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Differential Decomposition May Contribute to the Abundance of Sacramento Perch (*Archoplites interruptus*) in the Archaeological Record of California

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*Consistent with previous archaeological studies, Sacramento perch (*Archoplites interruptus*) represented the greatest proportion of native fish remains among the nearly 49,000 elements identified in five large Central Valley freshwater samples (CA-SAC-15/H, CA-CCO-548, -647, -767, and CA-SJO-3) when individual species are considered. Further, we provide evidence that there is a bias in California's zooarchaeological record that may be due in part to differential decomposition rather than the fishing habits of native peoples. Distinctive skeletal features of the single sunfish species (Centrarchidae) in this assemblage also may account for the elevated numbers of Sacramento perch. Representatives of Centrarchidae and Cyprinidae were buried for over seven years and the remains then excavated and assessed for decomposition. We further discuss issues in which either locally abundant fishes are not represented as expected or the ethnographic record appears to be at odds with the California archaeological record.*

A KEY QUESTION OF THE ARCHAEOLOGICAL record is whether or not the remains of organisms recovered during excavations accurately reflect their use by the local residents (Grayson 1984; Lyman 1994; Reitz and Wing 1999). As a case in point, Gobalet et al. (2004) found that Sacramento perch (*Archoplites interruptus*) comprised 45.7% of the 30,000 identifiable elements recovered from 36 archaeological sites in the Central Valley of California; similarly, Schulz and Simons (1973) found that 51.0% of their sample of index elements from a site near Sacramento were Sacramento perch. Noticeably scarce in the same archaeological record, particularly in the San Joaquin Valley, are remains of Chinook salmon (*Oncorhynchus tshawytscha*), which ethnographic and historic information (Yoshiyama 1999; Yoshiyama et al. 1998, 2000, 2001) suggests were a major dietary resource for the Indians that inhabited the Central Valley at the time of European contact. Additionally, the archaeological record seems to underrepresent the six native minnows (Cyprinidae)—thicktail chub (*Gila crassicauda*), hardhead (*Mylopharodon conocephalus*), hitch (*Lavinia exilicauda*), Sacramento blackfish (*Orthodon microlepidotus*), splittail (*Pogonichthys macrolepidotus*), and Sacramento pikeminnow (*Ptychocheilus grandis*)—that are large enough to make them attractive for consumption.

Though the paucity of salmonid remains in the San Joaquin River drainage is perplexing, it is possibly explainable if the bones were dried, pulverized, and consumed as "salmon flour" (Aginsky 1943; Curtis 1924;

Davis 1963; Dixon 1905, 1907; DuBois 1935; Kroeber 1925, 1971; Kroeber and Barrett 1962; Lightfoot and Parrish 2009; Rostlund 1952;). Kroeber (1932) also noted that fish processing was completed near the capture weirs, thus sparing the village from the scavengers attracted to the offal. In the Pacific Northwest, Stewart (1977) recorded various native practices, including the ceremonial return of salmon offal and bones to the sea, the burning of the uneaten remains, or the consumption of dried bones as snacks. Any of these practices may account for the paucity of salmon remains in the archaeological record, but no similar native practices have been recorded that would affect the abundance of Sacramento perch relative to the native minnows.

Sacramento perch remains are easily identifiable within the context of the native freshwater fishes of Central California, in part because they are the only native species of the sunfish family (Centrarchidae) found west of the Rocky Mountains (Moyle 2002). Our perception is that the vertebrae and other bones of Sacramento perch retain their diagnostic features, and we became suspicious that the abundance of Sacramento perch bones in the archaeological record was because their skeletal elements were more resistant to decomposition than the bones of cyprinids. Smith et al. (2011) suggested that it was bone density differences between the salmonids and Pacific cod (*Gadus macrocephalus*) that contributed to the greater representation of cod in the archaeological record in the Pacific Northwest. Bone density leading to differential decomposition may have a role in the Central Valley as well, but making such a determination is beyond the scope of our study. Grayson (1984), Lyman (1994), Nicholson (1996), Reitz and Wing (1999), and Behrensmeyer et al. (2000) have addressed differential decomposition issues in attempts to evaluate the accuracy of the archaeological record. It is thus not our intent here to evaluate all the potential taphonomic reasons remains might not persist, because these have already been addressed by these and other investigators.

It is impractical and unethical to undertake taphonomic studies of increasingly rare native fishes because most native freshwater fishes of California are in decline, extinct, or have been extirpated (Brown and Moyle 2005). Thicktail chub, Clear Lake splittail (*Pogonichthys ciscoides*), bull trout (*Salvelinus confluentus*), and pink salmon (*Oncorhynchus gorbuscha*) were once resident in the fresh waters of California but are now extinct or extirpated (Moyle 2002). For this study, we had a serendipitous die-off in 1997 of centrarchids, minnows, and a clupeid (threadfin shad, *Dorosoma petenese*) in the bed of the Kern River near the campus of California State University, Bakersfield. These fishes were all introduced to California (Moyle 2002). No native species were present among the hundreds of stranded corpses. Centrarchids that are now commonly found in the canals and streams of the Central Valley include bluegill (*Lepomis macrochirus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), and crappie (*Pomoxis* spp.; Moyle 2002). For this study, these species served as proxies for Sacramento perch. The introduced and abundant common carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*)—both cyprinids—served in the place of the native minnows.

We undertook this study for several reasons, one being the desire to take advantage of the serendipitous die-off of local fishes. We wanted to determine whether or not the bones of centrarchids are more resistant to decomposition than those of cyprinids, and as a consequence, help explain the comparative abundance of Sacramento perch at most archaeological sites in the Central Valley of California. Since we have observed that vertebrae are the most common diagnostic elements found in archaeological samples, another undertaking was to determine whether or not fish vertebrae are more resistant to decomposition than skull elements. Finally, in this paper, we share our findings on fish remains from several unpublished excavations of archaeological sites in and near the delta of the Sacramento and San Joaquin rivers (Fig. 1).

METHODS

Archaeological Material

The archaeological fish remains analyzed here were provided by the following individuals:

CA-SJO-3: Liz Honeysett
Far Western Anthropological Research, Inc., Davis, CA

CA-CCO-548, -767: Randy Wiberg
Holman and Associates, San Francisco, CA

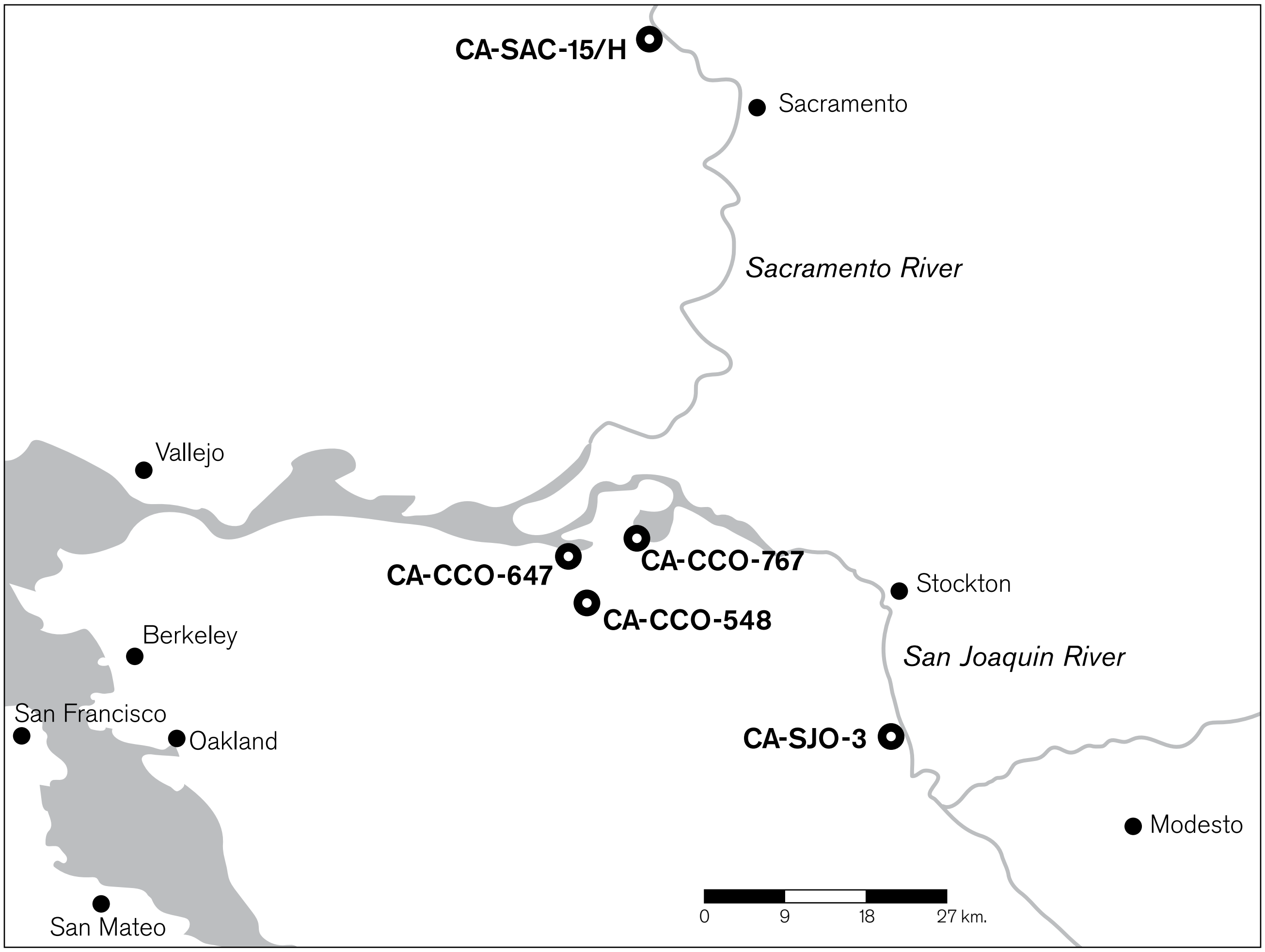

Figure 1. Location of archaeological sites in Contra Costa (CCO), Sacramento (SAC), and San Joaquin (SJO) counties considered in this study.

CA-CCO-647: Colin Busby
Basin Research Associates, San Leandro CA

CA-SAC-15/H: Richard Deis
AECOM, Sacramento, CA

Identifications of bones recovered from these archaeological sites and for the taphonomic study were made by using comparative fish skeletons housed at the Department of Biology, California State University, Bakersfield. J. M. Hash and J. F. Harwood completed the bulk of the identifications from CA-SJO-3, CA-CCO-548, and -647, Jereme W. Gaeta identified material from CA-CCO-767, and K. W. Gobalet made all the determinations for CA-SAC-15/H using his personal collection of fish skeletons (now housed at the California Academy of Sciences, San Francisco). Nomenclature follows Page et al. (2013), and the biology of the freshwater fishes can be found in Schulz and Simons (1973), McGinnis (1984), and Moyle (2002) along with the primary literature cited therein.

Taphonomic Study

Nine individual dead centrarchids (bluegill, crappie, small and largemouth bass), 20 cyprinids (common carp and goldfish), and a single clupeid (threadfin shad) were collected from around a shrinking pool in the bed of the Kern River under the Coffee Road Bridge in Bakersfield, California and buried in a common pit at a minimum depth of 23 cm. in sandy loam soil at the Environmental Studies Area on the campus of California State University, Bakersfield (CSUB). Before burial, the standard length (SL: tip of snout to the end of the hypural plate of the tail) of each individual was measured. Standard lengths for the centrarchids ranged from 25 mm. to 175 mm. and between 100 mm. and 410 mm. for the cyprinids. The single threadfin shad had a standard length of 100 mm. The specimens remained buried and undisturbed for 7.5 years from October, 1997 to April, 2005.

The remains were excavated and screened using 1 mm. (1/24") mesh and were isolated and viewed using a dissecting microscope. The centrum diameter of the vertebrae was measured with a vernier caliper. Vertebrae were counted as recovered only if the diameter could be measured (i.e., at least 50% of the centrum was intact), following methods similar to Butler's (1996:709). Diagnostic skull elements and vertebrae were identified to family. Expected vertebral recovery values were calculated by multiplying the number of buried individuals by the mean standard number of vertebrae found for each species. Percent recovery was calculated by comparing the number of buried vertebrae with the actual number recovered. Percent recovery was also calculated for 16 common and diagnostic skull and pectoral girdle elements (anguloarticular, basioccipital, ceratohyal, cleithrum, dentary, epihyal, hyomandibula, maxilla, opercle, preopercle, posttemporal, premaxilla, quadrate, scapula, urohyal, and vomer) in the same manner. As a measure of the integrity of the vertebrae, we calculated the percentage recovery of vertebrae with intact hemal or neural arches. To estimate the standard length of the fish from which individual vertebrae were recovered, we generated a regression plot of standard length to vertebral width based on museum skeletons for both the sunfishes and minnows, and used the regression equations to generate comparisons of similar-sized fishes. A two-sample proportion test was used in Minitab (State College, PA, USA) to compare mean recoveries ($\alpha = 0.05$).

RESULTS

Archaeological Material

Nearly 49,000 additional fish bones have been added to the totals for the Central Valley of California as a result of our evaluation of remains from CA-CCO-548, -647, -767, CA-SJO-3, and CA-SAC-15/H (Table 1). This adds considerable data to the total number of fish remains identified from the Central Valley of California. The 31% recovery of Sacramento perch among the nearly 49,000 remains is consistent with previous studies in that it is the most abundant single species represented in the middens of the Central Valley. This value may not seem as dramatic as the 45.7% recovery of Sacramento perch from 36 archaeological sites in the drainage of the Sacramento and San Joaquin rivers reported elsewhere (Gobalet et al. 2004) because the authors did not include a listing of elements in the Cyprinidae. In a separate sample of 296 fish remains from CA-CCO-548 (Gobalet 2004), 47.0% were Sacramento perch, even with the inclusion of cyprinids.

Taphonomic Study

Overall, 17.7% more centrarchid vertebrae were recovered than cyprinid vertebrae (Table 2). Consistent with these findings, the percentage of centrarchid vertebrae recovered with an intact hemal or neural arch was over 30% greater than for the cyprinids (Table 2). The percentage recovery of vertebrae among all individuals of standard length under 151 mm. was also significantly different with a nearly 27.7% greater recovery of centrarchid vertebrae (Table 2). Our regression equation for precaudal minnow vertebrae versus standard length was

$$y = 40.35\times + 2.08, R^2 = 0.98$$

and the equation for precaudal sunfish vertebrae versus standard length was

$$y = 31.96\times + 30.10, R^2 = 0.86$$

Among the skull elements analyzed, centrarchid preservation was greater for 12 of the 16 elements, with six of these being significantly greater ($p < 0.05$) (Table 3: urohyal, anguloarticular, posttemporal, cleithrum, vomer, and preopercle). With regard to the four cyprinid elements with greater recovery rates, in two cases (dentary and epihyal) the recovery was significantly greater than for centrarchids. Overall, the percentage recovery of skull elements was significantly greater for centrarchids than cyprinids (39.4% vs. 28.4%; Table 3). Our data also show that skull elements decompose more readily than vertebrae. We also found that a significantly greater proportion of vertebrae were recovered than skull elements for both centrarchids and cyprinids ($p < 0.001$). Curiously, no otoliths were recovered, and

Table 1

SUMMARY OF FISH REMAINS REPORTED FROM ARCHAEOLOGICAL SITES IN THE CENTRAL VALLEY OF CALIFORNIA PRESENTED AS NUMBER OF SPECIMENS

Taxon	Common Name	CCO-647	CCO-767	CCO-548	SAC-15/H	SJO-3	Total	%*
Acipenser sp.	sturgeon	171	83	101	23	13	391	
Clupeidae	herrings			7			7	
Clupea pallasi	Pacific herring			1			1	
Merluccius productus	Pacific hake	1					1	
Gasterosteus aculeatus	threespine stickleback			25	140	122	287	
Cyprinidae	carps minnows	4,422	932	9,342	5,975	3,304	23,975	49
Gila crassicauda	thicktail chub	188	23	104	279	133	727	
Lavinia sp.				3	48	1	52	
L. exilicauda	hitch	25	5	22	79	66	197	
Hesperoleucas symmetricus	California roach			1	4	1	6	
Mylopharodon conocephalus	hardhead	8	7	7		4	26	
Orthodon microlepidotus	Sacramento blackfish	19	17	33	489	31	589	
Pogonichthys macrolepidotus	splittail	23	2	4	34	16	79	
Ptychocheilus grandis	Sacramento pikeminnow	62	37	26	42	14	181	
Catostomus occidentalis	Sacramento sucker	1,784	460	742	2,680	258	5,924	12
Oncorhynchus sp.	Pacific salmon and trouts	14	5	16	199	1	235	
O. mykiss	rainbow trout			1		1	2	
O. tshawytscha	Chinook salmon	1					1	
Osmeridae	smelt			21	1		22	
Hypomesus transpacificus	delta smelt			3			3	
Spirinchus thaleichthys	longfin smelt				19		19	
Cotttus sp.	sculpins			2	3	5	10	
Centrarchidae	sunfishes			424			424	
Archoplites interruptus	Sacramento perch	3,812	1,011	5,177	3,588	1,432	15,020	31
Pomoxis sp.	crappie			2			2	
Embiotocidae	surfperches			6	108	32	146	
Hysterocarpus traskii	tule perch	53	7	357	47	89	553	
Cymatogaster aggregata	shiner perch					2	2	
Platichthys stellatus	starry flounder	5				5	10	
	Total	10,588	2,589	16,427	13,758	5,530	**48,892**	92

*Percent of total is given only for selected taxa.

Table 2

THE PERCENT RECOVERY OF VERTEBRAE AFTER 7.5-YEAR BURIAL

	Cyprinidae	Centrarchidae	P-value
All vertebrae	50.5	68.2	< 0.001
Vertebrae from individuals < 151 mm. SL	49.0	76.7	< 0.001
Vertebrae with intact arches	5.3	39.9	< 0.001

only a single element, a vertebra, was recovered from the threadfin shad.

DISCUSSION

In this study, we provide evidence that under identical conditions, the bones of members of the family Centrarchidae are more resistant to decomposition than members of the family Cyprinidae. Not only were there more centrarchid than cyprinid elements recovered after seven and a half years in the ground, but the surviving elements also contained more intact structural features (e.g., neural or hemal arches; Table 2). In only two of 16 cases (dentary and epihyal), was cyprinid recovery significantly greater for skull elements (Table 3).

Table 3

THE PERCENT RECOVERY OF THE 16 SKULL ELEMENTS FOR EACH FAMILY AND THE P-VALUES FOR THE DIFFERENCES

Skull Element	Cyprinidae	Centrarchidae	P-value
Anguloarticular	37.5	66.7	0.031*
Basioccipital	45.0	66.7	0.260
Ceratohyal	40.0	27.8	0.351
Cleithrum	22.5	55.6	0.014*
Dentary	60.0	33.3	0.049*
Epihyal	32.5	11.1	0.041*
Hyomandibula	25.0	11.1	0.169
Maxilla	25.0	33.3	0.523
Opercle	27.5	33.3	0.658
Postemporal	0.0	27.7	0.009*
Premaxilla	0.0	16.7	0.058
Preopercle	32.5	66.7	0.011*
Quadrate	45.0	50.0	0.724
Scapula	30.0	44.4	0.294
Urohyal	25.0	66.7	0.024*
Vomer	0.0	55.6	0.001*
Total Skull elements	**28.4**	**39.5**	**0.002**

*Denotes statistical significance ($\alpha = 0.05$).

Our percentage recovery of cyprinid elements was at odds with the conclusions drawn from Butler's (1996) study of tui chub. Butler and our studies together support one of Nicholson's (1996:525) findings that there was no predictable rate of decay at different localities for fish. Despite these studies, our findings suggest an explanation for the elevated percentage of Sacramento perch in the archaeological record of central California.

We also provide evidence that vertebrae in both lineages are more resistant to decomposition than skull elements. This conclusion is consistent with other studies, including those of Nicholson (1998:398), who found a greater recovery of cod vertebrae (*Gadus morhua*) over cranial elements in her taphonomic study, and Butler and Chatters (1994), who demonstrated that the vertebrae of Chinook salmon were denser than the skull elements of the same individuals. Collins (2010), on the other hand, showed that there was no significant difference in cranial and post-cranial bone loss in Atlantic salmon (*Salmo salar*) during accelerated decomposition under harsh chemical conditions in the laboratory. Needless to say, there is nothing simple about establishing a consistent pattern of preservation of vertebrate materials as they decompose in the wild or under somewhat controlled conditions.

Though we provide support for differential decomposition, there are other reasons why Sacramento perch may be better represented in the archaeological record of the Central Valley. These include the nature of the assemblage of fishes. The larger resident native fishes of the Central Valley include several members of the minnow family—thicktail chub, hitch, California roach (*Lavinia symmetricus*), hardhead, Sacramento blackfish, Sacramento splittail, and Sacramento pikeminnow—potentially two surfperches, depending on the proximity to salt water—tule perch (*Hysterocarpus traskii*) and shiner perch (*Cymatogaster aggregata*)—a single sucker (Catostomidae: Sacramento sucker), and a single sunfish (Centrarchidae: Sacramento perch). Sacramento suckers and the minnows are both in the higher-level fish clade, Cypriniformes, and thus many of their elements are similar (e.g., the vertebral elements associated with the Weberian apparatus and plural ribs) and can be mistaken for one another. With some attention to the details of the vertebrae and other commonly preserved elements, suckers and minnows can be discriminated with great confidence (Gobalet et al. 2005). However, discriminating among the minnows, based on vertebrae and numerous other elements, can be problematic, and we have only identified a few vertebrae as belonging to the Sacramento pikeminnow at CA-SAC-15/H, based on criteria described in Gobalet et al. (2005:338). Because of the difficulty in discriminating between minnows based on their vertebrae, the number of specimens of individual minnows is depressed because it is problematic to assign them to a genus. The Sacramento perch is the unique native centrarchid in the Central Valley. Its bones are likely only to be confused with the tule perch, also a member of Perciformes. Tule perch are generally smaller than Sacramento perch and most of their vertebrae (precaudal in particular) are distinctive and unlikely to be confused with those of Sacramento perch. So vertebrae are easily identifiable as Sacramento perch, in contrast with minnow vertebrae.

Many of the bones of Sacramento perch are unmistakable within the context of the depauparate native fish fauna of the Central Valley. For instance, any bone bearing a tiny pavement of teeth or the remnant tooth bases will be Sacramento perch (e.g., premaxilla,

Table 4

SUMMARY OF SAMPLE PER TAXON AND MESH SIZE FOR CA-CCO-548, CA-SJO-3 AND CA-SAC-15/H

Taxon	Sum 1/8"	Percent 1/8"*	Sum 1/16"	Percent 1/16"*	Sum 1/24"	Percent 1/24"*
Acipenser sp.	80	0.55	24		3	
Gasterosteus aculeatus	11		224	2.9	70	6.4
Cyprinidae	6,643	46.1	4,517	59.0	774	70.9
Gila crassicauda	325	2.3	116	1.5	3	
Lavinia sp.	62		19		2	
L. exilicauda	57		7		7	
L. symmetrticus			5		1	
Mylopharodon conocephalus	7		4			
Orthodon microlepidotus	279	1.9	241	3.1		
Pogonichthys macrolepidotus	35		16			
Ptychocheilus grandis	50		6			
Catostomus occidentalis	1,997	13.9	1,120	14.6	4	2.2
Oncorhynchus sp.	137	1.0	74	1.0	1	
O. mykiss	1					
Osmeridae			17		5	
Hypomesus transpacificus					5	
Spirinchus thaleichthys			19			
Cottus sp.	1		7		2	
Archoplites interruptus	4,501	31.2	1,034	13.5	110	10.1
Embiotocidae	95	0.7	45			
Cymatogaster aggregata			2			
Hysterocarpus traskii	129	0.9	163	2.1	84	7.7
Total	14,410		7,660		1,091	
Proportion Total		98.6		97.7		**97.3**

*Percentage is given only for selected taxa.

dentary, palatine, vomer, glossohyal, basibranchials, endopterygoid, infrapharyngobranchial, fifth ceratobranchial, gill rakers, etc.). Sculpins are extremely rare in the archaeological record of the Central Valley, and some of their bones bear a tiny pavement of teeth, but sculpins in the Central Valley are comparatively small and are very challenging to recover and identify at all. In this assemblage of fishes, the Sacramento perch is the only species with ctenoid scales and bones with comb-like projections (e.g., opercle, subopercle, interopercle) and distinctive lateral line canals and pores (e.g., frontal, posttemporal, preopercle, lachrymal, and other circumorbitals). Some of these elements may bear a resemblance to those of the tule perch (e.g,. a few immediate post-atlas vertebrae, circumorbitals, and pelvics), but the larger size of the elements will lend confidence to their identification as Sacramento perch. The quick identification of numerous elements as belonging to Sacramento perch is thus possible when a large assemblage of bones is being analyzed. The same elements so easily identified as Sacramento perch thus cannot be identified with confidence for any of the other fishes in the assemblage. All these elements therefore lead to an inflated number of Sacramento perch bones being identified. Reitz and Wing (1999:192) brought attention to this issue with the example of pig bones and teeth in an assemblage of multiple mammal species. We also note that the proportion of the materials that is identified as belonging to Sacramento perch is higher when screens larger than 1/16" mesh are used (Table 4). Up until recent decades, 1/8" mesh screens were considered small. Most of the data summarized by Gobalet et al. (2004) involved bones collected using 1/8" screens. This bias can distort the number of elements of Sacramento perch identified upward.

Like Sacramento perch, Sacramento suckers are also the only members of their family in the Central Valley assemblage of fishes. Some of the rationale discussed above for the Sacramento perch may apply to the Sacramento sucker as well. Their scales, however, are cycloid, and like the cyprinids they bear teeth only on the pharyngeal, not on multiple elements like the Sacramento perch. Their pattern of lateral line pores is not as exaggerated as in the Sacramento perch, making their fragmentary cranial elements difficult to distinguish from those of cyprinids. It is thus likely that only their vertebrae will inflate their numbers relative to the cyprinids, as do the vertebrae for Sacramento perch. In any event, Gobalet et al. (2004:819–820) found 12.7% of the remains reported were Sacramento suckers and we report 12% here (Table 1). This is quite consistent, and it is safe to say that suckers were a staple for the native peoples of the Central Valley when they could catch them. Despite the disdain most contemporary Americans have for eating suckers, one of us (K.W.G.) has eaten them fresh from the Kern River and found them excellent.

We have not mentioned the anadromous steelhead, salmon, nor sturgeons in this discussion because their bones are so distinctive that they should never be confused with those of any of the resident fishes, with the possible exception of those of the gill rakers and some tooth-bearing bones of the salmon and trout. The fish species that do not reach any notable size (e.g., threespine stickleback, any of the smelts, or sculpins) are often only identified with laborious microscopic examination of the bones, and each bear unique features (e.g., the scutes, the pelvic and pectoral girdles of threespine stickleback, and the large notochordal canal in the centrum of the smelts).

Taphonomic issues like those mentioned here may help account for some inconsistencies when the archaeological record does not reflect the ethnographic record. Lightfoot and Parrish (2009:205, 238) reported that Indians of the Northwest Coast Province of California harvested Pacific lampreys (*Entophenus tridentatus*) in mass, and that surf smelt (*Hypomesus pretiosus*) and night smelt (*Spirinchus starski*) were important food fishes for Indians of the Central Coast Province. Lampreys have never been identified among any archaeological remains in California, and true smelt (Osmeridae) vertebrae until recently were only found in coastal middens on Morro Bay, Elkhorn Slough (Gobalet and Jones 1995:818; Gobalet et al. 2004:808), and near Point St. George in Del Norte County (Tushingham and Bencze 2013:57). Providing additional examples, Allen and Pondella (2006:91) consider Pacific pompano (*Peprilus simillimus*), northern anchovy (*Engraulis mordax*), and Pacific sardine (*Sardinops sagax*) to be the most abundant pelagic fishes of southern California. Pacific pompano are a schooling species and reach 28 cm. in length (Love 2011:551), yet only a single vertebra from CA-SBA-38061 has been identified in an archaeological site in California. At the same time, northern anchovy and Pacific sardine are found in abundance in the California archaeological record when screens smaller than 1/8" mesh are used (Gobalet et al. 2004). Only four vertebrae of Pacific tomcod (*Microgadus proximus*) were identified among the over 105,000 archaeological remains from sites on San Francisco Bay (Gobalet et al. 2004:812). In the nineteenth century, however, Pacific tomcod were so abundant that they supported a commercial fishery (Goode 1884; Hooper 1875). Fitch (1972) is the only investigator to identify remains of the common wolf-eel (*Anarrhichthys ocellatus*) in a California midden (CA-SLO-2, Diablo Canyon, San Luis Obispo County). Wolf-eels reach at least 82 cm. in length, are found in very shallow waters, have easily recognizable large teeth, and are good to eat (Gobalet 2012; Love 2011). If we relied on the archaeological record alone, we would conclude that wolf-eels are extremely rare. Gamble (2008:18) cites the early observations of Crespí in 1769 that needlefish (possibly *Strongylura exilis*) were among the fishes taken by Indians in Goleta Slough, Santa Barbara County. This fish, that reaches nearly a meter in length (Eschmeyer et al. 1983:116), is absent from the archaeological record of California. Despite extensive anecdotal and historical evidence that the Indians of the Central Valley of California were harvesting colossal quantities of salmon (primarily Chinook salmon; Yoshiyama 1999), the archaeological record of the region appears to demonstrate the greater importance of Sacramento perch, Sacramento sucker, native cyprinids, and tule perch to the native inhabitants of the region (Table 1 and Gobalet et al. 2004). These examples show how problematic it is to assume that only fishes commonly used by the Indians should persist in the archaeological record.

Cultural traditions rather than taphonomic considerations may account for some of the absence of the above fishes from the archaeological record. In the Pacific

Northwest, for example, the wolf-eel was only eaten by medicine men wishing to improve their pharmaceutical skills (Swan 1868). This tradition may have been present in California as well. Just as important as cultural traditions, differential fish-bone density can also play a role in decomposition (Butler and Chatters 1994; Lam et al. 2003; Smith 2008; Smith et al. 2011). Pacific lampreys contain no bones, scales, or teeth, thus possessing little that would be expected to be preserved. Smith and Butler (2008) suggest that though lampreys have not been found among archaeological remains in the Pacific Northwest, investigators have not had a "search image" for their small horny mouthparts. The current trend in archaeological studies to use screens of 1/16" mesh or smaller is yielding dividends that may uncover these mouthparts, and have demonstrated the presence of osmerids (true smelts) in archaeological sites in coastal California (e.g., CA-DNO-13 (2,791 vertebrae) [Tushingham and Bencze 2013:57], CA-DNO-11 (2,595 vertebrae), Crescent City Airport (96 vertebrae), CA-SON-3417 (8 vertebrae), CA-MRN-150, -194, -195, -196W, -327 (collectively 39 vertebrae), CA-CCO-297 (one vertebra) CA-SCL-12 (3 vertebrae), CA-SLO-56 (117 vertebrae), CA-SLO-95 (4 vertebrae), CA-SLO-2357 (7 vertebrae), and CA-SDI-4426 (one vertebra); [K.W. Gobalet, unpublished data]). In the instance of smelts, the archaeological record is becoming more supportive of the ethnographic record. We also suspect that there is some confusion regarding what is considered a smelt. Page et al. (2013:85, 99) reported eight species of osmerids from the Pacific Ocean of North America and three New World silversides (Atherinopsidae) from the Pacific Ocean north of Mexico. The osmerids are "true" smelts according to ichthyologists, but two of the silversides have the unfortunate common names of topsmelt (*Atherinops affinis*) and jacksmelt (*Atherinopsis californiensis*), which undoubtedly creates considerable confusion. The two families are very distantly related evolutionarily. There thus may continue to be an insurmountable mismatch between the archaeological and ethnographic records.

SUMMARY

In light of the data presented here, we now recognize that the 28,408 bones of Sacramento perch identified among the 87,326 identified fish bones from archaeological sites in the Central Valley of California (Table 1 and Gobalet et al. 2004) do not necessarily reflect a preference of the local peoples for Sacramento perch. These large numbers of Sacramento perch bones instead may reflect the differential preservation of their bones as contrasted with those of the six large native minnows, or an abundance inflated by the particular fish assemblage and by the unique nature of the Sacramento perch skeleton.

NOTES

[1]Unpublished database in authors' possession.

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