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Secondary Abstract:	Thicktail chub (Gila crassicauda) era endémica de la mayoría de las vías fluviales del centro de California y era un componente clave de las pesquerías locales antes del 1800s. El declive de esta especie comenzó a finales del 1800s y finalmente se extinguió en la década de 1950. Se sabe poco sobre su biología, comportamiento, ecología o papel en las pesquerías de nativos americanos anteriores al contacto. Los sitios arqueológicos contienen una gran cantidad de huesos de thicktail chub y representan una fuente clave de datos para llenar nuestro considerable vacío en el conocimiento sobre esta especie. Utilizando el cacho de tui chub (Siphateles bicolor), desarrollamos ecuaciones de regresión para convertir seis elementos esqueléticos de thicktail chub en estimaciones de longitud estándar (SL) en el momento de la captura. Estimamos las longitudes de los peces antes de la extinción utilizando huesos arqueológicos de thicktail chub de dos sitios contemporáneos del Período Tardío previo al contacto (ca 700-200 cal BP), CA-CCO-138 y CA-CCO-647, en el delta de Sacramento-San Joaquín. Thicktail chub fueron la tercera y segunda ictiofauna más común, respectivamente, y comprenden entre el 22 y el 30% de los restos de peces identificados. Además, thicktail chub previos al contacto eran más largos que los especímenes capturados a principios del 1800s, alcanzando una longitud estándar máxima (SL) de 306 mm. Las distribuciones de tallas sugieren que la técnica de captura más probable fue el arpón y/o el anzuelo y el sedal. Una comparación de los hábitats preferidos y las épocas de desove de la ictiofauna asociada sugiere que thicktail chub era parte de una pesquería más grande cerca de la costa durante la primavera y el verano. Los resultados aportan información vital sobre la longitud de thicktail chub, su importancia como pez local adaptado a las llanuras aluviales y su papel clave en las pesquerías indígenas previas al contacto.
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Ancient Fishing Strategies for the Extinct Thicktail Chub (*Gila crassicauda*) in the Sacramento-San Joaquin Delta

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Jelmer W. Eerkens received his BS in Computer Science from UC Davis, and his MA (1996) and PhD (2001) in Anthropology from UC Santa Barbara. A Professor in the Department of Anthropology at UC Davis, he applies evolutionary models, especially ideas from cultural transmission theory, to better understand change in the archaeological record. Eerkens has conducted archaeological field research in California, Nevada, South-Central Peru, and Northwest Europe. Much of his research incorporates archaeometric applications such as stable isotope analysis, proteomics, gas chromatography, neutron activation, and X-ray fluorescence.

Kenneth W. Gobalet received his BS, MS, and PhD (1980) in Zoology from the University of California, Davis. He is an Emeritus Professor of Biology from California State University, Bakersfield, from which he retired in 2013 following over 30 years of college-level teaching. His academic specialization includes the archaeological remains of California fishes. His interest in fish remains was accidental. Though he was in a fisheries project in Central India in the Peace Corps (1969-1971) and studied the morphology of parrotfish feeding for his doctoral dissertation, he had to start from scratch to learn to distinguish fish remains. No, with nearly 50 years-experience, he has well over 50 publications in 28 reviewed journals and uncounted contributions to the archaeological literature.

Morgan V. Hall received her BA from UC Davis (2022) and is currently enrolled in the PhD program focusing on zooarchaeology and stable isotope analysis to understand historical ecology in the Chilean Andes.

Jason I. Miszaniec received his BA from McGill University (2012), his MA from Memorial University of Newfoundland (2014) and his PhD from UC Davis (2020). He is currently an Archaeologist with Stantec's Great Lakes Division, and an Honorary Fellow at the University of Wisconsin's Zoological Museum University. He has conducted field work in Newfoundland, Greenland, Alaska, and Wisconsin. Miszaniec's research interests are in the study of zooarchaeological remains, particularly fish, to understand long-term human and environmental interactions along the Pacific Coast and in the Arctic and Subarctic.

Ancient Fishing Strategies for the Extinct Thicktail Chub (*Gila crassicauda*) in the Sacramento-San Joaquin Delta

Thicktail chub (*Gila crassicauda*) were endemic to most waterways in Central California and were a key component of local fisheries before the 1800s. Decline of this species began in the late 1800s, with their eventual extinction in the 1950s. Little is known about their biology, behavior, ecology, or role in precontact Native American fisheries. Archaeological sites contain large numbers of thicktail chub bones and represent a key source of data to fill our considerable gap in knowledge. Using the extant and related tui chub (*Siphateles bicolor*), we developed regression equations to convert thicktail chub skeletal elements to estimates of standard length (SL). We estimated pre-extinction fish lengths using archaeological thicktail chub bones from two contemporaneous precontact Late Period (ca 700–200 cal BP) sites, CA-CCO-138 and CA-CCO-647, in the Sacramento-San Joaquin Delta. Precontact thicktail chub were longer than specimens caught in the early 1900s, achieving a maximum standard length (SL) of 306 mm. Size distributions suggest spearing was the most likely capture technique. A comparison of preferred habitats and spawning times suggest that thicktail chub were part of a larger spring-summer nearshore fishery. Results contribute vital information on thicktail chub lengths and their key role in precontact Indigenous fisheries.

Keywords: thicktail chub, tui chub, size estimation, fisheries, precontact, Sacramento-San Joaquin Delta

Dietary reconstructions derived from zooarchaeological and isotopic datasets indicate that endemic freshwater fish were a crucial resource for Indigenous people of the Sacramento-San Joaquin Delta, also known as the California Delta, but hereafter referred to simply as the Delta (Barton et al., 2020; Eerkens et al., 2021; Gobalet et al., 2004; Hash et al., 2015; Talcott, 2019). The reliance on freshwater fish from archaeological evidence contradicts ethnographic accounts, which emphasize the importance of anadromous Pacific salmon (*Oncorhynchus* spp.) in Delta diets (Gobalet et al., 2004; Yoshiyama, 1999). Despite the ubiquity and frequency of fish remains from Delta archaeological sites, little research has focused on the nature of freshwater fisheries.

Indigenous fisheries of the Delta were unique and differ greatly from those that exist today. Former tidal marshlands have been replaced by agricultural land through the construction of levees and canals, which have drained nearly the entirety of former wetland environments (Whipple et al., 2012). As well, invasive species have replaced most native floodplain-adapted fish, such as the Sacramento perch (*Archoplites interruptus*) and thicktail chub (*Gila crassicauda*). Most of these original, endemic species were unique to the Central Valley of California (Moyle, 2002).

Thicktail chub were once common over large stretches of California's Central Valley (Moyle, 2002). The species was in decline by the 1880s, and the last live individual was recorded in the early 1950s (Mills, 1963; Mills and Mamika, 1980). Only a few formaldehyde-preserved specimens exist today. However, their bones are prominent in archaeological sites in the Delta and along the San Joaquin, Sacramento, Pajaro, and Salinas Rivers, as well as sites around the San Francisco Bay (Figure 1; Broughton et al., 2015; Gobalet, 1990, 2020; Gobalet et al., 2004; Schulz, 1995). Significant erasure of Indigenous ecological knowledge by European colonizers in Central California means little recorded information about thicktail chub behavior or method of capture survives. As a result, knowledge of the species' ecology and Native fishing practices associated with their capture is sparse (Miller et al., 1989; Mills and Mamika, 1980; Moyle, 2002). Increasingly, archaeological datasets are used to retrace the biogeography, biology, and demographics, not just of extirpated and extinct species, such as thicktail chub, but of ecological systems in general (e.g., Dombrosky et al., 2016; Erlandson and Rick, 2008; Gobalet 1993, 2004; Gobalet et al., 2005; Guiry et al., 2020; Jones et al., 2021).

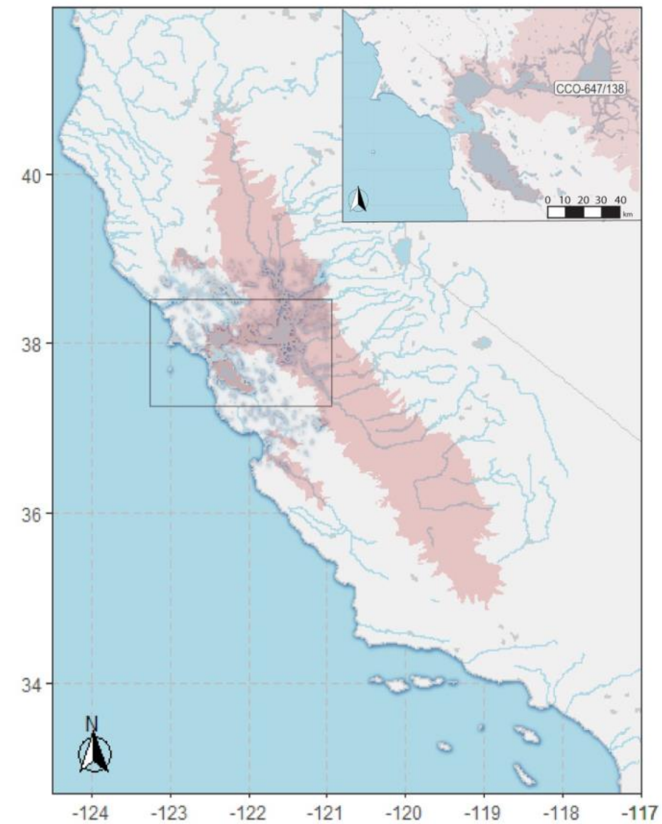

Figure 1: Map of California with inset map of the California Delta showing region and sites. Thicktail chub distribution prior to extirpation in the red shaded area (Santos et al., 2013).

Of keen interest to the archaeological record in the Delta is the degree to which Late Period Indigenous fisheries were specialized in harvesting particular shallow-water and marsh species. Precontact populations in Central California went through a series of faunal and botanical economic intensifications, where subsistence strategies diversified and shifted away from larger prey to focus on more energy-costly and small-bodied prey species, such as grass seeds, hares and rabbits, and migratory waterfowl (Broughton, 1994a, 1994b; Wohlgemuth, 1996). Of interest is whether the fisheries similarly intensified, for example through use of mass capture technologies such as fishing nets.

In this paper, we develop allometric regression formulae derived from known length tui chub (*Siphateles bicolor*) comparative skeletal material to predict the length of capture of thicktail chub from two nearby and contemporaneous Delta sites, CA-CCO-138 (Hotchkiss Mound) and CA-CCO-647 (hereafter we drop the "CA-" prefix when referring to the sites). We then compare length distributions to hypothetical fishing gear selectivity models, as well as to length distributions for Sacramento perch from CCO-647 (Miszaniec et al. 2021). Together, we use this information to estimate fishing methods used to catch thicktail chub and provide insight into possible seasonality of capture activities. In the future, these formulae can be used in diachronic studies to evaluate whether fisheries intensification also occurred, for example, as might be indicated through decreases in average standard length of thicktail chub.

Background

Prior to levee construction and the draining of wetlands to promote farming in the late 1800s and early 1900s, the Delta supported extensive marshlands. By some estimates, this was the largest estuarine system on the west coast of the Americas. Only around 3% of the Delta's historical tidal wetland remains today (Whipple, 2012). The Delta's year-round freshwater marshes were an oasis of productivity during the long dry season, where daily tidal surges cycled in marine nutrients that supported rich local fisheries. Of the 90 freshwater fish species in the Delta today, 40 are native to the region, and of those, 17 are endemic (Moyle, 2002). The productive Delta landscape was densely populated by Miwok, Ohlone, Patwin, Pomo, and Yokuts people at the time of contact (Bennyhoff, 1977; Kroeber, 1925, 1932).

Combined with upstream damming, the introduction of numerous invasive species, and runoff from farmlands and urban areas, the ecology of the Delta has dramatically altered over the last 150 years (Hundley, 2001; Norgaard et al., 2009). These rapid changes have led to decline, extirpation, and extinction of several native species.

Thicktail chub were characterized by a short, deep, and thick caudal tail peduncle, and a short, cone-shaped head. From 101 preserved thicktail chub specimens measured in previous studies, fish ranged from 49 to 268 mm standard length (SL) with females typically larger (Miller et al., 1989; Mills and Mamika, 1980). Thicktail chub are thought to have occupied lowland lakes, sloughs, slow-moving stretches of rivers, and the surface waters of San Francisco Bay. They are often described as carnivorous, feeding on invertebrates and small fish due to their stubby gill rakers, short intestines, and hooked pharyngeal teeth (Moyle, 2002) (see Figure 2). The precise reason(s) for their decline is not well known, but is likely related to alteration of tule marsh habitats used for spawning, changes to water systems due to reclamation projects and irrigation, siltation from hydraulic mining, commercial fishing, and/or introduction of invasive predatory species (Miller, 1963; Mills and Mamika, 1980; Moyle, 2002).

Figure 2: Sample of thicktail pharyngeal bones included in this study (top left), with blow up of single specimen (right) and magnification of hooked tooth (bottom left).

The few accounts and theories on how thicktail chub were harvested in precontact times vary. Pomo supposedly netted chub along with suckers (family Catastomidae), hardhead (*Mylopharodon conocephalus*), pike (*Esox lucius*; which were not found in California in precontact times), and trout (*Oncorhynchus mykiss*) (Johnson, 1978). By contrast, ethnographic reports suggest that Patwin caught chub, perch, and pikeminnow (*Ptychocheilus grandis*) with bipointed bone gorges (Kroeber, 1932). From historical accounts, Bay Miwok fished primarily with them nets from tule rafts (Cook, 1957: 133–137). Based on archaeological data, Talcott (2019) argues that thicktail chub, along with other endemic Delta fish species, were harvested when flood waters receded in the summer, leaving spawning fish stranded in residual pools where they could be caught easily by hand, net, or basket. Despite its popularity in midden deposits, Yokuts and Southern Valley Yokuts both comment that these fish were not very palatable (Latta, 1949; Wallace, 1978).

Archaeological Specimens

Archaeological fish bones used to reconstruct original fish length in this study are derived from two archeological sites in Contra Costa County, CCO-647 and CCO-138 (Figure 1). Both were village and burial sites located on stabilized sand dunes that rise several meters above the surrounding marshland.

CCO-647 was excavated between 2005 and 2007 for an urban development project (Basin Research 2016). A series of eight AMS radiocarbon dates show that the site was occupied between 820 and 320 cal BP (Eerkens et al., 2021). Fish made up the vast majority of identified faunal remains from CCO-647, including those used in this study (Hash et al., 2015). Yet, fishing related artifacts from CCO-647 were not extensive and consist entirely of piercing (n = 5; e.g., harpoon heads) or hook-and-line technologies (n = 6; e.g., gorges and fishhooks). The importance of fish in local diets was supported by quantitative mixing models based on stable isotope values of human bone collagen, which estimated that over 60% of dietary protein derived from freshwater fish (Eerkens et al., 2021: 7).

Of the fish specimens at CCO-647 identified to family level or lower (NISP = 10,588), freshwater species dominate, comprising over 98% of the assemblage. Minnows (family Cyprinidae) comprise 45% (NISP=4,747) of identified elements, followed by Sacramento perch at 36% (NISP=3,812), and Sacramento sucker at 17% (*Catostomus occidentalis*; NISP=1,784) (Table 1). Thicktail chub were the most abundant identifiable minnow, accounting for 188 (58%) of the 325 minnow elements identified to species level. If the percentage of thicktail chub bones within the sample identified to species level is extrapolated to the entire assemblage of minnow bones, we estimate that thicktail chub made up 26% of the entire fish assemblage, second only to Sacramento perch (ca. 36%). This percentage for thicktail chub is likely an underestimate because only a few elements (i.e., basioccipital, pharyngeal, dentary, cleithrum) are distinctive for the species.

Table 1: Number of identified specimens (NISP) of fish remains identified from CCO-647 and CCO-138. Adjusted NISP were derived for minnow specimens by allocating unidentified minnow specimens into each identified Cyprinid species according to proportional representation.

Taxa		CCO-647 NISP	CCO-647 Adj. NISP	CCO-647 Adj. %	CCO-138 NISP	CCO-138 Adj. NISP	CCO-138 Adj. %
Sturgeon	*Acipenser* sp.	171	171	1.6%	26	26	2.7%
Hardhead	*Mylopharodon conocephalus*	8	133	1.3%	-	-	-
Sacramento blackfish	*Orthodon microlepidotus*	19	317	3.0%	-	-	-
Hitch	*Lavinia exilicauda*	25	417	4.0%	5	132	13.6%
Sacramento pikeminnow	*Ptychocheilus grandis*	19	317	3.0%	11	291	29.9%
Sacramento splittail	*Pogonichthys macrolepidotus*	23	384	3.6%	-	-	-
Thicktail chub	*Gila crassicauda*	188	3136	29.8%	8	211	21.7%
Minnow (unidentified)	Cyprinidae	4422	-	n/a	611	-	n/a
Longfin smelt	*Spirinchus thaleichthys*	-	-	-	7	-	-
Sacramento sucker	*Catostomus occidentalis*	1784	1784	16.9%	7	7	0.7%
Trouts and salmon	*Salmonidae*	15	15	0.1%	7	7	0.7%
Threespine stickleback	*Gasterosteus aculeatus*	-	-	-	1	1	0.1%
Sacramento perch	*Archoplites interruptus*	3812	3812	36.2%	288	288	29.6%
Tule perch	*Hysterocarpus taski*	53	53	0.5%	1	1	0.1%
Total		**10,539**	**10,539**		**972**	**972**	

The Hotchkiss Mound (CCO-138) was partially excavated over several field seasons by the UC Berkeley archaeological field school in the 1930s through 1950s (Atchley, 1994; Cook and Elsasser, 1956; Cook and Heizer, 1962). A series of 46 AMS radiocarbon dates on materials from these earlier excavations range between 810 and 150 cal BP, showing occupation was contemporaneous with CCO-647 (Eerkens and Bartelink. 2019). Half the fish bones for this study derive from five, one-liter soil samples collected from the surface of the site in 2013. Sediment was water-screened through 1/32” mesh and sorted to isolate fish bones. In total, 2621 fish bones were examined, of which 972 were identified to family level or lower, and 361 to genus or species level (Miszaniec et al., 2018). Minnows account for 65% of the assemblage identified to family level or lower, Sacramento perch are 30%, and Sacramento sucker only 1%. Of the minnow bones, only 24 (4%) could be identified to species, with 11 pikeminnow (46%), eight thicktail chub (33%), and five hitch (21%). If we extrapolate backwards to the fraction of thicktail chub among the minnows, and the fraction of minnows among all fish, we estimate that 22% of all fish at CCO-138 are thicktail chub. This would rank them third behind Sacramento perch (30%) and pikeminnow (30%). An additional eight thicktail chub bones derive from a more recent excavation on the apron surrounding the site (report not yet available; Jeff Rosenthal, personal communication 2023).

Fish Size to Fishing Strategy

Reconstructed length profiles from archaeological fish assemblages are often used to identify cultural selection practices (e.g., Desse and Desse-Berset, 1996a; Dombrosky et al., 2022; Feltham and Marquiss, 1989; Granadeiro and Silva, 2000; Zohar et al., 1997). Such approaches assume that different harvesting strategies will result in the catch of fish of particular size ranges (Colley,1987; Granadeiro and Silva 2000; Greenspan, 1998). The generalized gear selectivity model assumes that fish are sampled from natural population profiles. Natural profiles are dominated by younger individuals, while older classes contain progressively fewer individuals due to natural attrition. Caution should be exercised when comparing archaeological length distributions to generalized population curves, as population curves are not standard between fish taxa, and will be influenced by aspects of physiology, ecology, and behavior (Klein, 1982; Greenspan 1998). Certain fish populations have seasonally regulated growth, characterized by relatively rapid growth during the first few years of life, which may result in a multimodal size profile because birth is often seasonal and not evenly distributed throughout the year (Sheldon, 1965; Craig and Oertel, 1966a, 1966b). In addition, fishers are not always sampling from typical population curves. Many species exhibit cohort-based habitat preference, for example, due to feeding or spawning behaviors. Thus, human fishing will select from a cross-section of the available population in a body of water, not necessarily a “natural distribution” of all fish of a species.

Given these assumptions, fish-length distributions are thought to be influenced by fishing technologies as follows. First, entangling nets (e.g., gill nets) are thought to result in a normal distribution of fish length, but narrower than the full range of all fish (i.e., smaller variance). Entangling nets select for fish that enter the mesh opening beyond their gill covers but cannot pass completely through. By contrast, larger fish will bounce off the net, and smaller fish will pass through (e.g., Balme 1983). Second, hook and line technologies will result in a similar normal distribution but with greater variance. Third, piercing technologies (e.g., spears or harpoons) will tend to capture only larger fish, resulting in less variance and a more negative- (or left-) skew. Fourth, entrapment nets, such as seins and dip nets, will result in a right skew with a sharp left cut off, as small fish may pass through the mesh. Finally, fish poisons will capture all fish, representing a catastrophic or natural profile.

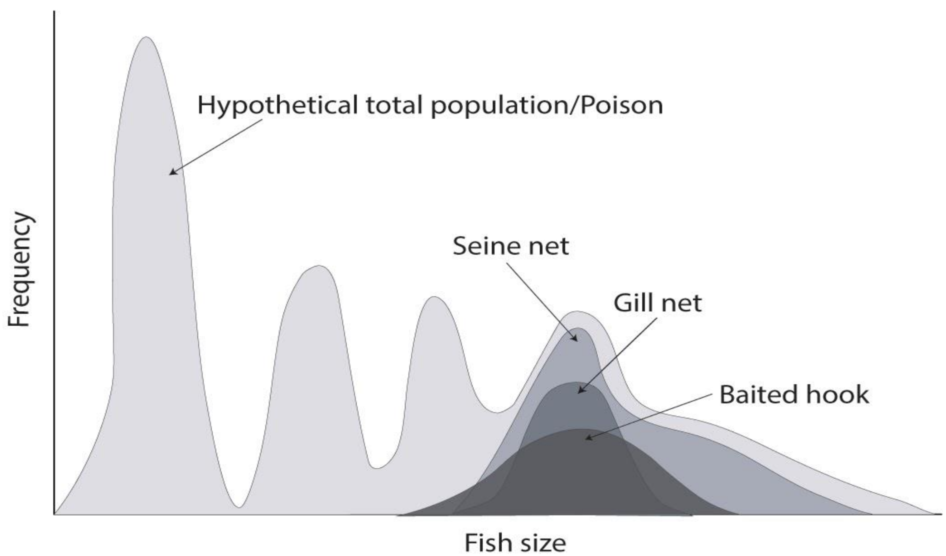

Figure 3. Graphical representation of predicted lengths, with a hypothetical natural population (or poison distribution) and hypothetical gear-selectivity curves (adapted from Greenspan, 1998).

Typically, gear selectivity is visually interpreted from histograms. Length distribution curves are based on assumptions related to gear selectivity. Such an approach does not take observer bias into account, nor does it consider how binning influences a histogram's distribution shape. To interpret the length distribution curves we calculated skewness and kurtosis for each archaeological assemblage, to capture the *shape* of the distribution curves (Figure 3). Broadly, skewness and kurtosis are measures of how a distribution may deviate from that of a normal distribution (Kallner, 2018; Shennan, 1988). Skewness measures the symmetry of a distribution. Kurtosis is a measure of whether the data are heavy-tailed or light-tailed relative to a normal distribution. We then developed generalized assumptions for skewness and kurtosis values for various fishing technologies (Table 2).

Table 2: Expected range of length classes, along with expected values of kurtosis and skewness for each fishing technology (modified from Colley, 1987).

Fishing Technology	Range	Kurtosis	Skewness
Fixed gill net	Small skew	~3	-0.5 to 0.5

Trap	Small skew	~3	-0.5 to 0.5
Seine net	Large skew	>3	>0.5
Spears and harpoons	Large skew	<3	<-0.5
Poison	All sizes	>3	>1
Hook and Line	Selective	<3	-0.5 to 0.5

Tui Chub Regression

Regression formulae were generated with skeletal elements from modern comparative tui chub (*Siphateles bicolor*; n = 55) of known lengths housed in the Peter D. Schulz Osteoichthyology collection at the University of California, Davis, collected in the 1970s and 1980s from Siskiyou and Shasta County, California, and from Churchill County, Nevada. Length estimation formulae are most effective when tailored for specific species; however, thicktail chub are extinct, and of the few museum specimens that exist, they are almost exclusively preserved whole in alcohol. Tui chub were originally classified within the *Gila* genus but were recently reclassified based on genetic data, rather than osteology, as part of a separate *Siphateles* genus (Harris, 2000); both are within the minnow subfamily Leuciscinae. Because tui chub is closely related and still widespread in many fisheries, we rely on the latter. Although predictive accuracy may decrease when applied to thicktail chub, regression formulae developed for subfamilies or families of marine fish still retain high predictive accuracy across species within those taxonomic categories (r^2=0.987) (Barrett, 1994; Desse and Desse-Berset, 1996b, 1996a).

Not all fish retain complete skeletal elements in the osteoichthyology collection, thus sample sizes vary slightly by element. Regression formulae were calculated for six elements of modern tui chub with known standard lengths: basioccipital (n=45), cleithrum (n=47), pharyngeal (n=46), dentary (n=44), opercle (n=45), and otolith (n=39). These elements were selected because they can often be differentiated among cyprinid species. Measurements for pharyngeals, dentaries, cleithrums, and opercles follow procedures established by Leunda et al. (2013: 328). Maximum centrum width and maximum length were taken on the basioccipitals and otoliths respectively (Figure 4). We measured selected skeletal elements for each comparative specimen with a pair of electronic calipers (RCBS) to the nearest 0.1 mm.

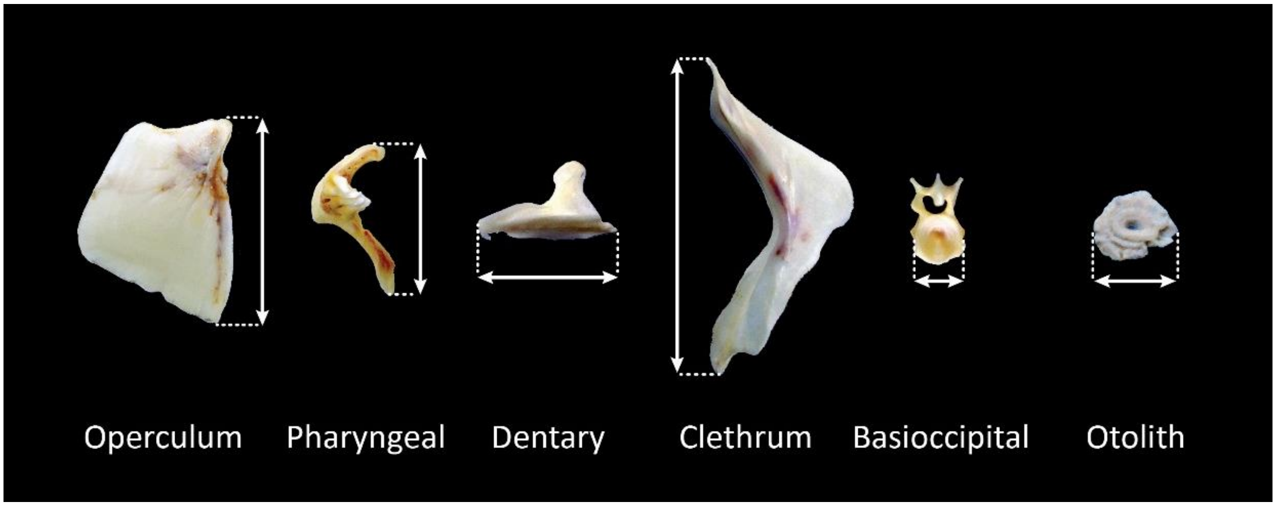

Figure 4. Measurements taken on skeletal elements of tui chub from the Peter D. Schulz Osteoichthiology comparative collection. These same measurements were taken on pharyngeals and basioccipitals of thicktail chub archaeological specimens from CCO-138 and CCO-647. Figure prepared by J. Darwent using specimen #5546.

Archaeological fish bone included in this study centers on basioccipitals and pharyngeals because they are diagnostic to species for minnows, were common in the archaeological materials, and were well-preserved (Table 3). However, we provide measurements (Supplemental Data) and regression equations for all six elements for future studies (Figure 5). Standard length (SL; body length from the tip of the fish's snout to end of the last vertebrae; Rojo, 1991) was selected as the output variable, as it was the most consistently recorded length among the modern tui chub samples. Tui chub fish lengths ranged between 102 and 332 mm (SL). Skeletal measurements for each comparative specimen were then plotted against its known length. Regression formulae were fitted using the "lm" function in R version 4.0.3 (R Core Team 2022) to derive linear equations, $y = ax + b$, representing the relationship between selected skeletal measurements (x) and estimated standard length (y). Skeletal lengths for archaeological specimens were then entered into the equation to derive length estimates for the ancient thicktail chub.

Table 3: Skeletal elements identified as thicktail chub from CCO-138 and CCO-647.

Site	Basioccipital	Pharyngeal	Total
CCO-138	3	13	16
CCO-647	24	37	61

Total	**27**	**50**	**77**

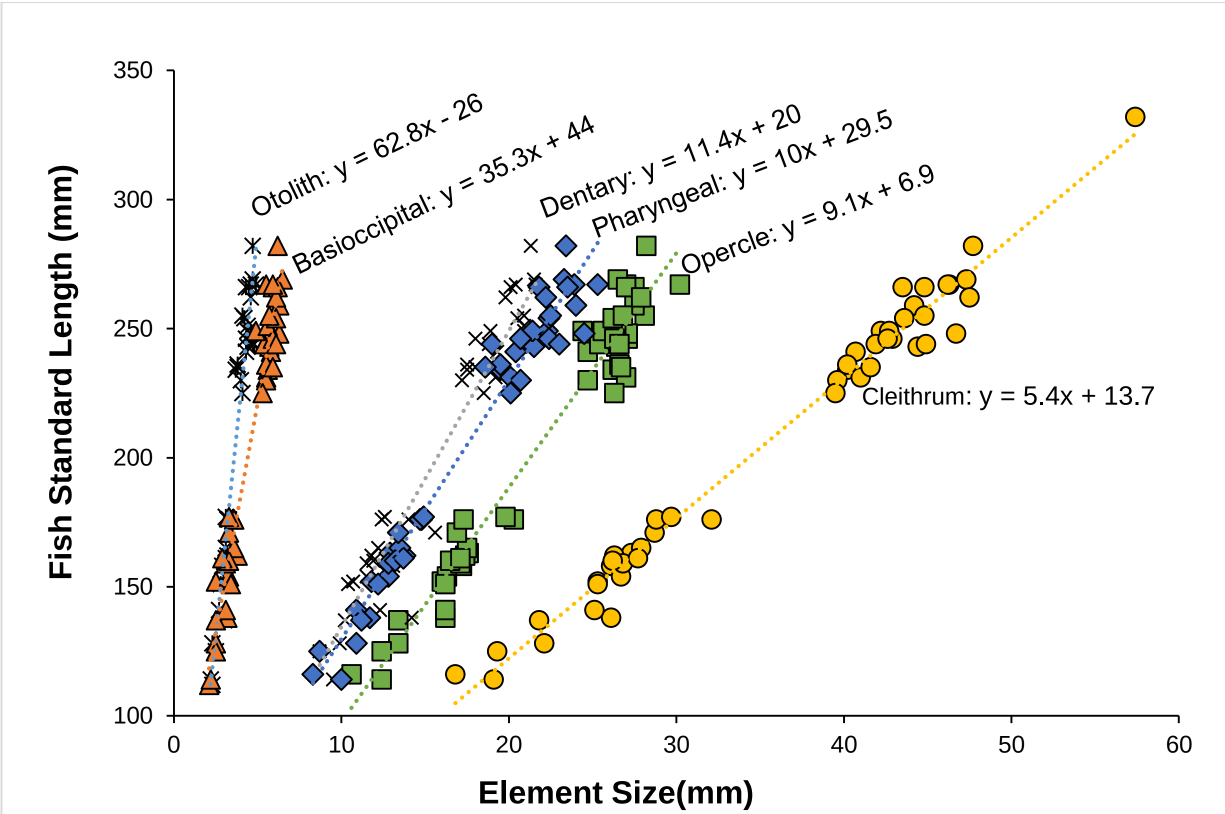

Figure 5: Regression analysis for tui chub skeletal element size vs. standard length: basioccipital (y = 35.3x + 44); cleithrum (y = 5.4x +13.7); dentary (y = 11.4x + 20); opercle (y = 9.1x + 6.9); otolith (y = 62.8x – 26); pharyngeal (y = 10x + 29.5).

Results

Comparative tui chub specimens appear to represent two distinct size cohorts, with one cluster between 110–180 mm (SL), and the other 220–290 mm (SL; see Figure 6). Entries indicate the fish were caught in three batches, one in July 1986, one in July 1987, and one in March of 1988. While the 1986 batch are all in the smaller size range, the other two batches include fish in both the smaller and larger batch. Regressions show that size of each of the six skeletal elements are strongly correlated with tui chub standard length, with R^2 correlation coefficients ranging between 0.93 and 0.98 (Table 4). In short, well over 90% of the variation in bone size is explained by tui chub standard length.

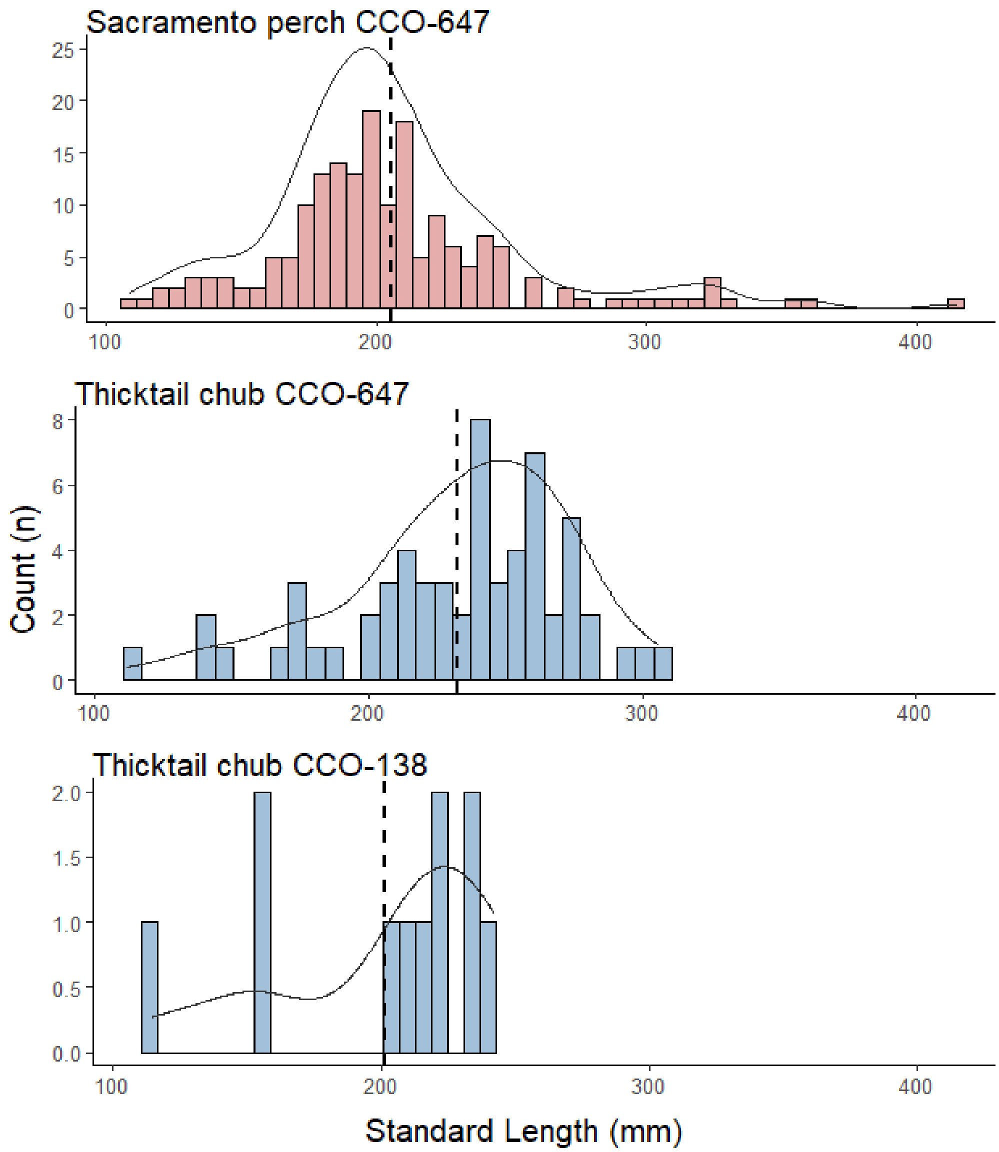

Figure 6: Histograms of Sacramento perch length estimates from CCO-647 (red) (Miszaniec et al., 2021) and thicktail chub length estimates from CCO-138 and CCO-647 (blue), with plotted disruption curve, and a dashed vertical line representing the mean.

Table 4: Tui chub regression results using the "lm" function in R version 4.0.3 (R Core Team 2022) to derive linear equations, y = ax + b, which represents the relationship between selected skeletal measurements (x) and estimated standard length (y).

Element	R^2	Standard Error	Equation
Basioccipital	0.95	12.4	y = 35.3x + 44
Cleithrum	0.98	7.3	y = 5.4x + 13.7

Dentary	0.93	13.7	y = 11.4x + 20
Opercle	0.96	10.6	y = 9.1x + 6.9
Otolith	0.94	13.7	y = 62.8x – 26
Pharyngeal	0.96	10.0	y = 10x + 29.5

In total, 61 thicktail chub bones from CCO-647 and 11 from CCO-138 were complete enough to include in the size estimate analysis. Using the regression formulae for pharyngeals and basioccipitals, we then predicted fish standard length for each of these 72 specimens. Summary statistics are presented in Table 5, while the on-line appendices provide individual measurements. We estimate that thicktail chub standard lengths ranged between 112- and 305-mm with an average of 232 mm SL at CCO-647, and between 115- and 242 mm SL with an average of 201 mm SL at CCO-138. Fish-length estimates for CCO-647 show a mode at 238 mm (n=7), while specimens at CCO-138 have two modes at 222 mm (n=2) and 236 mm (n=2).

Table 5: Descriptive statistics for thicktail chub from CCO-647 and CCO-138, and Sacramento perch from CCO-647 (Miszaniec et al., 2021).

Sample	Mean (mm)	Min (mm)	Max (mm)	Kurtosis	Skewness	n
Thicktail chub (CCO-647)	232	112	306	3.4	-0.78	61
Thicktail chub (CCO-138)	201	115	242	2.7	-1.00	11
Sacramento perch (CCO-647)	196	113	367	5.8	1.16	182

Discussion

Combining modern known length fish estimates with archaeological data provides new insight on the size of precontact thicktail chub. The maximum standard length of 306 mm SL (n=72) is about 35 mm longer than the maximum lengths recorded from preserved museum specimens (n=101; Miller 1963). However, this length discrepancy may be a product of several factors. Fish lengths are often correlated with health, and the availability of nutritional energy in an environment (Shin et al., 2005). Decreased fish length among 20th century samples may indicate that populations that were already in decline due to habitat degradation or competition with invasive species by the time these specimens were collected (Moyle, 2002). Longer archaeological specimens may indicate healthier populations in precolonial environments.

Although such an interpretation is tempting, we acknowledge that longer lengths may alternatively be due to methodological and sampling biases. By relying on tui chub to build the regression formulae, the predictive accuracy of the equations may have decreased (Barrett, 1994; Desse and Desse-Berset, 1996a). In addition, the 101 museum specimens measured by Miller (1963) may have been biased either by location or method of collection, and only represent a small sample of thicktail chub.

Thicktail chub length distributions from both archaeological sites were moderately skewed to the right (skewness of -1 and -0.8 for the two sites). Kurtosis for specimens from CCO-647 suggest a relatively high and sharp peak, and a long and flat tail (Kallner, 2018; Shennan, 1988). Kurtosis values for CCO-138 suggest a low and broad distribution with a shorter and thinner tail. Thicktail chub length distributions also display a high concentration of fish measuring greater than 200 mm (SL). As fish length is often correlated with age (Shin et al., 2005), it is likely that longer fish represent older individuals. This bias towards larger adult fish counters the hypothetical total population model, which would contain a higher frequency of younger small-bodied fish. Although SL distributions for archaeological thicktail chub have not previously been published, they differ from tui chub SL distributions from California, Nevada, and Oregon. Tui chub lengths were either dominated by small fish, or the distributions followed a bell curve, suggesting that fish were caught with the use of gill or entrapment nets (Butler, 1996; Greenspan, 1998; Raymond and Sobel, 1990).

Thicktail chub length distributions are also distinct from archaeological Sacramento perch lengths from CCO-647 (see Miszaniec et al., 2021). The shape of Sacramento perch length distributions match that of expected curves for entrapment nets (i.e., sein or dip nets). However, Miszaniec et al. (2021) note that the Sacramento perch length distribution may also represent sampling of nearshore spawning adults rather than signs of cultural selection. We believe there are three non-mutually exclusive scenarios that may have produced length curve biasing toward longer thicktail chub in archaeological specimens.

First, the results could represent selective harvesting of sub-populations of thicktail chub. Depending on age, fish will exhibit different seasonal movements and habitat preferences. A bias towards long fish may reflect a distinct population cohort representing seasonal movement mitigated by life history development. For instance, a bias towards adult fish may reflect a spawning population. Many fish of the Delta congregate *en masse* in the spring, and move to environments such as floodplains, streams, or backwaters to spawn, which would have increased likelihood of capture (Moyle, 2002). The most numerous fish from CCO-647, Sacramento perch and Sacramento suckers, both spawn in the spring, and although they exhibit varied habitat preferences, both can spawn in floodplain environments.

Second, the results could represent use of a particular fishing technology. Of the hypothetical selectivity curves, the thicktail chub distributions match best with expectations for single capture methods, such as piercing (e.g., spears or harpoons) and possibly hook-and-line technologies. Both techniques create a bias toward longer fish. In line with this interpretation, artifacts representing both piercing and hook-and-line technologies were recovered at CCO-647 (Basin Research Associates, 2016). Fishing with either a harpoon or spear could have occurred in shallow waters, especially if fish were spawning (Bennyhoff, 1950). From compiled ethnographic accounts, Lindstrom (1996) notes that at peak spawning, an average of 10 fish can be speared or harpooned in an hour. In hook-and-line technologies, fish size is mitigated mainly by hook size. While most minnows are difficult to catch with hook and line, the thicktail chub's hypothesized insectivorous diet may have made them vulnerable to hooking, due to its presumed predatory nature (John Lyons pers. comm., 2023; Moyle 2002).

Third, length distributions may have been influenced by post-capture human selection. Typically, body size correlates with higher meat yields (Broughton, 1999). Such an observation would be in line with theories derived from optimal foraging theory which postulate that humans strive to maximize caloric returns (MacArthur and Pianka, 1966). Regardless of how fish were caught, a preferential selection for larger fish could have truncated a normal distribution curve. On the other hand, experiments undertaken by Raymond and Sobel (1990) found that small schooling tui chub caught through mass harvesting (nets) had higher return rates than larger fish, as the latter required longer processing time. It must also be noted that netting technologies incur significant upfront manufacturing investment (Bettinger et al., 2006; Lindstrom, 1996; Tushingham and Bettinger, 2013).

Although the distribution curve of thicktail chub could have been produced by several factors (as listed above), we propose that they were primarily speared. Such an observation is supported when taking the length distributions of thicktail chub into consideration with those of Sacramento perch from CCO-647, which likely represent nearshore spawning adults (Miszaniec et al., 2021). Overlapping spawning time of several fish species, would have made shallow water spearing a lucrative activity. As discussed earlier, fish remains at both CCO sites were dominated by medium- to small-bodied species preferring slow moving waters. The widespread precontact wetland environment likely increased habitat suitability for these endemic fish, making spearing return rates for thicktail chub higher than other fishing techniques. Based on the known timing of spawning for the two other most abundant fish recovered from CCO-647, Sacramento perch and Sacramento sucker, we suggest that most thicktail chub were harvested in spring and early summer (Figure 7).

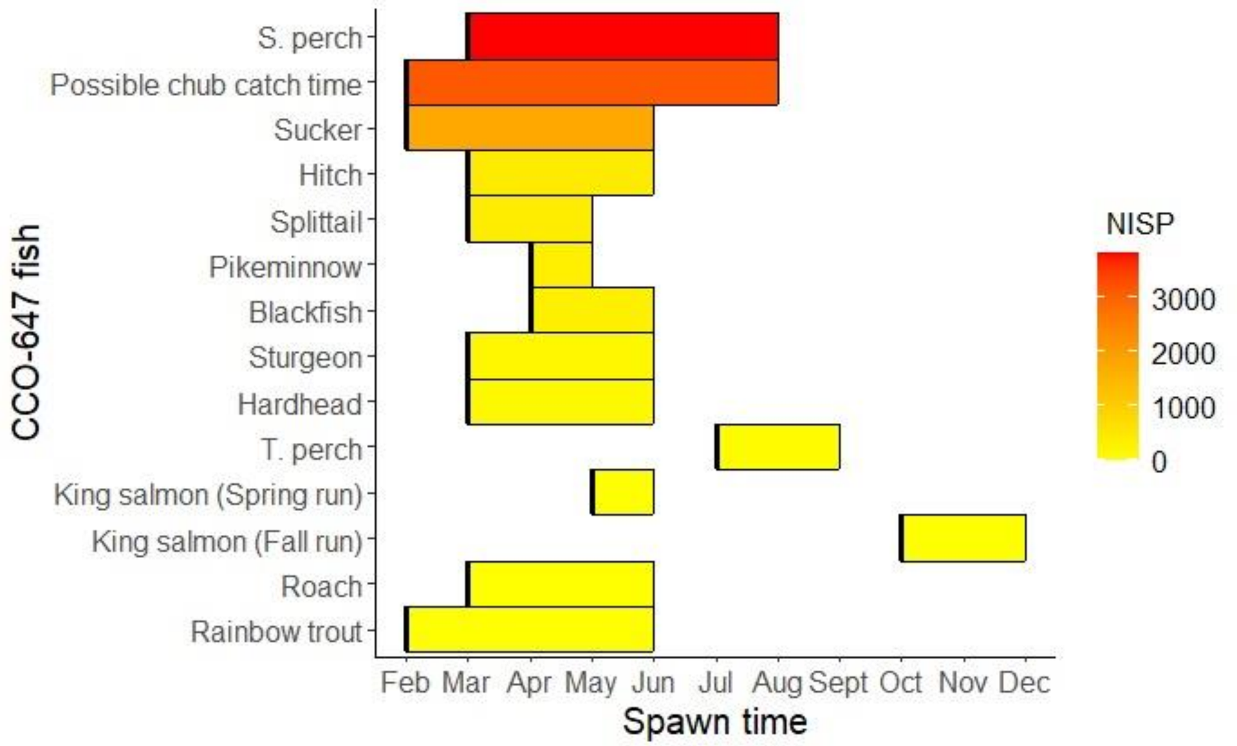

Figure 7: Spawning times of fish taxa recovered from CCO-647 (based on Moyle 2002); color scale represents adjusted NISP.

Conclusion

We developed regression formulae from comparative tui chub specimens for several skeletal elements to estimate standard length for the now extinct thicktail chub. These formulae can be used for tui chub and thicktail chub remains from other archaeological sites, and they have the potential to shed light on growth dynamics for both chubs, adding nuance to the unique

Indigenous technologies and fisheries across Central California. As well, the formulae can be used to assess whether tui or thicktail chub sizes decreased over archaeological time, as might be expected under diachronic intensification models.

Length estimation from archaeological specimens from the two archaeological sites examined here indicate that thicktail chub were longer than previously-recorded, historic-period museum specimens. Maximum ancient fish length was estimated at 306mm. The distribution of archaeological lengths showed a skew toward longer individuals. When taken together with length estimates for Sacramento perch, and when compared to the overall ichthyofaunal assemblage, we conclude that thicktail chub were likely speared when they were in shallow waters. Based on optimal foraging models, this probably occurred during spring and early summer at peak spawning time.

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References

Atchley, Sara M. 1994. *A Burial Analysis of the Hotchkiss Site (CA-CCO-138)*. Master's thesis, Sonoma State University.

Balme, Jane. 1983. Prehistoric Fishing in the Lower Darling, Western New South Wales. In *Animals and Archaeology: 2. Shell Middens, Fishes and Birds*, edited by Caroline Grigson and Juliet Clutton-Brock, 19–32. Oxford, UK: British Archaeological Reports, International Series 183.

Barrett, James H. 1994. Bone Weight and the Intraclass Comparison of Fish Taxa. In *Fish Exploitation in the Past: Proceedings of the 7th Meeting of the ICAZ Fish Remains Working Group*, edited by W. Van Neer, 3–15. Tervuren, Belgium: Annales du Musée Royale de l'Afrique Centrale, Sciences Zoologiques.

Barton, Loukas, Eerkens, J., Talcott, S., Kennedy, M., & Newsome, S. 2020. Something other than salmon: Isotopic evidence of late Holocene subsistence in California's Central Valley. In *Cowboy Ecologist: Essays in Honor of Robert L. Bettinger*, edited by Roshanne S. Bakhtiary, Terry L. Jones, and Michael G. Delacorte, 239–268. Center for Archaeological Research at Davis, Volume 19. University of California, Davis.

Basin Research Associates. 2016. *Archaeological Data Recovery Report, CA-CCO-647 Shea Homes Summer Lake Project Contra Costa County, California.* Berkeley: Basin Research Associates, Inc.

Bennyhoff, James A. 1950. *California Fish Spears and Harpoons*. Anthropological Records, Volume 9, Issue 4. University of California, Berkeley.

Bennyhoff, James A. 1977. *Ethnogeography of the Plains Miwok*. Center for Archaeological Research at Davis, Volume 5. University of California, Davis.

Bettinger, Robert L., Bruce Winterhalder, and Richard McElreath. 2006. A Simple Model of Technological Intensification. *Journal of Archaeological Science*, 33(4): 538–545. https://doi.org/10.1016/j.jas.2005.09.009

Broughton, Jack M. 1994a. Declines in Mammalian Foraging Efficiency during the Late Holocene, San Francisco Bay, California. *Journal of Anthropological Archaeology*, 13: 371–401. https://doi.org/10.1006/jaar.1994.1019

Broughton, Jack M. 1994b. Late Holocene Resource Intensification in the Sacramento Valley, California: The Vertebrate Evidence. *Journal of Archaeological Science*, 21(4): 501–514. https://doi.org/10.1006/jasc.1994.1050

Broughton, Jack M. 1999. *Resource Depression and Intensification During the Late Holocene, San Francisco Bay*. Berkeley: University of California Press.

Broughton, Jack M., Erik P. Martin, Brian McEneaney, Thomas Wake, and Dwight D. Simons. 2015. Late Holocene Anthropogenic Depression of Sturgeon in San Francisco Bay, California. *Journal of California and Great Basin Anthropology*, 35(1): 3–27. https://www.jstor.org/stable/45155437

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. https://doi.org/10.2307/282012

Colley, Sarah M. 1987. Fishing for Facts. Can we Reconstruct Fishing Methods from Archaeological Evidence? *Australian Archaeology*, 24: 16–26. https://www.jstor.org/stable/40286850

Cook, Sherburne F. 1957. The Aboriginal Population of Alameda and Contra Costa Counties, California. *University of California Publications, Anthropological Records*, 16: 131–156. Berkeley: University of California Press.

Cook, Sherburne F., and Albert B. Elsasser. 1956. Burials in the Sand Mounds of the Delta Region of the Sacramento-San Joaquin River System. *University of California Archaeological Survey Reports*, 35: 26–46. Berkeley: University of California Press.

Cook, Sherburne F., and Robert F. Heizer. 1962. Chemical Analysis of the Hotchkiss Site (CCo-138). *University of California Archaeological Survey Reports*, 57(1): 1–24. Berkeley: University of California Press.

Craig, Gordon Younger, and Gerhard Oertel. 1966a. Deterministic Models of Living and Fossil Populations of Animals. *Quarterly Journal of the Geological Society of London*, 122**:** 315–355. https://doi.org/10.1144/gsjgs.122.1.0315

Craig, Gordon Younger, and Gerhard Oertel. 1966b. Models of Living and Fossil Populations of Animals Generated by a Computer. *Nature*, 210**:** 438–439. https://doi.org/10.1038/210438a0

Desse, J., and Nathalie Desse-Berset. 1996a Archaeozoology of Groupers (Epinephelinae). Identification, Osteometry and Keys to Interpretation. *Archaeofauna*, 5: 121–127. https://revistas.uam.es/archaeofauna/article/view/8875/9102

Desse, J., and Nathalie Desse-Berset. 1996b. On the Boundaries of Osteometry Applied to Fish. *Archaeofauna*, 5: 171–179. https://revistas.uam.es/archaeofauna/article/view/8882/9109

Dombrosky, Jonathan, Thomas F. Turner, Alexandra Harris, and Emily Lena Jones. 2022. Body Size from Unconventional Specimens: A 3D Geometric Morphometrics Approach to Fishes from Ancestral Pueblo Contexts. *Journal of Archaeological Science*, 142:105600. https://doi.org/10.1016/j.jas.2022.105600

Dombrosky, Jonathan, Steve Wolverton, and Lisa Nagaoka, L. 2016. Archaeological Data Suggest Broader Early Historic Distribution for Blue Sucker (*Cycleptus elongatus*, Actinopterygii, Catostomidae) in New Mexico. *Hydrobiologia*, 771: 255–263. https://doi.org/10.1007/s10750-015-2639-9

Eerkens, Jelmer W., and Eric J. Bartelink. 2019. New Radiocarbon Dates from CA-CCO-138 (Hotchkiss Mound) and CA-CCO-139 (Simone Mound) and Insights into Mounds, Settlement Patterns, and Culture History in the California Delta. *California Archaeology*, 11: 45–63. https://doi.org/10.1080/1947461X.2019.1581979

Eerkens, Jelmer W., Lauren Canale, Eric Bartelink, Chris Canzonieri, Jason Miszaniec, and Jessica Morales. 2021. Stable Isotopes Demonstrate the Importance of Freshwater Fisheries in Late Holocene Native Californian Diets in the California Delta. *Journal of Archaeological Science: Reports*, 38:103044. https://doi.org/10.1016/j.jasrep.2021.103044

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

Feltham, Mark J. and Marquiss, Mick. 1989. The Use of First Vertebrae in Separating, and Estimating the Size of Trout (*Salmo trutta*) and Salmon (*Salmo salar*) in Bone Remains. *Journal of Zoology*, 219: 113–122. https://doi.org/10.1111/j.1469-7998.1989.tb02570.x

Gobalet, Kenneth W. 1990. Prehistoric Status of Freshwater Fishes of the Pajaro-Salinas River System of California. *Copeia*, 3: 680–685. https://doi.org/10.2307/1446434

Gobalet, Kenneth W. 1993. Additional archaeological evidence for endemic fishes of California's Central Valley in the coastal Pajaro-Salinas Basin. *The Southwestern Naturalist* 38(3) 218-223.

Gobalet, Kenneth W. 2004. Using archaeological remains to document regional fish presence in prehistory; a Central California case study. *Transactions of the Western Section of the Wildlife Society* 40:107-113.

Gobalet, Kenneth W. 2020. Fish Remains from Archaeological Site CA-ALA-565/H and a Summary of the Fishes in the Archaeological Record of the San Francisco Bay. In *Protohistoric Village Organization and Territorial Maintenance: The Archaeology of Síi Túupentak (CA-ALA-565/H) in the San Francisco Bay Area*, edited by Brian F. Byrd, Laurel Engbring, Michael Darcangelo and Allika Ruby, pp. 230–236, 448–458. Center for Archaeological Research at Davis, California.

Gobalet, Kenneth W., Thomas A. Wake, and Kalie L. Hardin. 2005. Archaeological record of native fishes of the lower Colorado River, how to identify their remains. *Western North American Naturalist* 65: 335-344.

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. https://doi.org/10.1577/T02-084.1

Granadeiro, José P., and Mónica A. Silva 2000. The Use of Otoliths and Vertebrae in the Identification and Size-Estimation of Fish in Predator-Prey Studies. *Cybium*, 24(4): 383–393. https://doi.org/10.26028/cybium/2000-244-005

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. https://doi.org/10.1006/jasc.1998.0276

Guiry, Eric J., Trevor J. Orchard, Thomas C. A. Royle, Christina Cheung, and Dongya Y. Yang. 2020. Dietary Plasticity and the Extinction of the Passenger Pigeon (*Ectopistes migratorius*). *Quaternary Science Reviews*, 233: 106225 https://doi.org/10.1016/j.quascirev.2020.106225

Harris, Phillip M. 2000. *Systematic Studies of the Genus* Siphateles *(Ostariophysi: Cyprinidae) from Western North America*. Ph.D. dissertation, Oregon State University.

Hash, John M., Kenneth W. Gobalet, and James F. Harwood. 2015. Differential decomposition may contribute to the abundance of Sacramento perch (*Archoplites interruptus*) in the archaeological record of California. *Journal of California and Great Basin Anthropology* 35(1): 87-97.

Hundley, Norris, Jr. 2001. *The Great Thirst: Californians and Water: A History, Revised Edition*. Berkeley: University of California Press.

Johnson, Patti J. 1978. Patwin. In: *Handbook of North American Indians Volume 8: California*, edited by Robert F. Heizer. Smithsonian Institution, Washington, DC, pp. 350-360.

Jones, Terry L., Joan Brenner Coltrain, David K. Jacobs, Judith Porcasi, Simon C. Brewer, Janet C. Buckner, John D. Perrine, and Brian F. Codding. 2021. Causes and consequences of the late Holocene extinction of the marine flightless duck (*Chendytes lawi*) in the northeastern Pacific. *Quaternary Science Reviews* 260: 106914. https://www.sciencedirect.com/science/article/pii/S0277379121001219

Kallner, Anders. 2018. Formulas. In *Laboratory Statistics (Second Edition): Methods in Chemistry and Health Sciences*, edited by Anders Kallner, 1–140. Amsterdam: Elsevier. http://dx.doi.org/10.1016/B978-0-12-814348-3.00001-0

Klein, Richard G. 1982. Patterns of Ungulate Mortality and Ungulate Mortality Profiles from Langebaanweg (early Pliocene) and Elandsfontein (Middle Pleistocene), South-western Cape Province, South Africa. *Annals of the South African Museum*, 90**:** 49–94.

Kroeber, Alfred L. 1932. The Patwin and their Neighbors. *University of California Publications in Archaeology and Ethnology* 29(4):253–423.

Kroeber, Alfred L. 1925. *Handbook of the Indians of California.* Bureau of American Ethnology Bulletin 78. Washington, D.C.: Smithsonian Institution, Government Printing Office.

Latta, Frank F. 1949. *Handbook of Yokuts Indians*. Exeter, CA: Bear State Books.

Leunda, Pedro M., David Galicia, Rafael Miranda, Javier Madoz, and Steve Parmenter. 2013. Bone-to-Body Biometric Relationships for Owens and Lahontan Tui Chubs and their Hybrids in California. *Journal of Fish and Wildlife Management*, 4(2): 326–331. https://doi.org/10.3996/022013-JFWM-018

Lindstrom, Susan. 1996. Great Basin Fisherfolk: Optimal Diet Breadth Modelling the Truckee River Aboriginal Subsistence Fishery. In *Prehistoric Hunter-Gatherer Fishing Strategies*, edited by Mark G. Plew, 114–180. Boise, ID: Department of Anthropology, Boise State University.

MacArthur, Robert H., and Eric R. Pianka. 1966. On Optimal Use of a Patchy Environment. *The American Naturalist*, 100(916): 603–609.

Miller, Robert R. 1963. Synonymy, Characters and Variation of *Gila crassicauda*, a Rare Californian Minnow, with an Account of its Hybridization with *Lavinia exilicauda*. *California Fish and Game*, 49(1): 20–29.

Miller, Robert R., James D. Williams, and Jack E. Williams. 1989. Extinctions of North American Fishes During the Past Century. *Fisheries Magazine*, 14(6): 22–38. https://doi.org/10.1577/1548-8446(1989)014%3C0022:EONAFD%3E2.0.CO;2

Mills, Terry J., and Kathy A. Mamika. 1980. *The Thicktail Chub,* Gila crassicauda*, an Extinct California Fish*. Inland Fisheries Endangered Species Program, Special Publication 80-2. Sacramento: State of California, The Resources Agency, Department of Fish and Game.

Miszaniec, Jason I., Jelmer W. Eerkens, and Eric J. Bartelink. 2018. An Icthyoarchaeological Study of Dietary Change in the California Delta, Contra Costa County. *Proceedings of the Society for California Archaeology*, 32: 269–278.

Miszaniec, Jason I., Matthew Ramirez, Jessica Morales, Christopher Canzonieri, and Jelmer W. Eerkens, 2021. Use of Archaeological Data in Retracing Diet and Growth of Extirpated Fish Populations in the California Delta: An Allometric and Isotopic Approach to Sacramento Perch (*Archoplites interruptus*) Historical Ecology. *Journal of Archaeological Science: Reports*, 39: 103–191. https://doi.org/10.1016/j.jasrep.2021.103191

Moyle, Peter B. 2002. *Inland Fishes of California, Revised and Expanded.* Berkeley: University of California Press.

Norgaard, Richard B., Giorgos Kallis, and Michael Kiparsky. 2009. Collectively Engaging complex Socio-ecological Systems: Re-envisioning Science, Governance, and the California Delta. *Environmental Science and Policy*, 12(6): 644–652. https://doi.org/10.1016/j.envsci.2008.10.004

Raymond, Anan W., and Elizabeth Sobel. 1990. The Use of Tui Chub as Food by Indians of the Western Great Basin. *Journal of California and Great Basin Anthropology*, *12*(1): 2–18. https://www.jstor.org/stable/27825400

R Core Team. 2022. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.r-project.org/

Rojo, Ilfonso L. 1991. *Dictionary of Evolutionary Fish Osteology, 1st Edition*. Boca Raton, FL: CRC Press.

Santos, Nicholas R., Jacob V. E. Katz, Peter B. Moyle, P. B., and Joshua H. Viers. 2013. A Programmable Information System for Management and Analysis of Aquatic Species Range Data in California. *Environmental Modelling and Software,* 53: 13–26. https://doi.org/10.1016/j.envsoft.2013.10.024

Schulz, Peter D. 1995. Prehistoric Fish Remains, Including Thicktail Chub, from the Pajaro River System. *California Fish and Game*, 81(2): 82–84.

Sheldon, Raymond W. 1965. Fossil Communities with Multi-Modal Size-Frequency Distributions. *Nature*, 206(4991): 1336–1338. https://doi.org/10.1038/2061336a0

Shennan, Stephen. 1988. Eight – Numeric Variables: The Normal Distribution. In *Quantifying Archaeology*, edited by Stephen Shennan, 101–113. Edinburgh: Edinburgh University Press. https://doi.org/10.1016/B978-0-12-639860-1.50011-0

Shin, Yunne-Jai, Marie-Joëlle Rochet, Simon Jennings, John G. Field, and Henrik Gislason. 2005. Using Size-Based Indicators to Evaluate the Ecosystem Effects of Fishing. *ICES Journal of Marine Science*, 62(3): 384–396.

Talcott, Susan D. 2019. *The Significance of Salmon in Pre-contact Hunter-Gatherer Diet: An Isotopic Perspective on Aquatic Resource Exploitation in Northern California*. Ph.D. dissertation, University of California, Davis.

Tushingham, Shannon, and Robert L. Bettinger. 2013. Why Foragers Choose Acorns Before Salmon: Storage, Mobility, and Risk in Aboriginal California. *Journal of Anthropological Archaeology*, 32(4): 527–537. https://doi.org/10.1016/j.jaa.2013.09.003

Wallace, William J. 1978. Southern Valley Yokuts. In *Handbook of North American Indians: Volume 8, California*, edited by Robert F. Heizer, 448–461. Washington, D.C.: Smithsonian Institution.

Whipple, Alison, Robin Grossinger, Daniel Rankin, Bronwen Stanford, and Ruth Askevold. 2012. *Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process.* SFEI Contribution No. 672. Richmond: San Francisco Estuary Institute-Aquatic Science Center.

Wohlgemuth, Eric. 1996. Resource Intensification in Prehistoric Central California: Evidence from Archaeobotanical Data. *Journal of California and Great Basin Anthropology*, 18(1): 81–103. https://www.jstor.org/stable/27825599

Yoshiyama, Ronald M. 1999. A History of Salmon and People in the Central Valley Region of California. *Reviews in Fisheries Science*, 7(3–4):197–239. https://doi.org/10.1080/10641269908951361

Zohar, Irit, T. Dayan, and Ehud Spanier. 1997. Predicting Grey Triggerfish Body Size from Bones. *International Journal of Osteoarchaeology*, 7:150–156. https://doi.org/10.1002/(SICI)1099-1212(199703)7:2%3C150::AID-OA329%3E3.0.CO;2-T

Table 1

Table 1: Number of identified specimens (NISP) of fish remains identified from CCO-647 and CCO-138. Adjusted NISP were derived for minnow specimens by allocating unidentified minnow specimens into each identified Cyprinid species according to proportional representation.

		CCO-647			**CCO-138**		
Taxa		**NISP**	**Adj. NISP**	**Adj. %**	**NISP**	**Adj. NISP**	**Adj. %**
Sturgeon	*Acipenser* sp.	171	171	1.6%	26	26	2.7%
Hardhead	*Mylopharodon conocephalus*	8	133	1.3%	-	-	-
Sacramento blackfish	*Orthodon microlepidotus*	19	317	3.0%	-	-	-
Hitch	*Lavinia exilicauda*	25	417	4.0%	5	132	13.6%
Sacramento pikeminnow	*Ptychocheilus grandis*	19	317	3.0%	11	291	29.9%
Sacramento splittail	*Pogonichthys macrolepidotus*	23	384	3.6%	-	-	-
Thicktail chub	*Gila crassicauda*	188	3136	29.8%	8	211	21.7%
Minnow (unidentified)	Cyprinidae	4422	-	n/a	611	-	n/a
Longfin smelt	*Spirinchus thaleichthys*	-	-	-	7	-	-
Sacramento sucker	*Catostomus occidentalis*	1784	1784	16.9%	7	7	0.7%
Trouts and salmon	*Salmonidae*	15	15	0.1%	7	7	0.7%
Threespine stickleback	*Gasterosteus aculeatus*	-	-	-	1	1	0.1%
Sacramento perch	*Archoplites interruptus*	3812	3812	36.2%	288	288	29.6%
Tule perch	*Hysterocarpus taski*	53	53	0.5%	1	1	0.1%
Total		**10,539**	**10,539**		**972**	**972**	

Table 2: Expected range of length classes, along with expected values of kurtosis and skewness for each fishing technology (modified from Colley, 1987).

Fishing Technology	**Range**	**Kurtosis**	**Skewness**
Fixed gill net	Small skew	~3	-0.5 to 0.5
Trap	Small skew	~3	-0.5 to 0.5
Seine net	Large skew	>3	>0.5
Spears and harpoons	Large skew	<3	<-0.5
Poison	All sizes	>3	>1
Hook and Line	Selective	<3	-0.5 to 0.5

Table 3: Skeletal elements identified as thicktail chub from CCO-138 and CCO-647.

Site	Basioccipital	Pharyngeal	Total
CCO-138	3	13	16
CCO-647	24	37	61
Total	**27**	**50**	**77**

Table 4

Table 4: Tui chub regression results using the "lm" function in R version 4.0.3 (R Core Team 2022) to derive linear equations, y = ax + b, which represents the relationship between selected skeletal measurements (x) and estimated standard length (y).

Element	R^2	**Standard Error**	**Equation**
Basioccipital	0.95	12.4	y = 35.3x + 44
Cleithrum	0.98	7.3	y = 5.4x + 13.7
Dentary	0.93	13.7	y = 11.4x + 20
Opercle	0.96	10.6	y = 9.1x + 6.9
Otolith	0.94	13.7	y = 62.8x – 26
Pharyngeal	0.96	10.0	y = 10x + 29.5

Table 5: Descriptive statistics for thicktail chub from CCO-647 and CCO-138, and Sacramento perch from CCO-647 (Miszaniec et al., 2021).

Sample	Mean (mm)	Min (mm)	Max (mm)	Kurtosis	Skewness	n
Thicktail chub (CCO-647)	232	112	306	3.4	-0.78	61
Thicktail chub (CCO-138)	201	115	242	2.7	-1.00	11
Sacramento perch (CCO-647)	196	113	367	5.8	1.16	182

Site#	Field Collection (FC) Bag#	Sample#	Genus	Species	Common Name	Skeletal Element	Element Measurement (mm)
CA-CCO-647	2084	2084	Gila	crassicauda	thicktail chub	basioccipital	5.7
CA-CCO-647	20i	20i-A	Gila	crassicauda	thicktail chub	basioccipital	5.0
CA-CCO-647	20i	20i-B	Gila	crassicauda	thicktail chub	basioccipital	6.1
CA-CCO-647	272i	272i-D	Gila	crassicauda	thicktail chub	basioccipital	6.2
CA-CCO-647	272i	272i-E	Gila	crassicauda	thicktail chub	basioccipital	5.4
CA-CCO-647	272i	272i-F	Gila	crassicauda	thicktail chub	basioccipital	4.7
CA-CCO-647	361g	361g-B	Gila	crassicauda	thicktail chub	basioccipital	3.6
CA-CCO-647	361g	361g-C	Gila	crassicauda	thicktail chub	basioccipital	3.6
CA-CCO-647	502h	502h-E	Gila	crassicauda	thicktail chub	basioccipital	5.8
CA-CCO-647	510/516	510/516-A	Gila	crassicauda	thicktail chub	basioccipital	6.1
CA-CCO-647	510/516	510/516-B	Gila	crassicauda	thicktail chub	basioccipital	7.4
CA-CCO-647	510/516	510/516-C	Gila	crassicauda	thicktail chub	basioccipital	5.5
CA-CCO-647	510/516	510/516-D	Gila	crassicauda	thicktail chub	basioccipital	6.2
CA-CCO-647	510/516	510/516-E	Gila	crassicauda	thicktail chub	basioccipital	4.5
CA-CCO-647	520h	520h-C	Gila	crassicauda	thicktail chub	basioccipital	6.5
CA-CCO-647	520h	520h-D	Gila	crassicauda	thicktail chub	basioccipital	7.1
CA-CCO-647	520h	520h-E	Gila	crassicauda	thicktail chub	basioccipital	6.1
CA-CCO-647	520h	520h-F	Gila	crassicauda	thicktail chub	basioccipital	5.5
CA-CCO-647	520h	520h-G	Gila	crassicauda	thicktail chub	basioccipital	6.6
CA-CCO-647	526g	526g	Gila	crassicauda	thicktail chub	basioccipital	6.4
CA-CCO-647	5h	5h	Gila	crassicauda	thicktail chub	basioccipital	4.7
CA-CCO-647	64h	64h-E	Gila	crassicauda	thicktail chub	basioccipital	4.9
CA-CCO-647	908g	908g	Gila	crassicauda	thicktail chub	basioccipital	5.5
CA-CCO-647	913g	913g	Gila	crassicauda	thicktail chub	basioccipital	4.5
CA-CCO-647	2084	2084	Gila	crassicauda	thicktail chub	pharyngeal	22.4
CA-CCO-647	108d	108d-A	Gila	crassicauda	thicktail chub	pharyngeal	15.3
CA-CCO-647	108h	108h-A	Gila	crassicauda	thicktail chub	pharyngeal	22.1
CA-CCO-647	108h	108h-B	Gila	crassicauda	thicktail chub	pharyngeal	20.1
CA-CCO-647	120f	120f	Gila	crassicauda	thicktail chub	pharyngeal	20.8
CA-CCO-647	15i	15i-A	Gila	crassicauda	thicktail chub	pharyngeal	20.8
CA-CCO-647	15i	15i-B	Gila	crassicauda	thicktail chub	pharyngeal	24.4
CA-CCO-647	15i	15i-C	Gila	crassicauda	thicktail chub	pharyngeal	15.9
CA-CCO-647	265i	265i-A	Gila	crassicauda	thicktail chub	pharyngeal	21.6
CA-CCO-647	265i	265i-B	Gila	crassicauda	thicktail chub	pharyngeal	24.4
CA-CCO-647	265i	265i-C	Gila	crassicauda	thicktail chub	pharyngeal	19.8
CA-CCO-647	265i	265i-D	Gila	crassicauda	thicktail chub	pharyngeal	22.7
CA-CCO-647	265i	265i-E	Gila	crassicauda	thicktail chub	pharyngeal	14.0
CA-CCO-647	272d	272d-A	Gila	crassicauda	thicktail chub	pharyngeal	8.2
CA-CCO-647	272d	272d-B	Gila	crassicauda	thicktail chub	pharyngeal	11.0
CA-CCO-647	272i	272i-A	Gila	crassicauda	thicktail chub	pharyngeal	21.2
CA-CCO-647	272i	272i-B	Gila	crassicauda	thicktail chub	pharyngeal	24.9

CA-CCO-647	272i	272i-C	Gila	crassicauda	thicktail chub	pharyngeal	22.4
CA-CCO-647	278g	278g	Gila	crassicauda	thicktail chub	pharyngeal	11.8
CA-CCO-647	361g	361g-A	Gila	crassicauda	thicktail chub	pharyngeal	10.8
CA-CCO-647	502h	502h-A	Gila	crassicauda	thicktail chub	pharyngeal	23.1
CA-CCO-647	502h	502h-B	Gila	crassicauda	thicktail chub	pharyngeal	24.4
CA-CCO-647	502h	502h-C	Gila	crassicauda	thicktail chub	pharyngeal	23.8
CA-CCO-647	502h	502h-D	Gila	crassicauda	thicktail chub	pharyngeal	19.1
CA-CCO-647	510/516	510/516-F	Gila	crassicauda	thicktail chub	pharyngeal	19.2
CA-CCO-647	510/516	510/516-G	Gila	crassicauda	thicktail chub	pharyngeal	14.2
CA-CCO-647	520h	520h-A	Gila	crassicauda	thicktail chub	pharyngeal	27.3
CA-CCO-647	520h	520h-B	Gila	crassicauda	thicktail chub	pharyngeal	21.4
CA-CCO-647	55i	55i	Gila	crassicauda	thicktail chub	pharyngeal	19.8
CA-CCO-647	59i	59i-A	Gila	crassicauda	thicktail chub	pharyngeal	24.8
CA-CCO-647	64h	64h-A	Gila	crassicauda	thicktail chub	pharyngeal	21.0
CA-CCO-647	64h	64h-B	Gila	crassicauda	thicktail chub	pharyngeal	18.3
CA-CCO-647	64h	64h-C	Gila	crassicauda	thicktail chub	pharyngeal	18.1
CA-CCO-647	64h	64h-D	Gila	crassicauda	thicktail chub	pharyngeal	18.3
CA-CCO-647	67g	67g	Gila	crassicauda	thicktail chub	pharyngeal	17.4
CA-CCO-647	706g	706g-A	Gila	crassicauda	thicktail chub	pharyngeal	19.9
CA-CCO-647	712f	712f-A	Gila	crassicauda	thicktail chub	pharyngeal	23.0

Predicted Standard Length (mm)
245.50
220.77
259.63
263.17
234.90
210.17
171.31
171.31
249.03
259.63
305.56
238.44
263.17
203.11
273.77
294.96
259.63
238.44
277.30
270.23
210.17
217.24
238.44
203.11
253.99
182.85
250.98
230.94
237.96
237.96
274.03
188.86
245.97
274.03
227.94
256.99
169.82
111.70
139.76
241.96
279.04

253.99
147.78
137.76
261.00
274.03
268.02
220.92
221.92
171.82
303.09
243.97
227.94
278.04
239.96
212.91
210.90
212.91
203.89
228.94
260.00

Site#	Context	Sample#	Genus	Species	Common Name
CA-CCO-138	mound apron	1397-A	Gila	crassicauda	thicktail chub
CA-CCO-138	mound apron	1397-B	Gila	crassicauda	thicktail chub
CA-CCO-138	northwest slope of mound	9A	Gila	crassicauda	thicktail chub
CA-CCO-138	mound apron	1397-C	Gila	crassicauda	thicktail chub
CA-CCO-138	top of mound, east side	3A	Gila	crassicauda	thicktail chub
CA-CCO-138	top of mound, east side	4A	Gila	crassicauda	thicktail chub
CA-CCO-138	top of mound, east side	4B	Gila	crassicauda	thicktail chub
CA-CCO-138	top of mound, east side	4C	Gila	crassicauda	thicktail chub
CA-CCO-138	top of mound, east side	5A	Gila	crassicauda	thicktail chub
CA-CCO-138	north slope of mound	7A	Gila	crassicauda	thicktail chub
CA-CCO-138	north slope of mound	7B	Gila	crassicauda	thicktail chub

Skeletal Element	Element Measurement (mm)	Predicted Standard Length (mm)
basioccipital	3.1	153
basioccipital	4.6	206
basioccipital	5.6	242
pharyngeal	19.2	222
pharyngeal	12.5	155
pharyngeal	20.6	236
pharyngeal	8.5	115
pharyngeal	20.6	236
pharyngeal	18.0	210
pharyngeal	19.2	222
pharyngeal	18.7	217

UCDZL#	Genus	Species	ommon_Nan	State	County	Locality	Collector	ate_Collecte
5037	Siphateles	bicolor	tui chub	NV	Churchill	Stillwater W	US Fish and	1986/7/1
5546	Siphateles	bicolor	tui chub	NV	Churchill	Stillwater W	US Fish and	1986/7/1
5547	Siphateles	bicolor	tui chub	NV	Churchill	Stillwater W	US Fish and	1986/7/1
5548	Siphateles	bicolor	tui chub	NV	Churchill	Stillwater W	US Fish and	1986/7/1
5549	Siphateles	bicolor	tui chub	NV	Churchill	Stillwater W	US Fish and	1986/7/1
5550	Siphateles	bicolor	tui chub	NV	Churchill	Stillwater W	US Fish and	1986/7/1
5551	Siphateles	bicolor	tui chub	NV	Churchill	Stillwater W	US Fish and	1986/7/1
5552	Siphateles	bicolor	tui chub	NV	Churchill	Stillwater W	US Fish and	1986/7/1
5553	Siphateles	bicolor	tui chub	NV	Churchill	Stillwater W	US Fish and	1986/7/1
5554	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5556	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5557	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5558	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5559	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5560	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5565	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5567	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5576	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5577	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5578	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5579	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5580	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5581	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5582	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5583	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5584	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5585	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5586	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5587	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5588	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5589	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5590	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5591	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5592	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5596	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5597	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5598	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5603	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5604	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5605	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5612	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5613	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23

5665	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5666	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/23
5803	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Schulz, Pete	1987/7/28
5815	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Taylor, T.	1988/3/2
5823	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Taylor, T.	1988/3/2
5825	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Taylor, T.	1988/3/2
5826	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Taylor, T.	1988/3/2
5836	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Taylor, T.	1988/3/2
5838	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Taylor, T.	1988/3/2
5839	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Taylor, T.	1988/3/2
5844	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Taylor, T.	1988/3/2
5848	Siphateles	bicolor	tui chub	CA	Shasta	Big Lake	Taylor, T.	1988/3/2
5849	Siphateles	bicolor	tui chub	CA	Siskiyou	Klamath Riv	Moyle, Pete	1970s

SL	Pharyngeal	Dentary	Cleithrum	Opercle	Basioccipital	Otolith
176	14.8	14	32.1	20.3	3.6	3.2
163	12.9		27.3	17.6		
158	12.9	13.1	26.1	17.2		2.9
138	11.7	14.2	26.1	16.2	3.2	
152	11.8	10.7	25.3	16	2.5	
162	13.8	11.8	26.3	17.4	3.8	3.2
165	13.5	12.2	27.9	17.5	3.6	3.1
141	10.9	12.3	25.1	16.2	3.1	2.7
171	13.4	15.6	28.7	16.9	3.3	
243	21.5	20.7	44.4	26.4	5.7	4.4
266						
267	23.9	20.4	46.3	27	5.5	4.9
249	22.3	20.9	42.2	24.4	5.6	4.4
176	14.7	12.4	28.8	17.3	3.6	3.3
234	19.5	17.5	40.2	26.2	5.6	3.7
266	21.8	20.1	43.5	27.5	5.9	4.3
241	20.4	19.3	40.7	24.7	5.8	4.3
112					2.1	2.3
255				28.1		
269	23.3	21.5	47.3	26.5	6.5	4.7
259	24		44.2	27.5	6.3	
231	20.1	19.2	41	27	5.5	
266	23.5	21.7	44.8	27	6.2	4.5
154	12.8	11.5	26.7	16.3	3.3	3
246	22.4	20.9	42.9	27.1	5.9	
159	12.8	11.5	26.8	17.1	3.1	3.1
244	19	18.8	41.9	25.4	5.4	4.7
248	24.5	21.6	46.7	27.1	6.3	4.6
262	22.2	19.8	47.5	27.9	6.1	4.6
160	13.2	11.9	26.2	16.5	3.3	
249	21.4	18.9	42.7	25.6	4.9	4.4
230	20.7	17.2	39.6	24.7	5.5	4
251		20.9		26.4	5.6	4.4
156						
128	10.9	9.9	22.1	13.4	2.5	2.3
332			57.4			
282	23.4	21.3	47.7	28.2	6.2	4.7
254	22.4	20.5	43.6	26.2	6.1	4.2
246	20.7	18	42.6	26.3	5.9	4.3
236	19.5	17.5	40.2	26.6	5.5	3.8
235	18.6	18	41.6	26.7	5.9	3.8
125	8.7	8.7	19.3	12.4	2.5	2.5

112						
137	11.2	10.2	21.8	13.4	2.5	3
255	22.5	20.9	44.8	26.8	5.7	4.1
267	25.3	21.6	46.2	30.2	5.9	4.6
244	23	20.6	44.9	26.6	6.1	4.8
177	14.9	12.6	29.7	19.8	3.3	3.1
102						
225	20.1	18.5	39.5	26.3	5.3	4.1
161	13.7	12.8	27.7	17.1	2.9	3.1
151	12.2	10.4	25.3	16.2	3.4	2.8
216						
114	10	9.5	19.1	12.4	2.2	2.2
116	8.3		16.8	10.6		