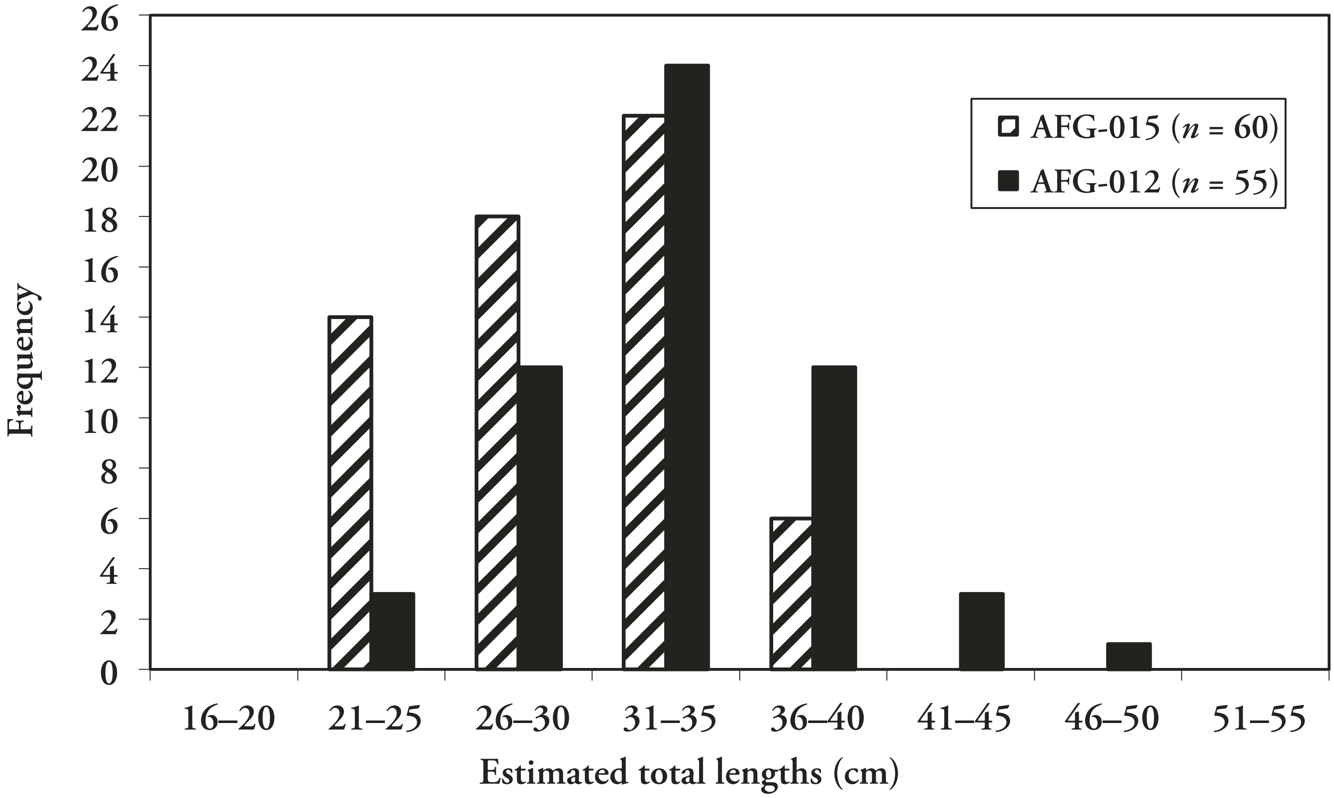

Figure 5. Saffron cod size frequency distributions, based on dentary #2 measurement (both rights and lefts), from the AFG-012 and Settlement Point (AFG-015) sites.

length) recorded from seven other North Pacific assemblages (Partlow and Kopperl 2011:Table 12.4).

Although fish size may provide clues to capture method, it is also dependent upon catch location and catch season (Greenspan 1998). Dip nets tend not to catch smaller fish (depending on mesh size), and hook and line technology might produce a relatively wide unimodal mortality profile centered on larger fish (Greenspan 1998). In either case, if saffron cod were targeted during spawning, then only mature, larger fish would be available, producing similar wide, unimodal mortality profiles, as seems to be the case for all four sites with size estimates. The Afognak Island saffron cod remains are similar in size to those found at the 7,000-year-old Tutiakoff (ADK-171) site in the Aleutians, where saffron cod were estimated (based on otolith depth) to range from 21–41 cm total length, with a mean of 27 ± 5 cm total length (Savinetsky et al. 2012:87). Savinetsky et al. (2012) interpret the Aleutian saffron cod as adults caught during winter spawning. Likewise, the majority of the saffron cod recovered from the ca. 2,500-year-old Peschanyi One site were estimated (based on otolith depth) to range between 25 and 35 cm total length with an average of 30 cm total length (Gudkov et al. 2005:297). Gudkov et al. (2005:298–299) suggest that the majority of the saffron cod at that site were also caught during spawning, probably through the winter ice close to shore.

DISCUSSION

Saffron cod are a well-documented, important subsistence resource for people living along the Chukchi and Bering seas, as well as the western North Pacific, in historic times. The archaeological site of Peschanyi One, on the Sea of Japan, supports this pattern for prehistory: saffron cod otoliths far outnumbered the otoliths of any other fish identified from this site (Gudkov et al. 2005:297). By contrast, the ethnohistoric record from the eastern North Pacific does not mention saffron cod at all. While a few archaeological sites from this region have produced saffron cod remains, saffron cod occur in relatively small percentages compared to other fish. For example, like the Settlement Point Site discussed above, the Aleutian site of Tutiakoff (ADK-171) produced a relatively small number of saffron cod remains compared to other fish species: saffron cod made up 5% of the fish remains identified to family level or better (Savinetsky et al. 2012:84).

Although saffron cod are absent from the ethnohistoric literature for the Kodiak Archipelago, ice fishing is not. During his stay on Kodiak ca. 1871, Pinart (2013) witnessed Alutiiq fishing through the ice for salmon. Similarly, Alutiiq alive today recall using leisters to spear and small hooks to jig through the ice for flounder over Karluk Lagoon during the winter (Steffian et al. 2015). While most bays in the region remain ice-free in the winter, those with large supplies of freshwater have been known to freeze over (Nybakken 1969:7). Specifically, Afognak Bay has frozen over as far out as the mouth of the bay (Clark 2005). Afognak Bay may have frozen over in the winter during the Little Ice Age (when the two Afognak sites were occupied).

Whether the Afognak Island saffron cod were caught by jigging through the ice or from shore if the bay remained ice-free, they may have been an important back-up subsistence resource available during winter. For example, when the salmon runs collapsed in 1935, one Alutiiq man from Old Harbor described surviving that winter by living off of cod which he jigged for from the shore. He said "the codfish saved us from starvation" (Mishler 2001:38). Alternatively, it is possible the saffron cod were caught in late summer at the mouth of the Afognak River while people were salmon fishing; saffron cod can be caught today during late summer/early fall salmon fishing in other parts of the Kodiak Archipelago.

To date, there are only four sites in the North American Pacific Northwest reported to have saffron cod remains: one from about 7,000 years ago (ADK-171), and three (AFG-012, AFG-015, and XMK-030—House Feature 5 midden) from about 500 years ago. Mink Island (XMK-030) also produced three saffron cod bones from levels dating to ca. 1,500 years ago. The three sites with saffron cod length estimates (AFG-012, AFG-015, ADK-171) appear to have the remains of mature fish, likely caught while spawning in brackish water close to shore. Whether the saffron cod from the Afognak Island sites represent a by-product of salmon fishing or an important resource caught during the winter where available is not yet clear. Future identifications of saffron cod remains from other sites in the eastern North Pacific will improve our understanding.

Finally, we would like to address the possibility that the presence of saffron cod in an archaeological site could be used as a paleoenvironmental indicator. Based on its current distribution from the Aleutians south to Sitka, and the fact that it can be taken from shore in the Kodiak Archipelago today, it is difficult to imagine that this species should be considered a reliable indicator of colder-than-present climates for Alaska sites in the past, as has sometimes been suggested (e.g., Dumond 2012:190; Krylovich 2009:162). On the other hand, if this species was taken primarily by ice fishing, and sea ice was only present near a site in colder-than-present periods, then it is possible that it could represent a colder climate.

ACKNOWLEDGEMENTS

Patrick Saltonstall provided timely support and steadfast encouragement. Pat Lubinski helped measure comparative fish and gave editorial advice. Useful comments that helped to make this a better article were provided by Gary Duker, Robert Foy, Erica Hill, Jeff Napp, and two anonymous reviewers. The Afognak Native Corporation and Alutiiq Museum and Archaeological Repository in Kodiak, Alaska, provided necessary logistical support during site excavations. Permission to perform faunal analyses of the Settlement Point remains was generously given by the Native Village of Afognak. This paper was presented as a poster at the annual meeting of the Alaska Anthropological Association and the Northwest Anthropological Conference, spring 2010. It was inspired by Orchard's (2003) pioneering work on Pacific cod regressions.

NOTES

1. Vertebrate fauna from AFG-012 and AFG-015 are curated at the Department of Anthropology, Central Washington University, Ellensburg, WA.
2. Saffron cod comparative specimens used in this study are part of the osteological collection housed in the Zooarchaeological Laboratory of the Department of Anthropology at Central Washington University, Ellensburg, WA.

REFERENCES

Antropova, Valentina V., and V. G. Kuznetsova
1964 The Chukchi. In *The Peoples of Siberia*, edited by M. G. Levin and L. P. Potapov, pp. 799–835. University of Chicago Press, Chicago.

Bailey, Geoff, James Barrett, Oliver Craig, and Nicky Milner
2008 Historical Ecology of the North Sea Basin: An Archaeological Perspective and Some Problems

of Methodology. In *Human Impacts on Ancient Marine Ecosystems: A Global Perspective*, edited by Torben C. Rick and Jon M. Erlandson, pp. 215–242. University of California Press, Berkeley.

Bean, Tarleton H.
1891 Report on the Salmon and Salmon Rivers of Alaska, with Notes on the Conditions, Methods, and Needs of the Salmon Fisheries. *Bulletin of the United States Fish Commission* 9:165–208.

Betts, Matthew W., Stéphane Noël, Eric Tourigny, Mélissa Burns, Peter E. Pope, and Stephen L. Cumbaa
2014 Zooarchaeology of the Historic Cod Fishery in Newfoundland and Labrador, Canada. *Journal of the North Atlantic* 24:1–21.

Birket-Smith, Kaj
1953 *The Chugach Eskimo*. Nationalmuseets Publikationsfond, Copenhagen.

Bond, W. A., and R. N. Erickson
1993 Fisheries Investigations in Coastal Waters of Liverpool Bay, Northwest Territories. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2204, Department of Fisheries and Oceans, Winnipeg, MB.

Brazil, Chuck, Doug Bue, and Travis Elison
2011 *2011 Kuskokwim Area Management Report*. Fishery Management Report no. 13-23. Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage.

Butler, Virginia L.
1996 Tui Chub Taphonomy and the Importance of Marsh Resources in the Western Great Basin of North America. *American Antiquity* 61(4):699–717.

Cannon, Aubrey
1991 *The Economic Prehistory of Namu*. Department of Archaeology, Simon Fraser University, Burnaby, BC.
1996 Scales of Variability in Northwest Salmon Fishing. In *Prehistoric Hunter-Gatherer Fishing Strategies*, edited by Mark G. Plew, pp 25–40. Boise State University Monograph Series, Boise.

Cannon, Aubrey, Dongya Yang, and Camilla Speller
2011 Site-Specific Salmon Fisheries on the Central Coast of British Columbia. In *The Archaeology of North Pacific Fisheries*, edited by Madonna L. Moss and Aubrey Cannon, pp. 57–74. University of Alaska Press, Fairbanks.

Carr, Steven M., David S. Kivlichan, Pierre Pepin, and Dorothy C. Crutcher
1999 Molecular Systematics of Gadid Fishes: Implications for the Biogeographic Origins of Pacific Species. *Canadian Journal of Zoology* 77:19–26.

Casteel, Richard W.
1974 A Method of Estimation of Live Weight of Fish from the Size of Skeletal Elements. *American Antiquity* 39(1):94–98.

Clark, Donald W.
1974 *Koniag Prehistory*. Tubinger Monographien zur Urgeschichte, vol. 1. Verlag W. Kohlhammer.
2005 *Ancient Afognak Precontact History and Archaeology of Afognak Bay*. Electronic document. Online at http://www.afognak.org/heritage/history/history-intro.php?src=ancient-afognak.

Cohen, Daniel M., Tadashi Inada, Tomio Iwamoto, and Nadia Scialabba
1990 *FAO Species Catalogue*, vol. 10. *Gadiform Fishes of the World (Order Gadiformes)*. An Annotated and Illustrated Catalogue of Cods, Hakes, Grenadiers, and Other Gadiform Fishes Known to Date. Rome, FAO.

Coulson Mark W., H. Dawn Marshall, Pierre Pepin, and Steven M. Carr
2006 Mitochondrial Genomics of Gadine Fishes: Implications for Taxonomy and Biogeographic Origins from Whole-Genome Data Sets. *Genome* 49:1115–1130.

Crockford, Susan
2012 Archaeozoology of Adak Island: 6,000 Years of Subsistence History in the Central Aleutians. In *The People of Before: The Geology, Paleoecology and Archaeology of Adak Island, Alaska*, edited by D. West, V. Hatfield, E. Wilmerding, C. Lefèvre, and L. Gualtieri, pp. 107–143. British Archaeological Reports, International Series, no. 2322, Archaeopress, Oxford.

Crowell, Aron L. and April Laktonen
2001 Súgucihpet / "Our Way of Living." In *Looking Both Ways: Heritage and Identity of the Alutiiq People*, edited by Aron L. Crowell, Amy F. Steffian, and Gordon L. Pullar, pp. 137–186. University of Alaska Press, Fairbanks.

Davydov, Gavrila Ivanovich
1977 *Two Voyages to Russian America, 1802–1807*. Translated by Colin Bearne, edited by Richard A. Pierce. Limestone Press, Kingston, ON.

de Laguna, Frederica
1972 *Under Mount Saint Elias: The History and Culture of the Yakutat Tlingit*. Smithsonian Contributions to Anthropology, vol. 7. Smithsonian Institution Press, Washington, DC.
1990a Eyak. In *The Handbook of North American Indians*, vol. 7, *Northwest Coast*, edited by Wayne Suttles, pp. 189–196. Smithsonian Institution Press, Washington, DC.
1990b Tlingit. In *The Handbook of North American Indians*, vol. 7, *Northwest Coast*, edited by Wayne Suttles, pp. 203–228. Smithsonian Institution Press, Washington, DC.

Dumond, Don E.
2012 Review of *The People Before: The Geology, Paleoecology, and Archaeology of Adak Island, Alaska*. *Alaska Journal of Anthropology* 10:188–191.

Emmons, George Thornton
1991 *The Tlingit Indians*, edited with additions by Frederica de Laguna. University of Washington Press, Seattle.

Fienup-Riordan, Ann
2007 *Yuungnaqpiallerput/The Way We Genuinely Live*: *Masterworks of Yup'ik Science and Survival*. University of Washington Press, Seattle

Fitzhugh, Ben
2003 *The Evolution of Complex Hunter-Gatherers: Archaeological Evidence from the North Pacific*. Kluwer Academic/Plenum, New York.

Frink, Lisa
2009 The Identity Division of Labor in Native Alaska. *American Anthropologist* 111(1):21–29.

Frost, Kathryn J., and Lloyd F. Lowry
1981 Trophic Importance of Some Marine Gadids in Northern Alaska and Their Body-Otolith Size Relationships. *Fisheries Bulletin* 79:187–192.

Gideon, Hieromonk
1989 *The Round the World Voyage of Hieromonk Gideon, 1803–1809*. Edited by R.A. Pierce; translated by Lydia T. Black. Limestone Press, Kingston, ON.

Gobalet, Kenneth W., Peter D. Schulz, Thomas A. Wake, and Nelson Siefkin
2004 Archaeological Perspectives on Native American Fisheries of California, with Emphasis on Steelhead and Salmon. *Transactions of the American Fisheries Society* 133(4):801–833.

Greenspan, Ruth L.
1998 Gear Selectivity Models, Mortality Profiles and the Interpretation of Archaeological Fish Remains: A Case Study from the Harney Basin, Oregon. *Journal of Archaeological Science* 25(10):973–984.

Gudkov, P.K., M.V. Nazarkin, and Yu. E. Vostretsov
2005 Reconstruction of Fossil Otoliths of the Structure of Populations of Pacific Navaga *Eleginus gracilis* (Gadidae) that Inhabited Amur Bay, 2,400–2,450 Years Ago. *Journal of Ichthyology* 45(4):295–300.

Hanson, Diane
1995 Subsistence during the Late Prehistoric Occupation of Pender Canal, British Columbia (DeRt-1). *Canadian Journal of Archaeology* 19(1):29–48.

Harvey, James T., Thomas R. Loughlin, Michael A. Perez, and Dion S. Oxman
2000 *Relationship between Fish Size and Otolith Length for 63 Species of Fishes from the Eastern North Pacific Ocean*. NOAA Technical Report, National Marine Fisheries Service 150, Seattle, WA.

Hilton, Michael R.
2002 *Evaluating Site Formation Processes at a Higher Resolution: An Archaeological Case Study in Alaska Using Micromorphology and Experimental Techniques*. Unpublished Ph.D. dissertation, Department of Anthropology, University of California, Los Angeles.

Holmberg. Heinrich Johan
1985 *Holmberg's Ethnographic Sketches*, edited by Marvin W. Falk, translated by Fritz Jaensch. University of Alaska Press, Fairbanks.

Hopky, G.E., and R.A. Ratynski
1983 Relative Abundance, Spatial and Temporal Distribution, Age and Growth of Fishes in Tuktoyaktuk Harbour, N.W.T., 28 June to 5 September, 1981. Canadian Manuscript Report of Fisheries and Aquatic Sciences 1713, Department of Fisheries and Oceans, Winnipeg, MB.

Hutchinson, Ian, and Aron L. Crowell
2006 *Great Earthquakes and Tsunamis at the Alaska Subduction Zone: Geoarchaeological Evidence of Recurrence and Extent*. Final Technical Report, NEHRP. Electronic Resource. Online at http://earthquake.usgs.gov/research/external/reports/01HQGR0022.pdf. Accessed November 29, 2014.

Jochelson, Waldemar
1905 *The Koryak*. E.J. Brill and G.E. Stechert, New York.
2002 *History, Ethnology and Anthropology of the Aleut*. Reprint of the 1933 edition published by the

Carnegie Institution of Washington. University of Utah Press, Salt Lake City.

Johnson, Scott W., John F. Thedinga, and A. Darcie Neff
2009 Invasion by Saffron Cod *Eleginus gracilis* into Nearshore Habitats of Prince William Sound, Alaska, USA. *Marine Ecology Progress Series* 389:203–212.

Johnson, Scott W., John F. Thedinga, A. Darcie Neff, Patricia M. Harris, Mandy R. Lindeberg, Jasek M. Maselko, and Stanley D. Rice
2010 Fish Assemblages in Nearshore Habitats of Prince William Sound, Alaska. *Northwest Science* 84(3):266–280.

Jones, Anore
2006 *Iqaluich Nigiñaqtuat, Fish That We Eat*. U.S. Fish and Wildlife Service, Office of Subsistence Management, Fisheries Resource Monitoring Program, Final Report no. FIS02-023, Anchorage, Alaska.

Knecht, Richard A., and Richard S. Davis
2008 The Amaknak Bridge Site: Cultural Change and the Neoglacial in the Eastern Aleutians. *Arctic Anthropology* 45(1):61–78.

Krylovich, Olga
2009 Fish Remains from Ancient Aleutian Archaeological Site (Adak Island, Aleutian Chain) and Environmental Changes. In *Fishes–Culture–Environment through Archaeoichthyology, Ethnography and History*, edited by D. Makowiecki, S. Hamilton-Dyer, I. Riddler, N. Trzaska-Nartowski, and M. Makohonienko, pp. 161–164. Environment and Culture, vol. 7. Bogucki Scientific Publishers, Poznán.

Kuzmin, Yaroslav V.
2008 Geoarchaeology of Prehistoric Cultural Complexes in the Russian Far East: Recent Progress and Problems. *Bulletin of the Indo-Pacific Prehistory Association* 28:3–10.

Langdon, Steve
1979 Comparative Tlingit and Haida Adaptation to the West Coast of the Prince of Wales Archipelago. *Ethnology* 18(1):101–119.

Laurel, Ben J., Allan W. Stoner, Clifford H. Ryer, Thomas P. Hurst, and Alisa A. Abookire
2007 Comparative Habitat Associations in Juvenile Pacific Cod and Other Gadids Using Seines, Baited Cameras, and Laboratory Techniques. *Journal of Experimental Marine Biology and Ecology* 351:42–55.

Leach, Foss
1997 *A Guide to the Identification of Fish Remains from New Zealand Archaeological Sites*. New Zealand Journal of Archaeology Special Publication, Wellington.

Leach, Foss, and Janet Davidson
2001 The Use of Size Frequency Diagrams to Characterize Prehistoric Fish Catches and to Assess Human Impact on Inshore Fisheries. *International Journal of Osteoarchaeology* 11(1–2):150–162.

Losey, Robert J., Tatiana Nomokonova, and Olga I. Goriunova
2008 Fishing Ancient Lake Baikal, Siberia: Inferences from the Reconstruction of Harvested Perch (*Perca fluviatilis*) Size. *Journal of Archaeological Science* 35(3):577–590.

Lowry, Lloyd F., Kathryn J. Frost, and John J. Burns
1983 Trophic Relationships among Ice-Inhabiting Phocid Seals and Functionally Related Marine Mammals in the Chukchi Sea. In *Environmental Assessment of the Alaskan Continental Shelf*, pp. 179–229. Final Reports of Principal Investigators, vol. 19. Outer Continental Shelf Environmental Assessment Program, Anchorage.

Lukin, Shauna
2001 Subsistence Fishing. In *Looking Both Ways: Heritage and Identity of the Alutiiq People*, edited by Aron L. Crowell, Amy F. Steffian, and Gordon L. Pullar, p. 178. University of Alaska Press, Fairbanks.

Maschner, Herbert D. G.
1997 Settlement and Subsistence in the Later Prehistory of Tebenkof Bay, Kuiu Island, Southeast Alaska. *Arctic Anthropology* 34(2):74–99.

McKechnie, Iain
2005 Column Sampling and the Archaeology of Small Fish at Ts´ishaa. In *Ts´ishaa: Archaeology and Ethnography of a Nuu-chah-nulth Origin Site in Barkley Sound*, edited by A. D. McMillan and D. E. St. Claire, pp. 206–223. Archaeology Press, Simon Fraser University, Burnaby, BC.
2007 Investigating the Complexities of Sustainable Fishing at a Prehistoric Village on Western Vancouver Island, British Columbia, Canada. *Journal of Nature Conservation* 15(3):208–222.

McKinney, Holly J.
2013 *Taphonomic Analysis of Fish Remains from the Mink Island Site (XMK-030): Implications for Zooarchaeological and Stable Isotope Research*. Un-

published Ph.D. dissertation, Department of Anthropology, University of Alaska Fairbanks.

Mecklenburg, Catherine W., T. Anthony Mecklenburg, and Lyman K. Thorsteinson
2002 *Fishes of Alaska*. American Fisheries Society, Bethesda, MD.

Mishler, Craig
2001 *Black Ducks and Salmon Bellies: An Ethnography of Old Harbor and Ouzinkie, Alaska*. Alaska Department of Fish and Game, Anchorage.

Morrow, James E.
1980 *The Freshwater Fishes of Alaska*. Northwest Publishing Company, Anchorage.

Moss, Madonna L.
1993 Shellfish, Gender and Status on the Northwest Coast: Reconciling Archeological, Ethnographic and Ethnohistoric Records of the Tlingit. *American Anthropologist* 95(3):631–652.
2008 Outer Coast Maritime Adaptations in Southern Southeast Alaska: Tlingit or Haida? *Arctic Anthropology* 45(1):41–60.
2012 Understanding Variability on Northwest Coast Faunal Assemblages: Beyond Economic Intensification and Cultural Complexity. *Journal of Island and Coastal Archaeology* 7(1):1–22.

Moss, Madonna L., Virginia L. Butler, and J. Tait Elder
2011 Herring Bones in Southeast Alaska Archaeological Sites: The Record of Tlingit Use of Yaaw (Pacific Herring, *Clupea pallasii*). In *The Archaeology of North Pacific Fisheries*, edited by Madonna L. Moss and Aubrey Cannon, pp. 281–292. University of Alaska Press, Fairbanks.

National Oceanic and Atmospheric Administration
2007 North Pacific Ocean Theme Page. Online at http://www.pmel.noaa.gov/np/pages/seas/npmap1.html. Accessed November 29, 2014.

Nelson, Edward William
1983 *The Eskimo about Bering Strait*. Smithsonian Institution Press, Washington, DC.

Noe-Nygaard, Nanna
1983 The Importance of Aquatic Resources to Mesolithic Man at Inland Sites in Denmark. In *Animals and Archaeology*, 2, *Shell Middens, Fishes, and Birds*, edited by C. Grigson and J. Clutton-Brock, pp. 125–142. Archaeopress, Oxford.

Nybakken, James Willard
1969 *Pre-Earthquake Intertidal Ecology of Three Saints Bay, Kodiak Island, Alaska*. Biological Papers of the University of Alaska, no. 9. Allen Press, Lawrence.

Oberg, Kalervo
1973 *The Social Economy of the Tlingit Indians*. Seattle: University of Washington Press.

Orchard, Trevor J.
2003 *An Application of the Linear Regression Technique for Determining Length and Weight for Six Fish Taxa: The Role of Selected Fish Species in Aleut Paleodiet*. British Archaeological Reports International Series no. 1172, Archaeopress, Oxford.

Owens, Hannah L.
2015 Evolution of Codfishes (Teleostei: Gadinae) in Geographical and Ecological Space: Evidence That Physiological Limits Drove Diversification of Subarctic Fishes. *Journal of Biogeography* 42(6):1091–1102.

Partlow, Megan A.
2000 *Salmon Intensification and Changing Household Organization in the Kodiak Archipelago*. Ph.D. dissertation, Department of Anthropology, University of Wisconsin, Madison. University Microfilms International, Ann Arbor.
2006 Sampling Fish Bones: A Consideration of Screen Size and Disposal Context in the North Pacific. *Arctic Anthropology* 43(1):67–79.

Partlow, Megan A., and Robert E. Kopperl
2011 Processing the Patterns: Elusive Archaeofaunal Signatures of Cod Storage on the North Pacific Coast. In *The Archaeology of North Pacific Fisheries*, edited by Madonna L. Moss and Aubrey Cannon, pp. 195–218. University of Alaska Press, Fairbanks.

Pinart, Alphonse
2013 Alphonse Louis Pinart in Alaska. Translated by Richard L. Bland. *Arctic Anthropology* 50:4–24.

Reimer, Paula J., Edouard Bard, Alex Bayliss, et al.
2013 IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years cal BP. *Radiocarbon* 55(4):1869–1887.

Rick, Torben C., and Jon M. Erlandson
2008 Archaeology, Marine Ecology, and Human Impacts on Marine Environments. In *Human Impacts on Ancient Marine Ecosystems: A Global Perspective,* edited by Torben C. Rick and Jon M. Erlandson, pp. 1–20. University of California Press, Berkeley.

Rojo, Alphonso
1986 Live Length and Weight of Cod (*Gadus morhua*) Estimated from Various Skeletal Elements. *North American Archaeologist* 7(4):329–351.

Saltonstall, Patrick

1997 *Archaeology at Settlement Point 1997 Preliminary Report*. Report Prepared for the Afognak Native Corporation. November, 1997. Unpublished manuscript on file at the Alutiiq Museum and Archaeological Repository, Kodiak, AK.

Savinetsky, Arkady, Dixie L. West, Zhanna A. Antipushina, Bulai F. Khassanov, Nina K. Kiseleva, Olga A. Krylovich, and Andrei M. Pereladov

2012 The Reconstruction of Ecosystems History of Adak Island (Aleutian Islands) during the Holocene. In *The People Before: The Geology, Paleoecology and Archaeology of Adak Island, Alaska*, edited by D. West, V. Hatfield, E. Wilmerding, C. Lefèvre, and L. Gualtieri, pp. 75–106. British Archaeological Reports, International Series, no. 2322, Archaeopress, Oxford.

Sepez, Jennifer

2008 Historical Ecology of Makah Subsistence Foraging Patterns. *Journal of Ethnobiology* 28(1):111–134.

Smith, Kathleen Lopp, and Verbeck Smith

2001 *Ice Window: Letters from a Bering Strait Village 1892–1902*. University of Alaska Press, Fairbanks.

Smith, Pippa

1995 A Regression Equation to Determine the Total Length of Hake (*Merluccius merluccius*) from Selected Measurements of the Bones. *International Journal of Osteoarchaeology* 5:93–95.

Soong, Joyce, Scott Kent, and Jim Menard

2008 *2006 Annual Management Report, Norton Sound, Port Clarence, and Kotzebue*. Fishery Management Report no. 8-32. Alaska Department of Fish and Game, Anchorage.

Steffian, Amy F., Marnie A. Leist, Sven D. Haakanson Jr., and Patrick G. Saltonstall

2015 *Ka'lunek/From Karluk: Kodiak Alutiiq History and the Archaeology of the Karluk One Village Site*. University of Alaska Press, Fairbanks.

Stuiver, Minze, and Pamela J. Reimer

1993 Extended ^{14}C Data Base and Revised Calib 3.0 ^{14}C Age Calibration Program. *Radiocarbon* 35: 215–230.

Stuiver, Minze, Pamela J. Reimer, and R. Reimer

2014 CALIB radiocarbon calibration, PC version 7.0.2. Online at http://calib.qub.ac.uk/calib/.

Suttles, Wayne

1990 Environment. In *The Handbook of North American Indians*, vol. 7, *Northwest Coast*, edited by Wayne Suttles, pp. 16–29. Smithsonian Institution Press, Washington, DC.

Sutton, Anne, and Sue Steinacher

2012 *Alaska's Nome Area Wildlife Viewing Guide*. Alaska Department of Fish and Game, Division of Wildlife Conservation, Nome.

Trost, Teresa, Randall Schalk, Mike Wolverton, and Margaret A. Nelson

2011 Patterns of Fish Usage in a Late Prehistoric Northern Puget Sound Shell Midden. In *The Archaeology of North Pacific Fisheries*, edited by Madonna L. Moss and Aubrey Cannon, pp. 265–280. University of Alaska Press, Fairbanks.

Turner, Lucien M.

1886 *Contributions to the Natural History of Alaska*. Government Printing Office, Washington, DC.

West, Catherine Foster

2009 Kodiak Island's Prehistoric Fisheries: Human Dietary Response to Climate Change and Resource Availability. *Journal of Island and Coastal Archaeology* 4(2):223–239.

Wilmerding, Elizabeth G., and Virginia Hatfield

2012 Six Thousand Years of Lithic Technology on Adak in a Broader Aleutian Context. In *The People of Before: The Geology, Paleoecology and Archaeology of Adak Island, Alaska*, edited by D. West, V. Hatfield, E. Wilmerding, C. Lefèvre, and L. Gualtieri, pp. 211–237. British Archaeological Reports, International Series, no. 2322, Archaeopress, Oxford.

Wolotira, Robert J., Jr.

1985 *Saffron Cod (*Eleginus gracilis*) in Western Alaska: The Resource and Its Potential*. NOAA Technical Memorandum NMFS F/NWC-79, Seattle, WA.

Yarborough, Linda Finn

2000 *Prehistoric and Early Historic Patterns along the North Gulf of Alaska Coast*. Unpublished Ph.D. dissertation, Department of Anthropology, University of Wisconsin, Madison.

Zohar, Irit, Tamar Dayan, and Ehud Spanier

1997 Predicting Grey Triggerfish Body Size from Bones. *International Journal of Osteoarchaeology* 7:150–156.