

FISH REMAINS, MOSTLY OTOLITHS AND TEETH, FROM THE PALOS VERDES SAND (LATE PLEISTOCENE) OF CALIFORNIA

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ABSTRACT: Eleven exposures of Palos Verdes Sand in southern California and an exposure in northern California believed to be equivalent to Palos Verdes Sand yielded nearly 2,000 otoliths, several hundred teeth and an assortment of other fish remains. These represented 18 kinds of sharks, skates and rays and 84 teleosts. In the southern Californian deposits, one shark and 10 teleosts were southern species, whereas the deposit in northern California contained remains of five teleosts that could be considered southern species at that latitude. Four of the 84 teleosts were mesopelagics but all of the others were typical inhabitants of the continental shelf, with most preferring non-rocky habitat and relatively shallow depths. Based upon the presence of six locally extinct southern species and an analysis of habitat and depth limitations of the 102 species comprising the "Palos Verdes Sand" fish fauna, these deposits were laid down during a lengthy period when ocean temperatures were considerably warmer than they are at present. Deposition occurred in sandy or sandy-mud bottom areas at depths no shallower than 10 fathoms nor deeper than 20.

The first report of fish remains from the Palos Verdes Sand is that of Arnold (1903) who noted two stings from "*Urolophus halleri*?" found in a deposit near San Pedro, California. Jordan and Hannibal (1923) quoted Arnold's record in their publication on fossil sharks and rays of the Pacific slope but did not add any others. In 1956, Kanakoff listed 28 species (13 kinds of sharks and rays plus 15 of bony fishes) from five southern Californian exposures of Palos Verdes Sand (Los Angeles County Museum, Invertebrate Paleontology sites [LACMIP] 59, 66-2, 68B, 77 and 131). He reported LACMIP 131 (in the 500 block, North Pacific Avenue, San Pedro) as being "Lower Pleistocene San Pedro sand" but the exposure at this locality is unquestionably Late Pleistocene Palos Verdes Sand.

Two publications by Fitch (1964, 1966) on a site at Playa del Rey (LACMIP 59) listed 62 species (14 elasmobranchs and 48 teleosts), and brought to 66 (17 elasmobranchs and 49 teleosts) the kinds of fishes known from the Palos Verdes Sand of southern California.

Subsequent to 1964, I have examined six additional exposures of Palos Verdes Sand in southern California (four near San Pedro and two on the mesa south of Upper Newport Bay), and one outcrop north of Arcata (Crannell Road) in northern California that appears to be an equivalent of Palos Verdes Sand. Two of the San Pedro localities and the Crannell Road deposit

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were sampled extensively in that several hundred pounds of fossiliferous matrix were collected, sieved under water and sorted from each, but only small quantities of material were examined from the other four sites. In all, these samples yielded nearly 2000 otoliths, several hundred teeth, and an assortment of vertebrae, caudal stings, fin spines, gill rakers, bucklers and miscellaneous bony fragments (Tables 1 and 2). A few additional fish remains, turned over to me by George P. Kanakoff, then curator of Invertebrate Paleontology, Los Angeles County Museum of Natural History, have been included in this account, and otoliths and teeth collected by Lloyd Barker and Roy Kohl at the Crannell Road site are mentioned in the species accounts. All of the material, except that in the Kohl and Barker collections, has been deposited at Los Angeles County Museum of Natural History.

Fanale and Schaeffer (1965), utilizing helium-uranium and ionium radiometric ratios and measurements, estimated the age of the youngest marine terrace at San Pedro (corresponding to Palos Verdes Sand) as 95,000 to 130,000 years before the present (B.P.). Valentine (1961) reported that the habitat, at the time and place of deposition, ranged from fine silty sand to coarse sand and gravel depending upon the locality and exposure to the open coast. Probable depth of deposition also varied depending upon locality, but none of the several deposits examined during my studies appears to have been laid down at depths greater than about 10 to 12 fathoms. Judged solely by the fish remains (Fitch 1964, 1966), deposits of Palos Verdes Sand represent a lengthy period when the ocean off southern California was considerably warmer than it has been at any time since temperature records were first kept (Fitch, 1969b). Many of the mollusks reported from these beds are locally extinct southern forms, and six of the fishes have not been seen much north of Magdalena Bay during modern times, while three others rarely have been reported from California even during several years of warmer than average ocean temperatures (Radovich, 1961).

SOUTHERN CALIFORNIA SITES

Playa del Rey Area

Lincoln Ave. (LACMIP 59)

Many tons of fossiliferous matrix from this site were examined by personnel from the Los Angeles County Museum of Natural History during a span of about three decades, and 1,409 otoliths, 276 teeth and numerous other fish remains were found in this material (Fitch, 1964, and Table 2). Because these items had been gleaned by an assortment of student volunteers who were looking primarily for mollusks, and since the work had been done without the aid of a microscope, I resampled the site in 1965 and removed a 200-pound field sample. Using microtechniques on the washed screenings from this field sample, I obtained an additional 1,174 identifiable teleost otoliths, and 58 teeth from 11 kinds of sharks, skates and rays (Fitch, 1966,

and Table 2). Unfortunately, three fish species in my earlier accounts of LACMIP 59 were misidentified. In my first report (Fitch, 1964), some of the otoliths I called *Phanerodon furcatus* should have been *Xenistius californiensis*, and others were *Trachurus symmetricus*; also, the sagitta listed as *Sebastodes aurora* should have been *Prionotus stephanophrys*. In my later account (Fitch, 1966), *Occa verrucosa* should have been noted as *Synodus lucioceps*.

San Pedro Area

Incinerator site

This locality was exposed when sand and gravel were excavated during and following construction of the Harbor Freeway to the northern limits of San Pedro. It is called the "Oyster Reef" by various college geology instructors who take field trips to the area. It covers about 100 acres, being bounded on four sides by the Union Oil Co. refinery (north), Harbor Freeway (east), the city incinerator (south), and Gaffey Street (west). A 50-pound field sample from this site yielded 36 otoliths from seven kinds of teleosts, and identifiable jaw teeth from five species of elasmobranchs and one teleost. In addition there were elasmobranch vertebrae (2) and dermal denticles (2), as well as teleost teeth (4), vertebrae (23) and fin spines (3). The 13 identified species, based upon otoliths (o), caudal stings (s) and teeth (t) from this site were:

<i>Citharichthys stigmaeus</i>	(8o)
<i>Cymatogaster aggregata</i>	(2o)
<i>Dasyatis dipterurus</i>	(1t)
<i>Galeorhinus zyopterus</i>	(1t)
<i>Genyonemus lineatus</i>	(7o)
<i>Lepidogobius lepidus</i>	(2o)
<i>Myliobatis californicus</i>	(1s, 7t)
<i>Pimelometopon pulchrum</i>	(1t)
<i>Porichthys myriaster</i>	(9o)
<i>Porichthys notatus</i>	(1o)
<i>Raja</i> spp.	(3t)
<i>Seriphus politus</i>	(7o)
<i>Squatina californica</i>	(2t)

Sun Lumber Co.

This exposure was excavated extensively during freeway construction and development of docking facilities throughout the Los Angeles-Long Beach harbor area. The site is bounded by the Union Oil Co. refinery (north), San Pedro-Wilmington Road (east and south) and the Harbor Freeway (west). It is about one-half mile east of the incinerator site, but fish remains have not been nearly so plentiful. Only two species were identified from four otoliths and a pharyngeal tooth found in a 50-pound field sample. One of the otoliths

was from *Porichthys notatus*, but the other three were too eroded to identify except as "embiotocids." The tooth was from *Rhacochilus vacca*, an embiotocid with massive, distinctive pharyngeal dentition. In addition, the 50-pound field sample contained 14 teleost vertebrae, one teleost fin spine and one rodent tooth.

Subsequent sampling in other exposures of this bed yielded otoliths of *Genyonemus lineatus* (4), *Lepophidium negropinna* (1) and *Seriphus politus* (1).

North Pacific Ave., 500 block (LACMIP 131)

Kanakoff (1956) listed three species of elasmobranchs and three of teleosts from this site, based upon teeth, stings and otoliths found while searching for mollusks over the several year period the outcrop was exposed. The only part of this bed remaining in 1969 was on private property and excavating was prohibited because of damage to the area by cave-ins. During the years the site could still be sampled, I removed several hundred pounds of fossiliferous matrix (mostly material that people had discarded while searching for mollusks) and processed this for fish remains. I found remains of the same three elasmobranchs that Kanakoff (1956) reported for this deposit (plus those of 10 others) and the three teleosts he noted. My sampling at this locality brought to 12 the number of identified sharks, skates and rays, and the list of teleosts now numbers 32 (Tables 1 and 2).

North Pacific Ave., 700 block [= V.T. Bridge site]

During construction of the western approach for the Vincent Thomas Bridge, the hill (terrace) on the east side of the street in the 700 block North Pacific Avenue was cut down and hauled away. For several days during these earth-moving activities, beds of shelly matrix were exposed and I removed about 500 pounds of this material to search for fish remains. Although these strata were only two short blocks (possibly 1,000 feet) north of LACMIP 131, the fish faunas at the two sites were not entirely complementary. In all, I recovered teeth and stings from 12 kinds of sharks, skates, and rays, and otoliths and teeth from 21 kinds of teleosts (Tables 1 and 2).

Newport Beach Area

Numerous outcrops near the top of the mesa that lies south of Upper Newport Bay were sampled by personnel from the Los Angeles County Museum of Natural History during two decades or more, and the fish remains from two of these were listed by Kanakoff in 1956. Subsequent to 1956, George Kanakoff sent additional fish remains to me that had been gleaned from exposures of Palos Verdes Sand in the Newport mesa, and I sampled several other outcrops that were uncovered during construction for housing projects and a shopping center. Fish remains were meager in all of these exposures, but since most of the fossiliferous Palos Verdes Sand in the Newport Beach area has been covered up, hauled away or otherwise rendered

TABLE 1
Elasmobranch remains from the Palos Verdes Sand of California
(all remains are teeth unless otherwise noted)

Species	Playa del Rey area		San Pedro area			Newport Beach area		Crannell Road
	Fitch, 1964	Fitch, 1966	500 blk.	700 blk.	others	All localities		
<i>Alopias vulpinus</i>	2	1	—	—	—	—	—	—
<i>Carcharhinus</i> spp.	26	7	4	3	—	69	—	—
<i>Carcharodon carcharias</i>	6 + 4v	—	—	1	—	3	—	—
<i>Cetorhinus maximus</i>	—	—	—	1r	—	1 + 1r	—	—
<i>Dasyatis dipterurus</i>	—	2	—	6	1	1 + 1s	—	—
<i>Galeorhinus zyopterus</i>	15	1	3	3	1	3	1*	—
<i>Heterodontus francisci</i>	—	1	2	3	—	2	—	—
<i>Isurus oxyrinchus</i>	2	2	2	—	—	13	—	—
<i>Lamna ditropis</i>	—	—	1	—	—	—	—	—
<i>Myliobatis californicus</i>	205	32	193	15	7 + 1s	1 + 1s	—	—
<i>Notorynchus maculatus</i>	4	—	—	1	—	—	—	—
<i>Prionace glauca</i>	—	—	1	—	—	1	—	—
<i>Raja</i> spp.	8v + 3d	4d	5 + 3d	5 + 2d	3	—	114 + 11d	—
<i>Rhizoprionodon longurio</i>	1	—	—	—	—	—	—	—
<i>Sphyrna</i> spp.	3 + 17v	6	2	2	—	1	—	—
<i>Squatina californica</i>	10 + 8v	6	3	2 + 1d	2	—	—	—
<i>Triakis semifasciata</i>	—	—	3	1	—	1	—	—
<i>Urolophus halleri</i>	164s	5s	22s	20s	—	36s	—	—
Unidentified elasmobranchs	3	15v	4v	6v	2v + 2d	—	—	1v

d = dermal denticlaes; r = gill rakers; s = caudal sting; v = vertebrae * in Lloyd Barker collection

TABLE 2

Teleost remains from the Palos Verdes Sand of California (all remains are otoliths unless otherwise noted)

Species	Playa del Rey area		San Pedro area			Newport Beach area	Crannell Road
	Fitch, 1964	Fitch, 1966	500 blk.	700 blk.	others	All localities	
<i>Allosmerus elongatus</i>	—	—	—	—	—	—	7
<i>Anmodytes hexapterus</i>	—	—	—	—	—	—	4
<i>Amhistichus koelzi</i>	—	—	—	1	—	—	—
<i>Amphistichus rhodoterus</i>	—	—	—	—	—	—	1
<i>Anarrhichthys ocellatus</i>	—	—	—	—	—	—	1t
<i>Anchoa compressa</i>	—	4	—	—	—	—	—
<i>Anisotremus davidsonii</i>	1	—	—	—	—	—	—
<i>Argentina sialis</i>	—	1	—	—	—	—	—
<i>Atheresthes stomias</i>	—	—	—	—	—	—	1t
atherinids	—	10	1	—	—	—	—
<i>Atherinops affinis</i>	1	—	—	1	—	—	—
<i>Atherinopsis californiensis</i>	3	1	2	—	—	—	—
<i>Bairdiella icistia</i>	—	—	1	—	—	—	—
<i>Calamus brachysomus</i>	—	—	1t	—	—	—	—
<i>Chitonotus pugetensis</i>	1	7	4	—	—	—	—
<i>Citharichthys sordidus</i>	29	7	4	6	—	—	10
<i>Citharichthys stigmaeus</i>	238	181	42	30	8	—	5
<i>Citharichthys xanthostigma</i>	—	—	4	—	—	—	—
<i>Citharichthys</i> spp.	23	47	9	—	—	—	—
<i>Clupea pallasi</i>	—	—	—	—	—	—	4

TABLE 2 (cont'd.)

<i>Coelorhynchus scaphopsis</i>	—	1	1	—	—	—	—
cottids	—	—	—	—	—	—	—
<i>Cymatogaster aggregata</i>	6	10	50	22	—	—	2
<i>Cynoscion nobilis</i>	5	—	—	—	—	—	29
<i>Cynoscion reticulatus</i>	4	1	5	1	—	1	—
<i>Diaphus theta</i>	—	—	—	—	—	—	—
<i>Electrona rissoi</i>	—	—	1	—	—	—	1
<i>Embiotoca jacksoni?</i>	—	—	—	1	—	—	—
embiotocids	—	—	—	—	—	—	—
<i>Engraulis mordax</i>	68	194	7	8	3 + 2t	1 + 6t	6 + 1t
<i>Eopsetta jordani</i>	—	—	—	—	—	—	2
<i>Genyonemus lineatus</i>	217	116	259	116	7	22	1
<i>Glyptocephalus zachirus</i>	—	—	—	—	—	—	1
<i>Hippoglossus stenolepis**</i>	—	—	—	—	—	—	1j
<i>Hyperprosopon anale</i>	—	—	—	—	—	—	6
<i>Hyperprosopon ellipticum</i>	—	—	—	—	—	—	2
<i>Hypomesus pretiosus</i>	—	—	—	—	—	—	18
<i>Icelinus quadriseriatus</i>	—	10	—	—	—	—	—
<i>Icelinus tenuis</i>	—	—	—	2	—	—	—
<i>Isopsetta isolepis</i>	—	—	—	—	—	—	—
<i>Lepidogobius lepidus</i>	1	8	18	8	2	—	21
<i>Lepophidium negropinna</i>	2	—	—	1	1	—	—
<i>Leptocottus armatus</i>	—	—	2	—	—	2 + 1c	13 + 4c
<i>Lethops connectens</i>	—	—	—	—	—	—	7
<i>Leuresthes tenuis</i>	6	4	—	—	—	—	—
<i>Lycodopsis pacifica</i>	—	—	—	—	—	—	1
<i>Lyopsetta exilis</i>	1	—	—	—	—	—	—

TABLE 2 (cont'd.)

Teleost remains from the Palos Verdes Sand of California (all remains are otoliths unless otherwise noted)

Species	Playa del Rey area		San Pedro area		Newport Beach area		Cranell Road
	Fitch, 1964	Fitch, 1966	500 blk.	700 blk.	others	All localities	
<i>Menticirrhus undulatus</i>	1	5	1	—	—	—	—
<i>Merluccius productus</i>	24	11	1	—	—	—	5
<i>Microgadus proximus</i>	—	—	—	—	—	—	411
<i>Micropogon ectenes</i>	2	—	—	1	—	—	—
<i>Microstomus pacificus</i>	—	—	—	—	—	—	2
<i>Oncorhynchus tshawytscha</i>	—	—	—	—	—	—	1
<i>Ophiodon elongatus</i>	—	—	—	—	—	—	11t
<i>Ophioscion</i> cf. <i>scierus</i>	—	—	1	—	—	—	—
<i>Otophidium scrippsi</i>	140	49	60	20	—	6	—
<i>Otophidium taylori</i>	83	65	24	12	—	1	—
<i>Otophidium</i> spp.	—	—	3	—	—	—	—
<i>Paralabrax</i> spp.	—	3	—	—	—	—	—
<i>Paralichthys californicus</i>	1	5	3	1	—	—	—
<i>Parophrys vetulus</i>	1	3	—	—	—	1	14
<i>Phanerodon furcatus</i>	—	—	—	—	—	—	3
<i>Pimelometopon pulchrum</i>	7t	—	—	1t	1t	19t	—
<i>Platichthys stellatus</i>	—	—	—	—	—	—	1* + 3s
<i>Pleuronichthys ritteri</i>	1	—	—	—	—	—	—
<i>Porichthys myriaster</i>	15	3	14	2	9	2	—
<i>Porichthys notatus</i>	161	278	46	14	2	—	1

TABLE 2 (cont'd)

<i>Porichthys</i> spp.	—	—	9	—	—	—	—	—	—
<i>Prionotus ruscarius</i>	—	—	1	—	—	—	—	—	—
<i>Prionotus stephanophrys</i>	1	2	1	—	—	—	—	—	—
<i>Rhacochilus vacca</i>	—	—	2	—	—	—	1t	—	2t
<i>Roncador stearnsi</i>	19	—	3	—	—	—	—	—	—
<i>Sebastes diploproa</i>	1	—	—	—	—	—	—	—	—
<i>Sebastes jordani</i>	1	—	—	—	—	—	—	—	—
<i>Sebastes paucispinis</i>	6	—	—	—	—	—	—	—	—
<i>Sebastes rhodochloris</i>	1	—	—	—	—	—	—	—	—
<i>Sebastes serranoides</i>	—	—	—	—	—	—	—	—	1*
<i>Sebastes</i> spp.	13	8	4	—	—	—	—	1	14
<i>Seriphus politus</i>	275	116	73	34	7	—	—	8	1
<i>Sphyræna argentea</i>	1	—	—	—	—	—	—	—	—
<i>Spirinchus starksi</i>	—	—	—	—	—	—	—	—	124
<i>Spirinchus thaleichthys</i>	—	—	—	—	—	—	—	—	5
<i>Stenobranchius leucopsarus</i>	—	1	—	—	—	—	—	—	—
<i>Symbolophorus californiensis</i>	—	1	1	—	—	—	—	—	1
<i>Symphurus atricauda</i>	—	13	2	—	—	—	—	—	—
<i>Synodus lucioceph</i>	—	1	—	—	—	—	—	—	—
<i>Theragra chalcogramma</i>	—	—	—	1	—	—	—	—	—
<i>Trachurus symmetricus</i>	2	3	—	—	—	—	—	—	—
<i>Umbrina roncadore</i>	13	4	6	—	—	—	—	—	—
<i>Xenistius californiensis</i>	7	—	—	—	—	—	—	—	—
<i>Zaniolepis latipinnis</i>	—	1	—	—	—	—	—	—	—
Unidentified teleosts	33	8	1	—	—	—	—	—	1

c = opercular spine; t = teeth; j = jaw; s = scales

* in Roy Kohl collection

** in Humboldt State College collection

inaccessible for paleontological investigation, the fauna seems worthy of listing.

LACMIP 66

This site was first investigated by museum personnel in 1945. At that time, and for nearly two decades, there were numerous exposures of fossiliferous Palos Verdes Sand on both sides of a dry creek and in eight erosion gullies that drained into it. These gullies were listed successively as LACMIP 66-1, 66-2, 66-3, etc., and although each was sampled extensively for mollusks, few fish remains were found. A housing development now covers the entire mesa south of Newport back bay where LACMIP 66 yielded a rich assemblage of mollusks (Kanakoff and Emerson, 1959).

Fish remains (otoliths = o, teeth = t, caudal stings = s) gleaned from the main creek and its tributary gullies by museum personnel were identified as follows:

<i>Cynoscion nobilis</i> :	66 (1o)
<i>Dasyatis dipterurus</i> :	66 (1s)
embiotocid:	66 (1o, 6t)
<i>Genyonemus lineatus</i> :	66-2 (8o); 66-10 (3o)
<i>Heterodontus francisci</i> :	66-10 (1t)
<i>Leptocottus armatus</i> :	66-2 (1o)
<i>Otophidium scrippsi</i> :	66 (1o); 66-2 (2o)
<i>Otophidium taylori</i> :	66 (1o)
<i>Parophrys vetulus</i> :	66-1 (1o)
<i>Pimelometopon pulchrum</i> :	66 (17t)
<i>Sebastes</i> sp.:	66 (1o)
<i>Seriphus politus</i> :	66 (3o); 66-2 (2o); 66-10 (2o)

Kanakoff (1956) noted 11 kinds of sharks and rays from LACMIP 66-2 and five species of teleosts. Ten of the 11 elasmobranchs were different species from the two noted above (i.e., *Carcharhinus lamiella* [= *obscurus*]; *Carcharodon carcharias*, *Cetorhinus maximus*, *Isurus glaucus* [= *oxyrinchus*], *Lamna ditropis*, *Myliobatis californicus*, *Prionace glauca*, *Sphyrna zygaena*, *Triakis semifasciata* and *Urobatis* [= *Urolophus*] *halleri*).

LACMIP 68-B

This exposure was near the top of a cliff about 90 feet above the high tide line in Newport back bay. A housing development, across the bay from the one covering LACMIP 66, has destroyed this site. Kanakoff (1956) reported 12 teeth from *Carcharhinus lamiella* [= *obscurus*].

LACMIP 136

This 14- to 22-foot thick bed of Palos Verdes Sand was rich in mollusks but contained few fish remains. It was in the cliff near the top of the mesa that lies south of Newport back bay. The housing development that covers

LACMIP 66 also destroyed this locality. About 200 pounds of fossiliferous matrix yielded remains from the following six elasmobranchs and five teleosts (r = gill raker):

<i>Cetorhinus maximus</i> :	(1r)
<i>Dasyatis dipterurus</i> :	(1s)
<i>Galeorhinus zyopterus</i> :	(3t)
<i>Genyonemus lineatus</i> :	(5o)
<i>Heterodontus francisci</i> :	(1t)
<i>Leptocottus armatus</i> :	(1o)
<i>Myliobatis californicus</i> :	(1t)
<i>Otophidium scrippsi</i> :	(3o)
<i>Pimelometopon pulchrum</i> :	(2t)
<i>Porichthys myriaster</i> :	(skull with 2o)
<i>Urolophus halleri</i> :	(1s)

Newport-Corona del Mar Shopping Center

During construction of a vast shopping center east of Pacific Coast Highway and between Newport Beach and Corona del Mar, several beach deposits of Palos Verdes Sand were exposed. Badly eroded shells of the bean clam, *Donax gouldii*, comprised the bulk of the mollusk remains in these beds, but shells of Pismo clams, *Tivela stultorum*, moon snails, *Polinices* spp., whelks, *Nassarius* spp. and olives, *Olivella biplicata*, were also common. A 50-pound field sample from one of these beds yielded six badly eroded otoliths from *Genyonemus lineatus* and one from *Seriphus politus*. These strata are now under parking lots and an assortment of buildings.

NORTHERN CALIFORNIA SITE

Crannell Road

This locality was exposed during highway construction north of Arcata where Crannell Road intersects U.S. Highway 101. Excavation of the hill at the southeast corner of this road junction revealed a three foot thick, highly fossiliferous layer of relatively coarse sand beneath 150 feet of muddy silt containing numerous thin beds and lenses of marine fossils. All of the fish remains from this locality (Tables 1 and 2) were recovered from the sandy matrix at the base of the hill, at an elevation of approximately 20 feet (Crannell Quadrangle, Calif., 7.5' series, U.S.G.S. 1966).

Numerous students from Humboldt State College have sampled this site extensively and frequently, as have amateur and professional paleontologists. I have had access to the collections of three students, Lloyd Barker, Jack Hopkins and Roy Kohl, and two of the species I have included (*Platichthys stellatus* and *Sebastes serranoides*) are based upon otoliths in Roy Kohl's collection, while the soupfin shark (*Galeorhinus zyopterus*) record is based upon a tooth in Lloyd Barker's collection. The Pacific halibut (*Hippoglossus*

stenolepis) is represented by a mandible in a collection at Humboldt State College.

In all, the 700 to 800 pounds of matrix that I examined from this site yielded 724 otoliths and otolith fragments, 137 teeth including four species of teleosts not represented by otoliths, plus an assortment of vertebrae, skate bucklers and wing spines and miscellaneous bony fragmentia (Tables 1 and 2).

SPECIES ACCOUNTS

Elasmobranchs

Alopias vulpinus (Bonnaterre)—common thresher

Teeth of the common thresher were found only at Playa del Rey (Fitch 1964, 1966).

Total material: 3 teeth.

Carcharhinus spp.—requiem sharks

Although Kanakoff (1956) reported teeth of *C. lamiella* [= *obscurus*] from Playa del Rey and two Newport Beach localities, I prefer to list them simply as *Carcharhinus* spp. until *Carcharhinus* taxonomy is better understood than at present. *Carcharhinus* teeth were found at Playa del Rey (Fitch 1964, 1966), San Pedro, and Newport Beach (Table 1); at least two species are represented.

Total material: 109 teeth.

Carcharodon carcharias (Linnaeus)—white shark

C. carcharias has been reported previously from Playa del Rey (Kanakoff, 1956; Fitch, 1964) and Newport Beach (Kanakoff, 1956). A white shark tooth also was found at San Pedro (Table 1).

Total material: 10 teeth and 4 vertebrae.

Cetorhinus maximus (Gunnerus)—basking shark

Kanakoff (1956) reported a *Cetorhinus* tooth from LACMIP 66-2 at Newport Beach. Since then I have found single gill rakers in material from the 700 block North Pacific Ave., San Pedro, and from LACMIP 136 at Newport Beach (Table 1).

Total material: 1 tooth and 2 gill rakers.

Dasyatis dipterurus (Jordan and Gilbert)—diamond stingray

Kanakoff (1956) identified a caudal sting from LACMIP 77 at Wilmington, Calif., as being from this species, and Fitch (1966) reported two *D. dipterurus* teeth from Playa del Rey. Eight additional teeth and a sting have been found since then at San Pedro (700 block North Pacific and the Incinerator site) and at two Newport Beach localities, LACMIP 66 and 136 (Table 1).

Total material: 10 teeth and 2 caudal stings.

Galeorhinus zyopterus Jordan and Gilbert—soupfin shark

The eight teeth that Kanakoff (1956) identified as being from *Triakis semifasciata* proved to be from *Galeorhinus*. Fitch (1964, 1966) subsequently reported soupfin shark teeth from Playa del Rey, and included the seven that Kanakoff had misidentified. *Galeorhinus* teeth were later found in several San Pedro deposits, at Newport Beach and at Crannell Road (Table 1).

Total material: 27 teeth, including one in the Lloyd Barker collection.

Heterodontus francisci (Girard)—horn shark

Kanakoff (1956) reported finding four dorsal spines from *Heterodontus* at Newport Beach (LACMIP 66-2), and Fitch (1966) noted one tooth from LACMIP 59 at Playa del Rey. Seven additional teeth have been found at San Pedro and Newport Beach localities in recent years (Table 1).

Total material: 8 teeth and 4 dorsal spines.

Isurus oxyrinchus Rafinesque—mako

Kanakoff (1956) reported teeth from *I. glaucus* [= *oxyrinchus*] in deposits at Newport Beach (LACMIP 66-2) and San Pedro (LACMIP 131), and both Kanakoff (1956) and Fitch (1964, 1966) reported them from Playa del Rey (LACMIP 59). Only two additional mako teeth have been found in Palos Verdes Sand subsequent to these reports, and both of these were from the LACMIP 131 locality (Table 1).

Total material: 22 teeth.

Lamna ditropis Hubbs and Follett—salmon shark

Kanakoff (1956) noted five salmon shark teeth from the Palos Verdes Sand at Newport Beach (LACMIP 66-2), and reported that it is "strictly northern in distribution." Actually, *L. ditropis* inhabits oceanic waters both north and south of southern California, so Newport Beach can not be considered as being outside of its normal range, latitudinally. A salmon shark tooth found in Palos Verdes Sand at San Pedro (LACMIP 131) has not been reported previously.

Total material: 6 teeth.

Myliobatis californicus Gill—bat ray

Bat ray teeth are large and very distinctive, so they are easily seen in fossiliferous matrix. Their abundance in southern California Pliocene and Pleistocene deposits, especially Palos Verdes Sand (Table 1), reflects the ease with which they can be found. Kanakoff (1956) reported 160 *M. californicus* teeth from LACMIP 131 at San Pedro, and caudal stings from Playa del Rey and Newport Beach (LACMIP 66-2). I reported finding teeth of *M. californicus* at Playa del Rey (Fitch, 1964, 1966) and subsequently

have found them in fossiliferous Palos Verdes Sand at San Pedro and Newport Beach (Table 1).

Total material: 613 teeth and 8 stings.

Notorynchus maculatus Ayres—sevengill shark

N. maculatus previously was reported from Playa del Rey by Kanakoff (1956) and Fitch (1964) based upon 12 teeth. A single tooth found at San Pedro (700 block, North Pacific Ave.) has not been noted previously. The range of *N. maculatus* has generally been given as northern British Columbia to southern California, but there are now several records of capture from Baja California as far south as Pta. San Carlos.

Total material: 13 teeth.

Prionace glauca (Linnaeus)—blue shark

Blue shark teeth are rare in southern California fossil deposits, but Kanakoff (1956) reported finding eight at Playa del Rey and one at Newport Beach (LACMIP 66-2). In my sampling of the Palos Verdes Sand, I have found but a single tooth from *P. glauca* and that was in screenings from LACMIP 131 at San Pedro.

Total material: 10 teeth.

Raja spp.—unidentified skates

I previously reported *Raja* from Palos Verdes Sand based upon eight vertebrae and seven bucklers and “wing” spines (Fitch, 1964, 1966). Subsequent sampling at San Pedro has turned up five additional bucklers and 13 teeth, but *Raja* remains have not been found at Newport Beach. In northern California (Crannell Road), skate remains were abundant, and I was able to find 114 teeth and 11 wing spines and bucklers (dermal denticles) in the material I examined. Lloyd Barker’s collection contains 16 teeth and five dermal denticles.

Total material: 143 teeth, 28 dermal denticles and 8 vertebrae.

Rhizoprionodon longurio (Jordan and Gilbert)—Pacific sharpnose shark

R. longurio was previously reported from Playa del Rey (as *Scoliodon longurio*) by Fitch (1964) who had a single tooth from there. No additional remains from this species have been found in any exposure of Palos Verdes Sand.

Total material: 1 tooth.

Sphyrna spp.—unidentified hammerheads

Kanakoff (1956) reported finding four teeth from *Sphyrna zygaena* at Playa del Rey and one at Newport Beach (LACMIP 66-2), but in my reports on the Playa del Rey fauna (Fitch 1964, 1966), I did not attempt to determine from what species of *Sphyrna* the nine teeth and 17 vertebrae came. Four

hammerhead teeth that I have obtained from deposits of Palos Verdes Sand at San Pedro (Table 1) appear to be from a single species, but I do not feel qualified to place a specific name on them. Gilbert (1967) reports only two species of *Sphyrna* from California during modern times, *S. tiburo* and *S. zygaena*.

Total material: 18 teeth and 17 vertebrae.

Squatina californica Ayres—Pacific angel shark

Teeth, vertebrae and dermal denticles of *S. californica* have turned up in Palos Verdes Sand at Playa del Rey (Fitch 1964, 1966) and San Pedro (Table 1), but no identifiable angel shark remains have been found at Newport Beach, as yet.

Total material: 23 teeth, 8 vertebrae, and 1 dermal denticle.

Triakis semifasciata Girard—leopard shark

Although Kanakoff (1956) reported finding eight teeth of *Triakis* at Playa del Rey and Newport Beach, a critical comparison of his material with teeth from living sharks revealed that they were actually from *Galeorhinus zyopterus*, a close relative. Deposits of Palos Verdes Sand at San Pedro and Newport Beach have yielded *Triakis* teeth, however (Table 1).

Total material: 5 teeth.

Urolophus halleri Cooper—round stingray

Several hundred caudal sting fragments have been identified as being from round stingrays (Kanakoff, 1956; Fitch, 1964, 1966), and subsequent sampling of the Palos Verdes Sand has turned up additional stings (Table 1), but so far no other remains from *Urolophus* have been found. The jaws of an adult round stingray contain more than 1,000 teeth, but these are so small that they easily pass through a 20-mesh screen, and I have not examined very much residue that is finer than what is retained by 20-mesh screens.

Total material: 246 stings and fragments of stings.

Unidentified elasmobranchs

Most of the deposits of Palos Verdes Sand that I have examined have contained a few elasmobranch remains that are unidentifiable for one reason or another (Fitch, 1964, 1966; Table 1). Teeth sometimes are too fragmented or eroded to identify, and too little is known about vertebrae, wing spines and bucklers to assign reliable specific names.

Total material: 27 vertebrae, 3 teeth, and 2 bucklers.

Teleosts

Allosmerus elongatus (Ayres)—whitebait smelt

Allosmerus elongatus has been reported as ranging from the Strait of Juan de Fuca, Washington to San Pedro, but its occurrence south of Morro

Bay is subject to doubt. It seldom is taken in the surf zone or at depths greater than about 300 feet, but throughout much of this area, particularly north of San Francisco, whitebait smelt are extremely abundant during most years. The species is reported to attain a length of about nine inches, but of many thousands that I have seen over the past 20 years, none has exceeded six inches. The 9-inch fish probably was misidentified. Eleven otoliths from the Crannell Road deposit (four in the Lloyd Barker collection) constitute the only fossil record for the species. Sagittae of a large adult will exceed 3.5 mm in length.

Total material: 11 otoliths 2.7 to 3.6 mm (not figured).

Ammodytes hexapterus Pallas—Pacific sand lance

Pacific sand lance otoliths have been found in several Pliocene and Pleistocene deposits in California (Fitch, 1968, and unpublished data), but until now, they have not been reported from Palos Verdes Sand. If otoliths of this

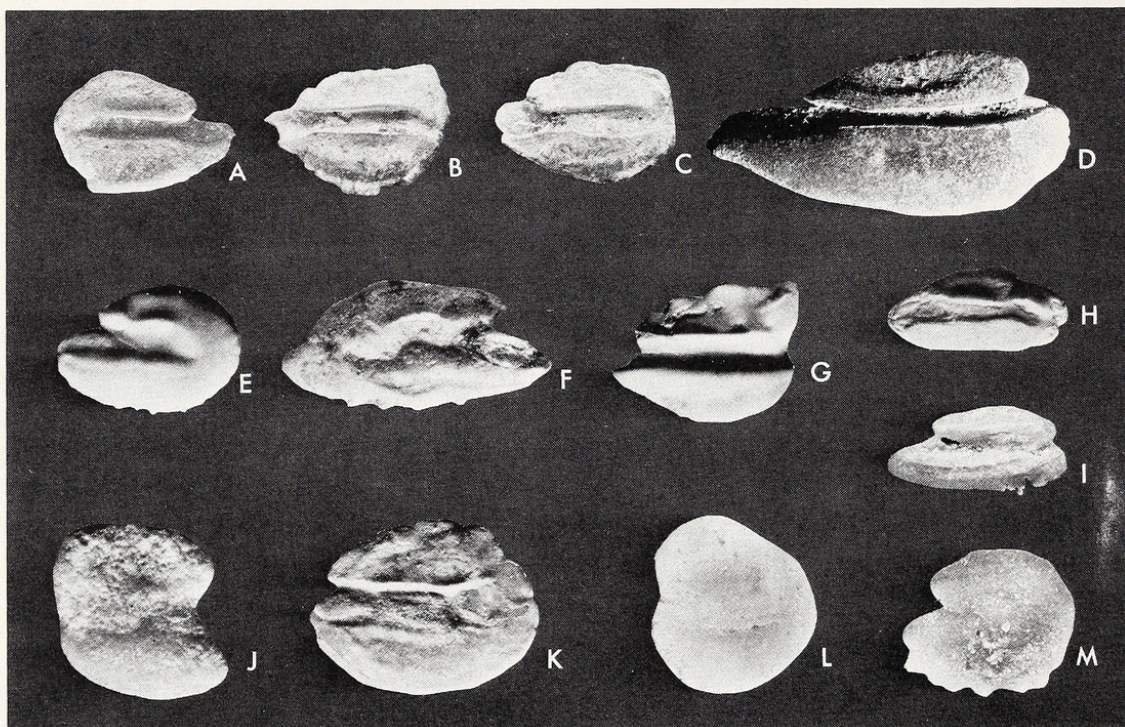


FIGURE:1. Fish otoliths found in various deposits of "Palos Verdes Sand." Lengths (in mm) are given for each otolith; notations are made regarding its position in the skull (left or right); otolith condition is noted if imperfect; and locality of fossil deposit is given. All otoliths in this figure are sagittae, and all views are inner faces. a. *Spirinchus thaleichthys*, 2.7, l, Crannell Road; b. *Hypomesus pretiosus*, 3.0, r, Crannell Road; c. *Spirinchus starksi*, 3.5, r, Crannell Road; d. *Oncorhynchus tshawytscha*, 11.8, r, Crannell Road; e. *Anchoa compressa*, 1.9, r, Playa del Rey; f. *Engraulis mordax*, 4.0, l, V.T. Bridge; g. *Argentina sialis*, 3.0, r, Playa del Rey; h. *Synodus lucioceps*, 3.0, r, Playa del Rey; i. *Clupea pallasii*, 3.5, r, Crannell Road; j. *Stenobranchius leucopsarus*, 2.0, l, Playa del Rey; k. *Symbolophorus californiensis*, 4.4, r, Playa del Rey; l. *Electrona rissoi*, 3.6, r, LACMIP 131, badly eroded; m. *Diaphus theta*, 2.2, r, Crannell Road. Photographs by Jack W. Schott.

northern species had been found in southern California exposures of Palos Verdes Sand, it could be deemed "unexpected" to say the least, but their presence at the Crannell Road site is well within their normal present day range.

Total material: 4 otoliths (Fig. 6f).

Amphistichus koelzi (Hubbs)—calico surfperch

The calico surfperch ranges from Cape Flattery, Washington, to Santo Tomas Point, Baja California. It is a typical inhabitant of the sandy beach surf zone, but occasionally strays into depths of 60 to 75 feet. The species attains a length of about 10 inches and a pound in weight. Remains of *A. koelzi* have not been found in any other deposits. Sagittae of a large adult will exceed 7.0 mm in length.

Total material: 1 otolith 4.5 mm long (Fig. 5b).

Amphistichus rhodoterus (Agassiz)—redtail surfperch

The redtail surfperch ranges from Cape Flattery, Washington to Monterey Bay. It also is a typical surf zone inhabitant that occasionally strays into deeper water (to at least 60 feet). The species attains a length of 16 inches and nearly four pounds in weight. Remains of *A. rhodoterus* have not been found in any other deposit; the Crannell Road exposure lies well within their present-day range. The sagittae of a large adult will exceed 10.0 mm in length.

Total material: 1 partially digested otolith 6.6 mm long (Fig. 5d).

Anarrhichthys ocellatus Ayres—wolf-eel

The wolf-eel ranges from southeastern Alaska to Imperial Beach, California, but is rare south of Point Conception. It prefers the rocky subtidal and adjacent offshore shallow areas, but has been captured as deep as 400 feet. It is reported to attain eight feet, but the largest authentic record in recent years was six feet eight inches and 40 pounds. Otoliths of this species have not been found, but *A. ocellatus* has large, very distinctive teeth and two of these were recovered from the Crannell Road deposit.

Total material: 2 teeth, including one in the Lloyd Barker collection.

Anchoa compressa (Girard)—deepbody anchovy

Otoliths of *A. compressa* previously were reported from Playa del Rey (Fitch, 1966), and no additional remains have been found.

Total material: 4 otoliths (Fig. 1e).

Anisotremus davidsonii (Steindachner)—sargo

Fitch (1964) reported a sargo otolith from Playa del Rey that previously had been noted by Kanakoff (1956); no additional remains of *A. davidsonii* have been found.

Total material: 1 otolith (Fig. 4i).

Argentina sialis Gilbert—Pacific argentine

Fitch (1966) reported a Pacific argentine otolith from Playa del Rey; no additional remains have been found.

Total material: 1 otolith (Fig. 1g).

Atheresthes stomias (Jordan and Gilbert)—arrowtooth flounder

Otoliths of *A. stomias* have been found in Pliocene and Pleistocene deposits of southern California (Fitch, 1968; and unpublished data) but never in Palos Verdes Sand. Their teeth are large and have distinctive dart-shaped tips. Two jaw teeth of *A. stomias* were recovered from the Crannell Road deposit.

Total material: 2 teeth: one in the Lloyd Barker collection.

Atherinops affinis (Ayres)—topsmelt

The topsmelt previously was reported from Playa del Rey based upon a single otolith (Fitch, 1964); one additional topsmelt otolith has been found in a Palos Verdes Sand deposit in southern California (Table 2).

Total material: 2 otoliths (Fig. 4e).

Atherinopsis californiensis Girard—jacksmelt

Jacksmelt otoliths (4) previously were reported from Playa del Rey (Fitch, 1964, 1966). Subsequent sampling has yielded two additional otoliths from Palos Verdes Sand in the San Pedro area (Table 2).

Total material: 6 otoliths (Fig. 4f).

Bairdiella icistia (Jordan and Gilbert)—bairdiella

The bairdiella ranges from the head of the Gulf of California to southern Mexico, and it is one of the species that was successfully introduced into Salton Sea. It is an inhabitant of relatively shallow (to about 150 feet) near-shore waters in non-rocky habitat. The species seldom reaches a foot in length or a pound in weight. Sagittae of a large adult will exceed 11.0 mm in length. A single broken otolith was found in one of the San Pedro deposits (Table 2).

Total material: 1 otolith 3.7 mm long (Fig. 5q).

Calamus brachysomus (Lockington)—Pacific porgy

The pacific porgy has been recorded from Oceanside (twice) to 150 miles south of Lima, Peru, but it apparently does not spawn north of Sebastian Viscaïno Bay, Baja California. Young fish are abundant in shallow water where the bottom is sandy or firm sandy mud whereas adults prefer somewhat deeper water in the same type of habitat. A large individual will exceed 20 inches in length and four pounds. Their flat-topped round molars

are easily recognized, and one of these was found in a Palos Verdes Sand deposit at San Pedro (Table 2).

Total material: 1 tooth.

Chitonotus pugetensis (Steindachner)—staghorn sculpin

Staghorn sculpin otoliths have been found in a number of Pliocene and Pleistocene deposits in southern California including Playa del Rey (Fitch, 1964; 1966). Aside from the Playa del Rey locality, the only other Palos Verdes Sand exposure to yield *C. pugetensis* otoliths was in the San Pedro area (Table 2).

Total material: 12 otoliths (Fig. 6l).

Citharichthys sordidus (Girard)—Pacific sanddab

Pacific sanddab otoliths have been found in many fossil deposits throughout California, often in great numbers, and their occurrence in Palos Verdes Sand has been reported at Playa del Rey (Fitch, 1964; 1966). Subsequent sampling of Palos Verdes Sand has yielded *C. sordidus* otoliths in all areas except Newport Beach (Table 2). Of 13 otoliths seen from the Crannell Road deposit, three are in the Lloyd Barker collection.

Total material: 59 otoliths (Fig. 3b).

Citharichthys stigmaeus Jordan and Gilbert—speckled sanddab

Speckled sanddab otoliths have been found in more deposits and more abundantly than those of *C. sordidus*. Previously they have been reported in Palos Verdes Sand at Playa del Rey (Fitch, 1964; 1966), but their occurrence in the San Pedro area and at Crannell Road (Table 2) has not been noted previously. They have not been found in the Newport Beach exposures of Palos Verdes Sand.

Total material: 504 otoliths (Fig. 3a).

Citharichthys xanthostigma Gilbert—longfin sanddab

Although longfin sanddab otoliths have been reported from the Pleistocene of southern California (Fitch, 1968), and have been found in many other Pliocene and Pleistocene deposits (unpublished data), only one exposure of Palos Verdes Sand contained some (Table 2).

Total material: 4 otoliths (Fig. 3c).

Clupea pallasii Valenciennes—Pacific herring

Pacific herring otoliths have been found in several Pliocene and Pleistocene deposits of southern California (Fitch, 1967, 1968; unpublished data), but five sagittae from Crannell Road (Table 2, plus one in the Lloyd Barker collection) represent the first record for the species from Palos Verdes Sand.

Total material: 5 otoliths (Fig. 1i).

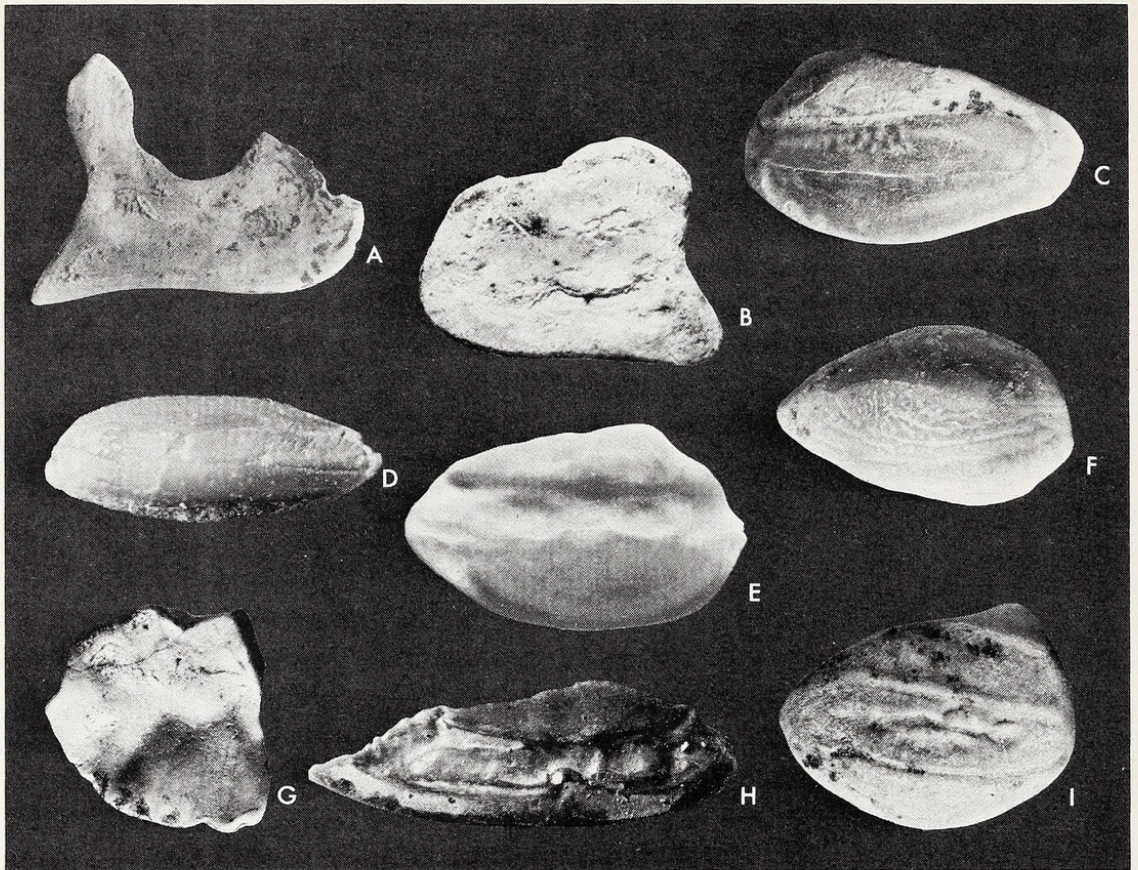


FIGURE 2. Fish otoliths found in various deposits of "Palos Verdes Sand." Lengths (in mm) are given for each otolith; notations are made regarding its position in the skull (left or right); otolith condition is noted if imperfect; and locality of fossil deposit is given. All otoliths in this figure are sagittae, and all views except *Theragra* are inner faces. a. *Porichthys myriaster*, 13.0, l, LACMIP 131; b. *Porichthys notatus*, 6.0, r, V.T. Bridge; c. *Lepophidium negropinna*, 10.2, r, V.T. Bridge; d. *Microgadus proximus*, 12.0, r, Crannell Road; e. *Coelorhynchus scaphopsis*, 7.9, l, Playa del Rey; f. *Otophidium taylori*, 7.9, l, V.T. Bridge; g. *Theragra chalcogramma*, 5.1, l, V.T. Bridge, badly eroded and posterior end missing; h. *Merluccius productus*, 19.6, l, Crannell Road; i. *Otophidium scrippsi*, 7.8, l, V.T. Bridge. Photographs by Jack W. Schott.

Coelorhynchus scaphopsis (Gilbert)—Gulf rattail

Otoliths of the Gulf rattail have been found only in Palos Verdes Sand. The species was previously reported by Fitch (1966) for Playa del Rey based upon a single otolith. A second otolith subsequently was found in a San Pedro exposure (Table 2).

Total material: 2 otoliths (Fig. 2e).

Cymatogaster aggregata Gibbons—shiner perch

Shiner perch otoliths previously have been reported from Palos Verdes Sand at Playa del Rey (Fitch, 1964, 1966). Subsequently they have been found at all San Pedro localities and Crannell Road, but not at Newport Beach

(Table 2). Lloyd Barker's collection contained 17 otoliths from *C. aggregata*.

Total material: 135 otoliths (Fig. 5i).

Cynoscion nobilis (Ayres)—white seabass

Five white seabass otoliths previously were reported from Palos Verdes Sand at Playa del Rey (Kanakoff, 1956; Fitch, 1964). A single otolith subsequently was found by museum personnel in one of the Newport Beach localities (LACMIP 66; Table 2).

Total material: 6 otoliths (Fig. 5p).

Cynoscion reticulatus (Günther)—striped corvina

Fossil remains of this southern species have been found only in Palos Verdes Sand. They have been reported from Playa del Rey based upon 5 otoliths (Fitch, 1964, 1966), and six additional otoliths were found in two deposits at San Pedro (Table 2).

Total material: 11 otoliths (Fig. 5r).

Diaphus theta Eigenmann and Eigenmann—California headlightfish

Otoliths of this mesopelagic lanternfish have been found in many Pliocene and Pleistocene deposits in southern California (Fitch, 1968, and unpublished data), but the single sagitta from the Crannell Road locality (Fitch, 1969a; Table 2) is the only record of *D. theta* from Palos Verdes Sand.

Total material: 1 otolith (Fig. 1m).

Electrona rissoi (Cocco)—chubby flashlightfish

Otoliths of *E. rissoi* have been found in Pliocene (Fitch and Reimer, 1967) and Pleistocene deposits (Fitch, 1968), including Palos Verdes Sand at San Pedro (Fitch, 1969a).

Total material: 1 otolith (Fig. 1l).

Embiotoca cf. *jacksoni* Agassiz—black perch

Otoliths of *E. jacksoni* have been found in a Pliocene deposit near San Diego (unpublished data), but the single badly worn otolith from Palos Verdes Sand at San Pedro (Table 2) represents the only record (a doubtful one) from Pleistocene.

Total material: 1 badly eroded otolith (Fig. 5f).

Engraulis mordax Girard—northern anchovy

Northern anchovy otoliths were abundant in Palos Verdes Sand at Playa del Rey (Fitch, 1964; 1966), and were present at two San Pedro localities and Crannell Road, but none has been found at Newport Beach (Table 2). The fossil record of *E. mordax* in California is unbroken over the 10 million year span since the beginning of the Pliocene, including the

most recent 7,000 years of the earth's history as divulged by investigating Indian middens (Fitch, 1969b).

Total material: 280 otoliths including one in the Lloyd Barker collection (Fig. 1f).

Eopsetta jordani (Lockington)—petrale sole

Otoliths of *E. jordani* have been found in several Pleistocene deposits (Fitch, 1967, and unpublished data), but they have not previously been reported from Palos Verdes Sand. A single sagitta was found in the Crannell Road deposit (Table 2), and three others are in the Lloyd Barker collection. Total material: 4 otoliths (Fig. 3g).

Genyonemus lineatus (Ayres)—white croaker

Otoliths of *G. lineatus* were among the five most abundant sagittae at Playa del Rey (Fitch, 1964, 1966), and have turned up at all other localities where Palos Verdes Sand has been sampled (Kanakoff, 1956; Table 2). Although white croakers have been reported as far north as Vancouver Island, their occurrence north of San Francisco is spotty (Miller and Gotshall, 1965) and depends a great deal upon warm oceanic temperatures. The sagittae in the Crannell Road deposit (including 2 in the Lloyd Barker collection) were from large adults.

Total material: 740 otoliths (Fig. 5l).

Glyptocephalus zachirus Lockington—rex sole

Rex sole remains have been found in an assortment of Pliocene and Pleistocene deposits in California (Fitch, 1967, 1968, and unpublished data) but not previously in Palos Verdes Sand. No otoliths of *G. zachirus* were found in any of the southern California localities (Table 2) but two (one in the Roy Kohl collection) were present in Crannell Road material examined. Total material: 2 otoliths (Fig. 3j).

Hippoglossus stenolepis Schmidt—Pacific halibut

The Pacific halibut ranges from the Bering Sea to Point Piedras Blancas, California, in depths of 60 to 3,600 feet. Males are known to reach a weight of 123 pounds, and females, 495. Otoliths of *H. stenolepis* have never been found in any fossil deposit, but in the Humboldt State College collection there is a lower jaw of a fairly large individual that came from the Crannell Road deposit.

Total material: 1 lower jaw in Humboldt State College collection.

Hyperprosopon anale Agassiz—spotfin surfperch

The spotfin surfperch is an inhabitant of the surf zone along sandy, outer coast beaches between Seal Rock, Oregon, and Blanca Bay, Baja California. Individuals occasionally are caught in depths of 60 feet or more



FIGURE 3. Fish otoliths found in various deposits of "Palos Verdes Sand." Lengths (in mm) are given for each otolith; notations are made regarding its position in the skull (left or right); otolith condition is noted if imperfect; and locality of fossil deposit is given. All otoliths in this figure are sagittae, and all views are inner faces. a. *Citharichthys stigmaeus*, 2.8, l, V.T. Bridge; b. *Citharichthys sordidus*, 6.7, l, LACMIP 131; c. *Citharichthys xanthostigma*, 3.6, r, LACMIP 131; d. *Paralichthys californicus*, 8.2, r, LACMIP 131; e. *Pleuronichthys ritteri*, 3.2, l, Playa del Rey; f. *Lyopsetta exilis*, 3.5, r, Playa del Rey; g. *Eopsetta jordani*, 6.0, l, Crannell Road; h. *Parophrys vetulus*, 6.3, l, Crannell Road; i. *Microstomus pacificus*, 5.4, r, Crannell Road; j. *Glyptocephalus zachirus*, 2.0, l, Crannell Road, badly eroded; k. *Platichthys stellatus*, 9.5, l, Crannell Road; l. *Isopsetta isolepis*, 6.3, r, Crannell Road. Photographs by Jack W. Schott.

but they are not abundant at any depth. The largest fish reported was eight inches long and weighed just five ounces. Their otoliths have been found in several Pliocene and Pleistocene deposits (unpublished data), but only at Crannell Road have they turned up in Palos Verdes Sand. One of seven

otoliths from this site is in the Roy Kohl collection. Sagittae of a large adult will exceed 6.5 mm in length.

Total material: 7 otoliths from 2.5 to 5.2 mm long (Fig. 5g).

Hyperprosopon ellipticum (Gibbons)—silver surfperch

The silver surfperch ranges from Clallam County, Washington, to Point Dume, California. It prefers the surf zone along sandy, outer coast beaches, but also frequents rocky subtidal pools and occasionally strays into depths of 60 feet or more. They are known to attain a length of 10.5 inches and a weight of about one-quarter pound. The two otoliths from the Crannell Road deposit (Table 2) represent the only fossil record for this species. Sagittae of a large adult will exceed 6.0 mm in length.

Total material: 2 otoliths 3.9 to 4.5 mm long (Fig. 5e).

Hypomesus pretiosus (Girard)—surf smelt

The surf smelt ranges from Prince William Sound, Alaska, to Long Beach, California but it is rarely seen south of Morro Bay. It is an inhabitant of sandy beaches along the outer coast, where it spawns during daylight hours in the breaking surf and strays into depths of 60 feet or more when not spawning. The species is known to reach a length of 10 inches and a weight of about three ounces. Only one genus (*Mallotus*) in family Osmeridae has a fossil record according to McAllister (1963). *H. pretiosus* is but one of four osmerids from which otoliths were found in the Crannell Road deposit. In addition to the 18 that I found, there are three in the Lloyd Barker collection. Sagittae of a large adult will exceed 5.0 mm in length.

Total material: 21 otoliths 2.6 to 3.4 mm long (Fig. 1b).

Icelinus quadriseriatus (Lockington)—yellowchin sculpin

The yellowchin sculpin previously was reported from Palos Verdes Sand at Playa del Rey based upon 10 otoliths (Fitch, 1966). No additional otoliths have turned up since then.

Total material: 10 otoliths (Fig. 6k).

Icelinus tenuis Gilbert—spotfin sculpin

Otoliths of the spotfin sculpin have been found in a number of Pliocene and Pleistocene deposits in southern California (Fitch, 1967, 1968, and unpublished data), but they have not been reported previously from Palos Verdes Sand. Two otoliths from one of the San Pedro sites were identified as from this species (Table 2).

Total material: 2 otoliths (Fig. 6j).

Isopsetta isolepis (Lockington)—scaly-fin sole

The scaly-fin sole ranges from Alaska to southern California, but it is rare south of about Morro Bay. It inhabits areas where the bottom is sandy or sandy mud, and prefers depths shallower than about 150 feet although it

has been found deeper than 300. It is known to attain a length of 22 inches, but no weights are available for such large individuals. The Crannell Road site is the only locality where fossil remains of *I. isolepis* have been found. In addition to the 21 otoliths that I found, I have seen two in the Lloyd Barker collection and one in Roy Kohl's. Sagittae of a large adult will exceed 9.0 mm in length.

Total material: 24 otoliths 1.4 to 6.3 mm long (Fig. 3l).

Lepidogobius lepidus (Girard)—bay goby

The bay goby has been recorded from Palos Verdes Sand at Playa del Rey (Fitch, 1964, 1966), but the 28 otoliths obtained from San Pedro sites (Table 2) have not been noted previously. This species has not been found at Newport Beach or Crannell Road (Table 2).

Total material: 37 otoliths (Fig. 6g).

Lepophidium negropinna Hildebrand and Barton—giant cusk-eel

Remains of *L. negropinna*, a locally extinct southern species, have been found only in the Palos Verdes Sand of southern California. The two sagittae from Playa del Rey were reported by Fitch (1964), but the two from San Pedro sites (Table 2) have not been previously noted.

Total material: 4 otoliths (Fig. 2c).

Leptocottus armatus Girard—staghorn sculpin

Staghorn sculpin remains have been found in several southern California Pliocene and Pleistocene deposits (Fitch, 1967, 1968, and unpublished data), but until now, only an opercular spine had been reported from Palos Verdes Sand (Kanakoff, 1956). There were no otoliths of *L. armatus* at Playa del Rey and few at San Pedro and Newport Beach sites (Table 2), but the Crannell Road deposit yielded 13 otoliths and four opercular spines (plus four otoliths and three spines in the Lloyd Barker collection and five otoliths in Roy Kohl's).

Total material: 22 otoliths and 7 opercular spines (Fig. 6m).

Lethops connectens Hubbs—halfblind goby

Otoliths of this species have been found in two southern California Pleistocene deposits (Fitch, 1968, unpublished data), but not in Palos Verdes Sand south of Monterey, which is the present-day northern limit of their range. The Crannell Road site, several hundred miles north of their known range, yielded seven otoliths of *Lethops* (Table 2).

Total material: 7 otoliths (Fig. 6h).

Leuresthes tenuis (Ayres)—grunion

Fossil grunion otoliths have been found only at Playa del Rey whence they have been reported by Fitch (1964, 1966).

Total material: 10 otoliths (Fig. 4d).

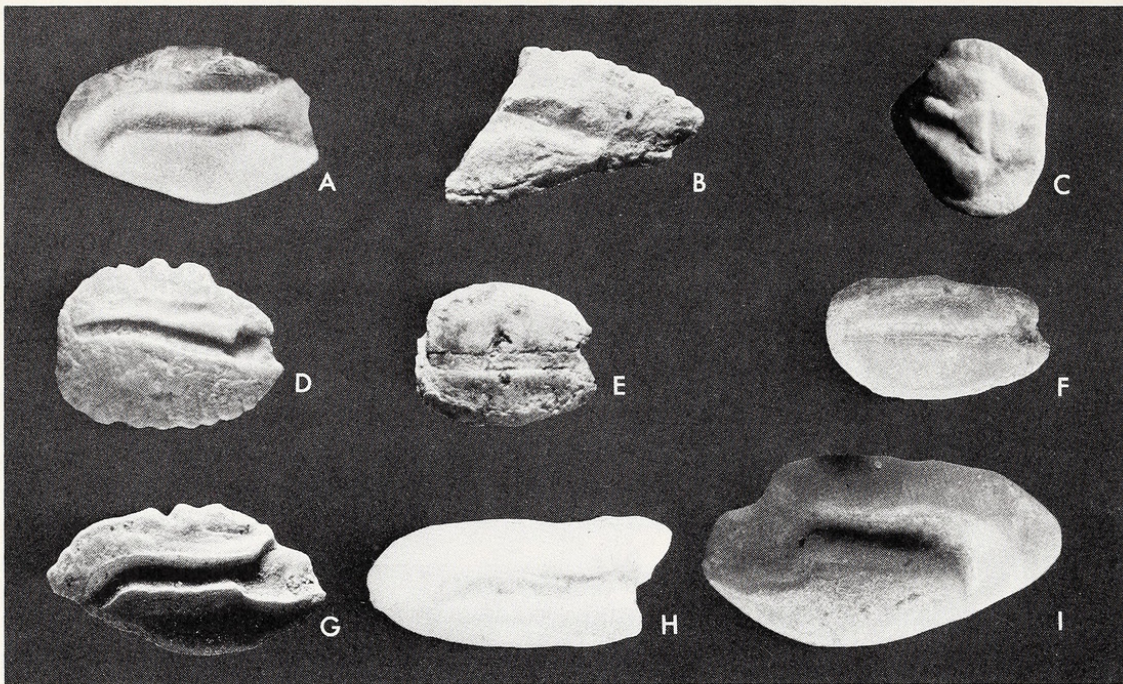


FIGURE 4. Fish otoliths found in various deposits of "Palos Verdes Sand." Lengths (in mm) are given for each otolith; notations are made regarding its position in the skull (left or right); otolith condition is noted if imperfect; and locality of fossil deposit is given. All otoliths in this figure are sagittae, and all views are inner faces: a. *Trachurus symmetricus*, 6.7, l, Playa del Rey, badly eroded and rostrum missing; b. *Paralabrax* sp. 7.8, r, Play del Rey, anterior half missing; c. *Symphurus atricauda*, 2.5, r, Playa del Rey; d. *Leuresthes tenuis*, 2.9, l, Playa del Rey; e. *Atherinops affinis*, 3.1, l, V.T. Bridge, badly eroded and anterior tip missing; f. *Atherinopsis californiensis*, 5.8, l, LACMIP 131; g. *Xenistius californiensis*, 9.0, l, Playa del Rey, rostrum tip missing; h. *Sphyraena argentea*, 10.7, l, Playa del Rey, badly eroded and anterior end missing; i. *Anisotremus davidsonii*, 9.8, r, Playa del Rey, eroded and rostrum tip missing. Photographs by Jack W. Schott.

Lycodopsis pacifica (Collett)—blackbelly eelpout

Although sagittae of *L. pacifica* have been found in numerous Pliocene and Pleistocene deposits of California (Fitch, 1967, 1968, and unpublished data), only the Crannell Road site among the Palos Verdes Sand localities investigated (Table 2) contained an otolith.

Total material: 1 otolith (Fig. 6o).

Lyopsetta exilis (Jordan and Gilbert)—slender sole

Slender sole otoliths are abundant in many Pliocene and Pleistocene deposits, but the single otolith reported from Playa del Rey (Fitch, 1964) is the only evidence of the species in Palos Verdes Sand.

Total material: 1 otolith (Fig. 3f).

Menticirrhus undulatus (Girard)—California corbina

Aside from the six otoliths reported from Playa del Rey (Fitch, 1964,

1966), only one additional sagitta has been found in deposits of Palos Verdes Sand (Table 2).

Total material: 7 otoliths (Fig. 5k).

Merluccius productus (Ayres)—Pacific hake

Otoliths of Pacific hake (initially reported by Kanakoff, 1956) have been present in almost every Pliocene and Pleistocene deposit that I have investigated (Fitch, 1969b), but most have been from small fish. Except for the Crannell Road deposit, where all five hake otoliths (Table 2) were from large fish, the Palos Verdes Sand localities have yielded few large sagittae. Twenty otoliths from Crannell Road in the Lloyd Barker and Roy Kohl collections also are mostly from large fish.

Total material: 61 otoliths (Fig. 2h).

Microgadus proximus (Girard)—Pacific tomcod

Pacific tomcod otoliths have been found in numerous Pliocene and Pleistocene deposits of California (Fitch, 1967, 1968, and unpublished data; Fitch and Reimer, 1967), but only at the Crannell Road site are they abundant. This deposit, the only Palos Verdes Sand to contain them, yielded 411 sagittae to my efforts (Table 2), and 623 others to Lloyd Barker and Roy Kohl.

Total material: 1,034 otoliths (Fig. 2d).

Micropogon ectenes Jordan and Gilbert—berrugato

Fossil otoliths from this locally extinct southern species have been found only in Palos Verdes Sand: two at Playa del Rey (Fitch, 1964) and one at San Pedro (Table 2).

Total material: 3 otoliths (Fig. 5m).

Microstomus pacificus (Lockington)—Dover sole

Sagittae of *M. pacificus* have been rare in the Pliocene and Pleistocene deposits that I have examined. Prior to finding two at the Crannell Road locality (Table 2), only Timms Point Silt had yielded an otolith (Fitch, 1968). An additional Dover sole otolith was seen in the Lloyd Barker collection.

Total material: 3 otoliths (Fig. 3i).

Oncorhynchus tshawytscha (Walbaum)—King salmon

King salmon have been taken in the Pacific Ocean from San Diego to the Bering Sea and south, on the Asiatic side, to Japan. They are seldom seen or caught south of Morro Bay, however. They are known to attain lengths of at least five feet and a weight of 126.5 pounds, but a 50-pounder is rare enough to generate publicity when brought ashore. Aside from a very questionable record of *O. tshawytscha* from the Pleistocene of Oregon, based

upon fragments of jaws, teeth and vertebrae (Uyeno and Miller, 1963), the otolith from the Crannell Road locality (Table 2) represents the only fossil occurrence of this important anadromous fish. Sagittae from a large adult king salmon will exceed 15.0 mm in length.

Total material: 1 otolith 11.8 mm long (Fig. 1*d*).

Ophiodon elongatus Girard—lingcod

The lingcod ranges from northwestern Alaska to San Carlos anchorage, Baja California, but is not abundant south of Point Conception except on a few offshore banks. It appears to prefer rocky bottom areas and depths shallower than about 350 feet, but many are caught on sandy or sandy-mud bottoms, and to depths of 2,700 feet. Lingcod reportedly attain lengths exceeding five feet and weights over 70 pounds, but 40-pound fish are rare off California. The strong conical jaw teeth of large *O. elongatus* are distinctive among California's marine fishes, and 11 of the teleost teeth I found in the Crannell Road deposit had come from this species. An additional 12 lingcod teeth were seen in the Lloyd Barker collection.

Total material: 23 jaw teeth.

Ophioscion sp.—sciaenid

Several species of *Ophioscion*, smallish sciaenids that seldom attain a foot in length, are inhabitants of the tropical eastern Pacific. In this genus, two of the three pairs of otoliths (sagittae and lapilli) are almost identical in size. Except among ostariophysans, teleost lapilli from a given fish are almost invariably microscopic compared with sagittae from the same individual. Thus, the lapilli of *Ophioscion* are easily identified to genus by their size and configuration, but I have been unable to find characters among several species that will permit a specific determination. *O. scierus* has been noted at Magdalena Bay on the outer coast of Baja California during historic times, but this is not sufficient reason to name the lapillus found in Palos Verdes Sand at San Pedro.

Total material: 1 lapillus 6.6 mm long (Fig. 5*n*).

Otophidium scrippsi Hubbs—basketweave cusk-eel

Otoliths of *O. scrippsi* have been among the most abundant teleost remains in many southern California Pliocene and Pleistocene deposits (Fitch, 1964, 1966, and unpublished data; Fitch and Reimer, 1967; Kanakoff, 1956). They were found at all Palos Verdes Sand localities except Crannell Road (Table 2).

Total material: 275 otoliths (Fig. 2*i*).

Otophidium taylori (Girard)—spotted cusk-eel

Otoliths of *O. taylori*, an inhabitant of more northerly and deeper water than *O. scrippsi*, have been found in even more Pliocene and Pleistocene deposits than *O. scrippsi*, but were missing at Crannell Road (Table 2). The

first fossil occurrence of these was noted by Kanakoff (1956).

Total material: 185 otoliths (Fig. 2f).

Paralabrax spp.—sand or kelp bass

Three *Paralabrax* otoliths, reported from Palos Verdes Sand at Playa del Rey by Fitch (1966), are the only serranid remains found in the Pliocene or Pleistocene of southern California to date.

Total material: 3 otoliths (Fig. 4b).

Paralichthys californicus (Ayres)—California halibut

California halibut otoliths have been found only at Signal Hill (Fitch, 1967), Playa del Rey (Fitch, 1964, 1966) and two San Pedro sites (Table 2).

Total material: 10 otoliths (Fig. 3d).

Parophrys vetulus Girard—English sole

Otoliths of *P. vetulus* have been found in many Pliocene and Pleistocene deposits including Palos Verdes Sand (Fitch, 1964, 1966, 1968; Fitch and Reimer, 1967). None was found in Palos Verdes Sand at San Pedro, but one turned up at Newport Beach and 14 at Crannell Road (Table 2). An additional 12 were seen in the Lloyd Barker collection.

Total material: 31 otoliths (Fig. 3h).

Phanerodon furcatus Girard—white seaperch

Otoliths of *P. furcatus* have not been found often, nor have they been abundant (unpublished data). I have found only one in Palos Verdes Sand (Crannell Road, Table 2), although the Lloyd Barker and Roy Kohl collections also contain white seaperch otoliths (3) from Crannell Road. The nine otoliths from the Playa del Rey locality that I reported as *Phanerodon* (Fitch, 1964) were misidentified. A careful re-examination of these has revealed that seven of the nine were from *Xenistius californiensis* and the other two (small and badly eroded) from *Trachurus symmetricus*.

Total material: 13 otoliths (Fig. 5c).

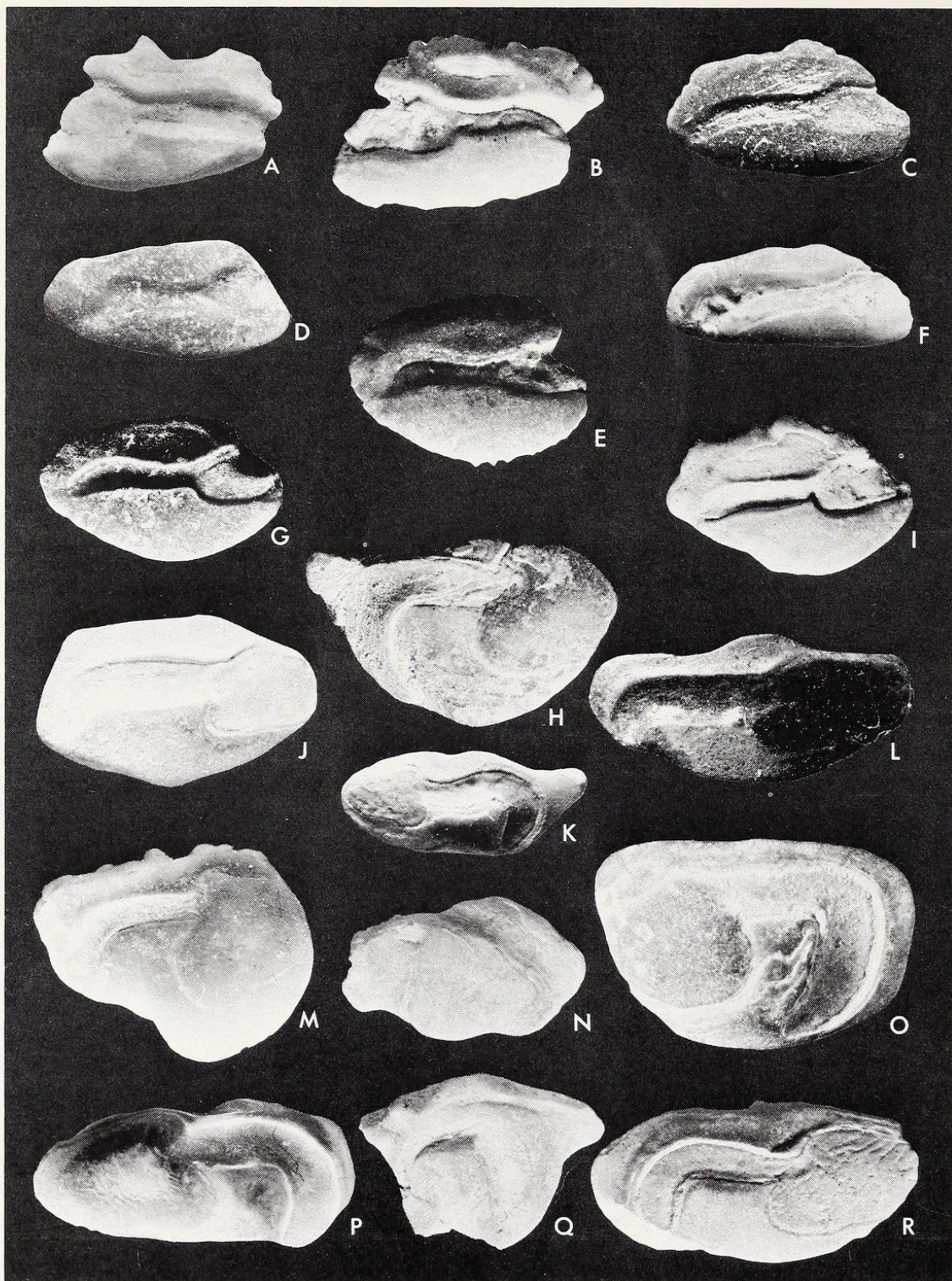
Pimelometopon pulchrum (Ayres)—California sheephead

The distinctive jaw and pharyngeal teeth of *P. pulchrum* have been found in many fossil deposits, but to date, no sheephead otoliths have turned up. Teeth previously were reported from Palos Verdes Sand at Newport Beach (Kanakoff, 1956), and Playa del Rey (Fitch, 1964), but those from San Pedro (Table 2) are being noted for the first time. None has been found at Crannell Road.

Total material: 28 teeth.

Platichthys stellatus (Pallas)—starry flounder

The starry flounder ranges throughout the north Pacific, having been recorded south to Santa Barbara in the eastern Pacific, but generally north



of Morro Bay. They prefer sandy or sandy mud bottoms and have been caught in fresh, brackish, and salt water. In the ocean, they are most abundant in depths shallower than 200 feet, but some individuals have been caught five times that deep. They are reported to reach a length of three feet and a weight of 20 pounds, but few are seen that exceed 15. A single otolith in the Roy Kohl collection, plus five stellate scales (two in Lloyd Barker's collection) are the

FIGURE 5. Surfperch and croaker otoliths found in various deposits of "Palos Verdes Sand." Lengths (in mm) are given for each otolith; notations are made regarding its position in the skull (left or right); otolith condition is noted if imperfect; and locality of fossil deposit is given. All otoliths in this figure except *Ophioscion* (a lapillus) are sagittae, and all views are inner faces. a. *Rhacochilus vacca*, 8.1, r, LACMIP 131, badly eroded and portions missing from both ends; b. *Amphistichus koelzi*, 4.5, r, V.T. Bridge, portions missing from rostrum and posterior end; c. *Phanerodon furcatus*, 8.6, l, Crannell Road; d. *Amphistichus rhodoterus*, 6.6, l, Crannell Road, badly eroded; e. *Hyperprosopon ellipticum*, 3.9, l, Crannell Road; f. *Embiotoca* cf. *jacksoni*, 6.0, l, V.T. Bridge, badly eroded; g. *Hyperprosopon anale*, 5.2, l, Crannell Road; h. *Roncador stearnsi*, 9.4, l, LACMIP 131, badly eroded; i. *Cymatogaster aggregata*, 6.0, l, V.T. Bridge; j. *Seriphus politus*, 7.9, l, V.T. Bridge; k. *Menticirrhus undulatus*, 5.1, r, Playa del Rey; l. *Genyonemus lineatus*, 11.5, l, Crannell Road; m. *Micropogon ectenes*, 7.8, l, V.T. Bridge; n. *Ophioscion* sp., 6.6, r, LACMIP 131; o. *Umbrina roncador*, 10.9, r, LACMIP 131; p. *Cynoscion nobilis*, 21.5, r, Playa del Rey; q. *Bairdiella icistia*, 3.7, r, LACMIP 131, ventral margin missing; r. *Cynoscion reticulatus*, 8.7, l, V.T. Bridge. Photographs by Jack W. Schott.

only fossil record of this species. All of these remains are from the Crannell Road deposit. Sagittae of a large adult will exceed 12.0 mm in length.

Total material: 1 otolith 9.5 mm long (Fig. 3k) and 5 scales.

Pleuronichthys ritteri (Starks and Morris)—spotted turbot

The single otolith of *P. ritteri* that I reported from Playa del Rey (Fitch, 1964) is the only known fossil record of this species.

Total material: 1 otolith (Fig. 3e).

Porichthys myriaster Hubbs and Schultz—specklefin midshipman

Otoliths of *P. myriaster* have been found in every Palos Verdes Sand locality, except Crannell Road, and were present in several other Pliocene and Pleistocene exposures in southern California (Fitch and Reimer, 1967; Fitch, unpublished data). In addition to the otoliths listed here (Table 2), the Los Angeles County Museum collections contain a disarticulated, but nearly complete, skull including otoliths that came from a Newport Beach exposure of Palos Verdes Sand (LACMIP 136).

Total material: 47 otoliths (Fig. 2a) and a disarticulated skull.

Porichthys notatus Girard—plainfin midshipman

Otoliths of *P. notatus* are one of the five most abundant teleost remains in Palos Verdes Sand (Table 2) having been reported from Playa del Rey (Fitch, 1964, 1966), but not previously from San Pedro or Crannell Road. They are common to extremely abundant in numerous other Pliocene and Pleistocene exposures throughout California (Fitch, 1967, 1968, and unpublished data; Fitch and Reimer, 1967). Two of the three I have seen from Crannell Road are in Lloyd Barker's collection.

Total material: 504 otoliths (Fig. 2b).

Prionotus ruscarius Gilbert and Starks—shortfin searobin

P. ruscarius has never been caught north of Magdalena Bay, Baja California; it ranges from there south to Panama. It appears to prefer moderate depths, possibly 20 to 150 feet, in areas of sandy or sandy mud bottom. Shortfin searobins are reported to attain a foot in length and possibly a pound in weight. A single otolith in Palos Verdes Sand at San Pedro (Table 2) is the only known fossil record of this species. Sagittae of a large adult will exceed 7.5 mm in length.

Total material: 1 otolith 6.6 mm long (Fig. 6p).

Prionotus stephanophrys Lockington—lumptail searobin

In a previous report (Fitch, 1964), I erroneously identified an otolith *P. stephanophrys* as *Sebastodes* [= *Sebastes*] *aurora*. Subsequently (Fitch, 1966), I noted two additional lumptail searobin otoliths from Playa del Rey, but the sagitta from San Pedro (Table 2) has not been reported until now. Fossil remains of *P. stephanophrys* are known only from Palos Verdes Sand.

Total material: 4 otoliths (Fig. 6n).

Rhacochilus vacca (Girard)—pile perch

Pile perch remains have been found in several Pliocene and Pleistocene deposits in southern California (Fitch, 1967, and unpublished data), but until now they have not been reported from Palos Verdes Sand. Their massive, straight sided pharyngeal teeth are very distinctive, and two of these were found at the Crannell Road site and one at San Pedro (Table 2). The only pile perch otolith in Palos Verdes Sand came from one of the San Pedro localities.

Total material: 1 otolith (Fig. 5a) and 3 pharyngeal teeth.

Roncador stearnsi (Steindachner)—spotfin croaker

Spotfin croaker otoliths have been found only in the Signal Hill Pliocene (Fitch and Reimer, 1967), and in Palos Verdes Sand (Fitch, 1964; Table 2).

Total material: 22 otoliths (Fig. 5h).

Sebastes diploproa (Gilbert)—splitnose rockcod*Sebastes jordani* (Gilbert)—shortbelly rockcod*Sebastes paucispinis* Ayres—bocaccio*Sebastes rhodochloris* (Jordan and Gilbert)—swordspine rockcod

Otoliths from these four species of *Sebastes* have all been reported (as *Sebastodes*) from Palos Verdes Sand at Playa del Rey (Fitch, 1964). All except *S. paucispinis* were represented by a single otolith (there were 6 of *paucispinis*), and all except *paucispinis* have been found in other Pliocene

and Pleistocene deposits of southern California (unpublished data), but not in other exposures of Palos Verdes Sand (Table 2).

Total material: 6 otoliths of *S. paucispinis* and 1 each of the other three species (Figs. 6b to 6e).

Sebastes serranoides (Eigenmann and Eigenmann)—olive rockcod

The olive rockcod ranges from Crescent City to Cape Colnett, Baja California, in depths to 480 feet, but it is rare north of San Francisco. The species is reported to attain a length of 24 inches and a weight of seven to eight pounds, but no fish of that size has been measured or weighed. A single otolith found by Roy Kohl at the Crannell Road deposit is the only known fossil record of this species. Sagittae of a large adult will exceed 20.0 mm in length.

Total material: 1 otolith 21.0 mm long (Fig. 6a).

Seriphus politus Ayres—queenfish

Queenfish otoliths have been abundant in many Pliocene and Pleistocene deposits throughout southern California (Fitch, 1967, 1968, and unpublished data; Fitch and Reimer, 1967) and were particularly common in Palos Verdes Sand at Playa del Rey (Fitch, 1964, 1966). Subsequently, otoliths of *S. politus* have been found in all other exposures of Palos Verdes Sand including Crannell Road (Table 2). The single otolith from the Crannell Road deposit was tiny and badly eroded, however.

Total material: 514 otoliths (Fig. 5j).

Sphyraena argentea Girard—California barracuda

Otoliths of *S. argentea* have been found in two Pliocene deposits of southern California (unpublished data), but the single badly eroded otolith from Palos Verdes Sand at Playa del Rey (Fitch, 1964) is the only record of the species in the Pleistocene.

Total material: 1 otolith (Fig. 4h).

Spirinchus starksi (Fisk)—night smelt

Otoliths of *S. starksi* have been found in several Pleistocene deposits of southern California (Fitch, 1967, and unpublished data), but until now, they have not been reported from Palos Verdes Sand. The material I examined from Crannell Road contained 124 night smelt otoliths and many others were seen in the Lloyd Barker and Roy Kohl collections.

Total material: 177 otoliths (Fig. 1c).

Spirinchus thaleichthys (Ayres)—longfin smelt

The longfin smelt ranges from Hinchinbrook Island, Prince William Sound, Alaska, to San Francisco. It spawns in fresh water, but when not spawning, it is found in shallow to moderate depths outside the surf zone along the open coast. It is known to attain a length of just over six inches, and

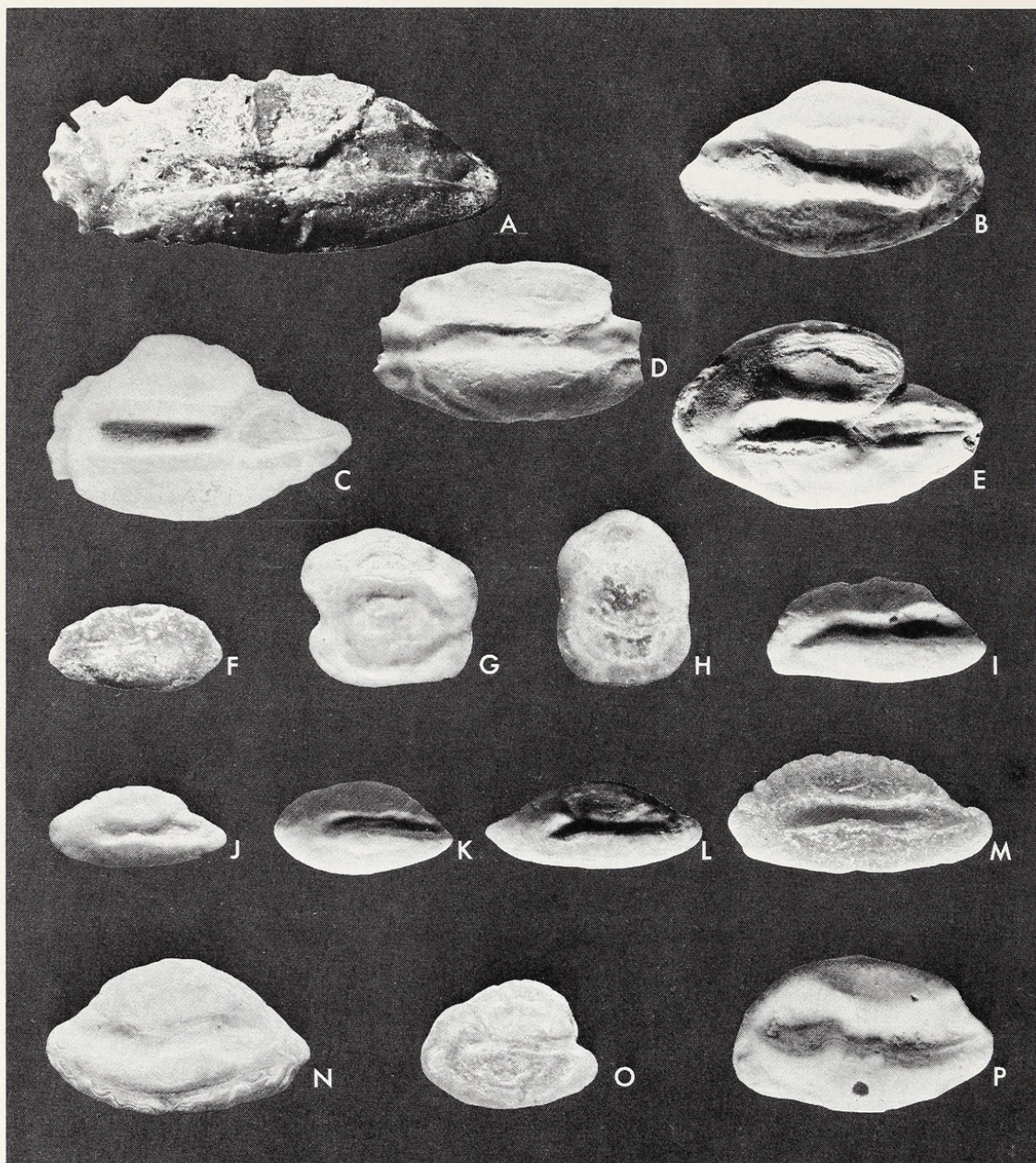


FIGURE 6. Fish otoliths found in various deposits of "Palos Verdes Sand." Lengths (in mm) are given for each otolith; notations are made regarding its position in the skull (left or right); otolith condition is noted if imperfect; and locality of fossil deposit is given. All otoliths in this figure are sagittae, and all views are inner faces. a. *Sebastes serranoides*, 21.0, l, Crannell Road; b. *Sebastes rhodochloris*, 7.0, r, Playa del Rey; c. *Sebastes diploproa*, 12.9, l, Playa del Rey; d. *Sebastes paucispinis*, 7.3, l, Playa del Rey, badly eroded and pieces missing from both ends; e. *Sebastes jordani*, 6.4, l, Playa del Rey; f. *Ammodytes hexapterus*, 3.0, r, Crannell Road; g. *Lepidogobius lepidus*, 2.3, l, V.T. Bridge; h. *Lethops connectens*, 1.4, l, Crannell Road; i. *Zaniolepis latipinnis*, 3.3, l, Playa del Rey, badly eroded; j. *Icelinus tenuis*, 3.8, l, V.T. Bridge; k. *Icelinus quadriseriatus*, 2.8, l, Playa del Rey, badly eroded; l. *Chitonotus pugetensis*, 4.6, l, Playa del Rey; m. *Leptocottus armatus*, 7.5, l, Crannell Road; n. *Prionotus stephanophrys*, 6.8, r, Playa del Rey; o. *Lycodopsis pacifica*, 3.2, l, Crannell Road; p. *Prionotus ruscarius*, 6.6, l, LACMIP, 131, badly eroded. Photographs by Jack W. Schott.

a weight of slightly more than one ounce. The five otoliths I found in the Crannell Road deposit constitute the only known fossil record for this species. Sagittae of a large adult will exceed 4.0 mm in length.

Total material: 5 otoliths 2.7 to 3.8 mm long (Fig. 1a).

Stenobranchius leucopsarus (Eigenmann and Eigenmann)—northern lampfish

The single otolith of *S. leucopsarus* from Playa del Rey (Fitch, 1966) is still the only record of this species from Palos Verdes Sand although its otoliths have been present in many other Pliocene and Pleistocene deposits and abundant in some (Fitch, 1967, 1968, and unpublished data).

Total material: 1 otolith (Fig. 1j).

Symbolophorus californiensis (Eigenmann and Eigenmann)—California lanternfish

Otoliths from *S. californiensis* have been found in several Pliocene and Pleistocene deposits in southern California including Palos Verdes Sand at Playa del Rey and Crannell Road (Fitch, 1964, 1969a). A single otolith also was found at one of the San Pedro sites (Fitch, 1969a; Table 2). The sagitta from Crannell Road is broken, and only the posterior half was found, but there is no question regarding its identification.

Total material: 3 otoliths (Fig. 1k).

Symphurus atricauda (Jordan and Gilbert)—California tonguefish

Two additional otoliths of *S. atricauda* have been found in Palos Verdes Sand at San Pedro (Table 2) since I first reported the species at Playa del Rey (Fitch, 1966). These 15 otoliths constitute the only fossil record of the species.

Total material: 15 otoliths (Fig. 4c).

Synodus lucioceps (Ayres)—California lizardfish

The California lizardfish has been recorded from San Francisco Bay to Cape San Lucas and throughout much of the Gulf of California. Larvae and young individuals up to about three inches live in the upper water layers, often over deep water many miles from shore. Adults live at or near the bottom in sandy areas, usually in depths of 60 to 150 feet but sometimes shallower or deeper. The largest individual known was 25½ inches long and weighed just over four pounds. A single otolith from *S. lucioceps* was found at Playa del Rey; it was erroneously identified as *Occa verrucosa* in a previous report (Fitch, 1966). In *Occa* the cauda (posterior portion of the sulcus or groove on the inner face of the otolith) terminates farther forward than it does in *Synodus*, and this differentiating character sometimes is difficult to distinguish in eroded, worn, or broken otoliths. Sagittae of a large adult *S. lucioceps* will exceed 8.0 mm.

Total material: 1 otolith 3.0 mm long (Fig. 1k).

Theragra chalcogramma (Pallas)—walleye pollock

Four walleye pollock otoliths from Early Pleistocene in the cold-water Timms Point Silt (Fitch, 1968) and a badly eroded, broken fragment from the Palos Verdes Sand at San Pedro (Table 2) constitute the only fossil record for this northern species. The only reasonable explanation for its presence in a warm-water deposit would entail predation offshore in deep (cold) water, erosion by digestive action in the alimentary tract of the predator and excretion in shallow (warm) water several hours after ingestion. Otoliths of prey species often are broken while being eaten, and erosion of all exposed surfaces including concave areas can be accomplished only by digestive action.

Total material: 1 eroded otolith fragment (Fig. 2g).

Trachurus symmetricus (Ayres)—Pacific jack mackerel

The three otoliths reported from Playa del Rey (Fitch, 1966) and two that I misidentified as *Phanerodon furcatus* (Fitch, 1964) constitute the only record of *T. symmetricus* from Palos Verdes Sand although jack mackerel sagittae have been present in several other Pliocene and Pleistocene deposits (Fitch, 1967, 1968, and unpublished data).

Total material: 5 otoliths (Fig. 4a).

Umbrina roncadore Jordan and Gilbert—yellowfin croaker

Remains of *U. roncadore* have been found only in the San Diego Fm. (Pliocene) and in Palos Verdes Sand. The 17 otoliths from Playa del Rey (Table 2) have been reported (Fitch, 1964, 1966), but those from the San Pedro site have not been noted previously.

Total material: 23 otoliths (Fig. 5o).

Xenistius californiensis (Steindachner)—salema

The salema ranges from Monterey Bay to Peru, but it seldom is present off California except during warm water years and even then it usually is not abundant. It is an inhabitant of shallow water (to perhaps 60 feet) along the outer coast, but sometimes enters bays and lagoons. Salemas are reported to attain a length of 10 inches, but no weights are available for fish that size. Seven otoliths from Playa del Rey, erroneously identified as *Phanerodon furcatus* in my earliest report on that site (Fitch, 1964), constitute the only fossil record of this species. When in perfect condition, sagittae of adult *X. californiensis* differ from *P. furcatus* in many respects, but the two best characters on the worn fossils (i.e., posterior otolith taper and angle of downward flexure of the cauda) were overlooked in making my earlier determinations. Sagittae of a large adult will exceed 9.0 mm in length.

Total material: 7 otoliths 6.6 to 9.7 mm long (Fig. 4g).

Zaniolepis latipinnis Girard—longspine combfish

The single otolith of *Z. latipinnis* reported from Palos Verdes Sand at Playa del Rey (Fitch, 1966) is still the only fossil record of the species.

Total material: 1 otolith (Fig. 6i).

Unidentified teleosts

Many otoliths are so badly broken or worn that they cannot be identified, even to family. Many others can be placed in a particular family but cannot be identified as to genus, and still others can be given generic, but not specific, names. Juvenile rockcod otoliths (*Sebastes* spp.) are almost impossible to assign to species, yet they are easy to distinguish from *Sebastolobus* and *Scorpaena*, the other two commonest genera in the family.

Forty-three otoliths found in various exposures of Palos Verdes Sand were too broken or worn to assign any taxon (Table 2). Twenty-three otoliths and nine teeth could be placed in three families (atherinids: 11 otoliths; cottids: 2 otoliths; and embiotocids: 10 otoliths and 9 teeth) but could not be assigned to genera within these families. Finally, 131 otoliths unquestionably belonged to four genera (*Citharichthys*, *Otophidium*, *Porichthys* and *Sebastes*) but could not be identified to species. For the first three named genera no additional species could have resulted, but if additional *Sebastes* otoliths could have been identified, it could have increased the faunal list for Palos Verdes Sand. As an example, at Crannell Road only one species of *Sebastes* could be named, but the 20 unnamed otoliths (six in Lloyd Barker's collection) were unquestionably from at least four additional species. Some, if not all of these, very likely were different from the four named species found in the Playa del Rey area (Table 2).

Total material: 197 otoliths and 9 teeth.

DISCUSSION

Three of the 18 (at least) kinds of sharks, skates and rays reported from Palos Verdes Sand of southern California (Table 1) are "southern" species. *Rhizoprionodon* has been recorded only once north of Mexico, but *Carcharhinus* and *Sphyrna* are observed or caught in our coastal waters during most periods when ocean temperatures are considerably warmer than normal (Radovich, 1961). The other 15 kinds of elasmobranchs are year around residents of the ocean off California, but some of these are not present during all months and others are never abundant.

Since 10 of the 59 teleosts from the southern Californian deposits of Palos Verdes Sand are southern species and three are mesopelagics, one would not expect to capture these in routine netting operations or inside the 100-fathom curve. The 46 remaining species are year around residents, however, and all but three of these (*Pimelometopon*, *Sebastes rhodochloris* and *Theragra*) were components of beach seine and trawl catches made off southern California during recent years (Carlisle, Schott and Abramson, 1960; Carlisle, 1969; Table 3). Only *Theragra*, of the three not captured in these netting operations, is not normally taken south of Point Conception. *Pimelometopon* and *Sebastes rhodochloris* are common in offshore rocky habitat which is unsuitable for trawling.

Six of the 10 southern teleosts (*Bairdiella*, *Cynoscion reticulatus*, *Lepophidium*, *Micropogon*, *Ophioscion* and *Prionotus ruscarius*) have not been captured within several hundred miles of California during modern times (Table 4). Of the remaining four, *Xenistius* and *Prionotus stephanophrys* have been noted on many occasions, whereas, neither *Calamus* nor *Coelorrhynchus* has been reported north of Mexico more than two or three times.

TABLE 3

Teleosts reported from Palos Verdes Sand which comprised portions of beach seine and trawl catches

Method and depth of capture					
Beach seine only ¹ < 10 feet	Beach seine and trawl ^{1, 2} Maximum depth (in feet) noted		Trawl only ² Minimum depth (in feet) noted		
<i>Amphistichus koelzi</i>	<i>Citharichthys sordidus</i>	528	<i>Argentina sialis</i>		120
<i>Anchoa compressa</i>	<i>Citharichthys stigmaeus</i>	540	<i>Chitonotus pugetensis</i>		126
<i>Anisotremus davidsonii</i>	<i>Cymatogaster aggregata</i>	346	<i>Citharichthys xanthostigma</i>		60
<i>Atherinops affinis</i>	<i>Embiotoca jacksoni</i>	60	<i>Icelinus quadriseiatus</i>		60
<i>Atherinopsis californiensis</i>	<i>Engraulis mordax</i>	600	<i>Icelinus tenuis</i>		186
<i>Cynoscion nobilis</i>	<i>Genyonemus lineatus</i>	426	<i>Lyopsetta exilis</i>		60
<i>Leptocottus armatus</i>	<i>Lepidogobius lepidus</i>	300	<i>Merluccius productus</i>		360
<i>Leuresthes tenuis</i>	<i>Paralabrax</i> spp.	120	<i>Otophidium scrippsi</i>		60
<i>Menticirrhus undulatus</i>	<i>Paralichthys californicus</i>	436	<i>Otophidium taylori</i>		60
<i>Roncador stearnsi</i>	<i>Pleuronichthys ritteri</i>	285	<i>Parophrys vetulus</i>		60
<i>Sphyræna argentea</i>	<i>Porichthys myriaster</i>	387	<i>Porichthys notatus</i>		60
<i>Umbrina roncador</i>	<i>Rhacochilus vacca</i>	60	<i>Sebastes diploproa</i>		180
	<i>Seriphus politus</i>	126	<i>Sebastes jordani</i>		378
	<i>Symphurus atricauda</i>	563	<i>Sebastes paucispinis</i>		120
			<i>Synodus lucioceps</i>		60
	<i>Trachurus symmetricus</i>	600	<i>Zaniolepis latipinnis</i>		118

¹ from Carlisle, Schott and Abramson (1960)

² from Carlisle (1969)

TABLE 4

Fish species whose fossil record is exclusively in
deposits of Palos Verdes Sand

Southern Californian exposures	Crannell Road (Northern California)
<i>Alopias vulpinus</i>	<i>Allosmerus elongatus</i>
<i>Dasyatis dipterurus</i>	<i>Amphistichus rhodoterus</i>
<i>Notorynchus maculatus</i>	<i>Anarrhichthys ocellatus</i>
<i>Rhizoprionodon longurio</i> *	<i>Hippoglossus stenolepis</i>
<i>Amphistichus koelzi</i>	<i>Hyperprosopon ellipticum</i>
<i>Anchoa compressa</i>	<i>Hypomesus pretiosus</i>
<i>Anisotremus davidsonii</i>	<i>Isopsetta isolepis</i>
<i>Argentina sialis</i>	<i>Onocorhynchus tshawytscha</i>
<i>Bairdiella icistia</i> *†	<i>Ophiodon elongatus</i>
<i>Calamus brachysomus</i> *	<i>Platichthys stellatus</i>
<i>Coelorhynchus scaphopsis</i> *	<i>Sebastes serranoides</i>
<i>Cynoscion reticulatus</i> *†	<i>Spirinchus thaleichthys</i>
<i>Lepophidium negropinna</i> *†	
<i>Leuresthes tenuis</i>	
<i>Menticirrhus undulatus</i>	
<i>Micropogon ectenes</i> *†	
<i>Ophioscion</i> sp.*†	
<i>Paralabrax</i> sp.	
<i>Pleuronichthys ritteri</i>	
<i>Prionotus ruscarius</i> *†	
<i>Prionotus stephanophrys</i> *	
<i>Symphurus atricauda</i>	
<i>Synodus lucioceps</i>	
<i>Xenistius californiensis</i> *	
<i>Zaniolepis latipinnis</i>	

* southern species

† locally-extinct southern species

In our area, *Pionotus* and *Coelorhynchus* are found in depths exceeding 60 feet, but *Xenistius* and *Calamus* reside in relatively shallow near-shore waters.

Five of the 37 teleosts found in the northern California equivalent of Palos Verdes Sand (Crannell Road) are southern species for that latitude (i.e., *Genyonemus*, *Hyperprosopon anale*, *Lethops*, *Sebastes serranoides* and *Symbolophorus*), but only *Lethops* has not been reported that far north (by several hundred miles) during modern times. Except for the two mesopelagics (*Diaphus* and *Symbolophorus*), all of the fishes identified from the Crannell Road deposit can be captured at depths shallower than 120 feet. *Diaphus* has

been netted off northern California in 35 fms (210 feet), but *Symbolophorus* generally inhabits waters outside the continental shelf.

In my investigations of Plio-Pleistocene fishes of California I have identified the remains of 23 kinds (at least) of elasmobranchs and 150 species of teleosts. Some species (e.g., *Citharichthys*, *Genyonemus*, *Porichthys*, *Seriplus*, etc.) have turned up in almost every deposit I have examined, but others have been in only one stratum, or at one particular site to the exclusion of all others. Thirty-seven fishes, including four elasmobranchs, are found exclusively in Palos Verdes Sand, including the northern Californian equivalent (Table 4), but only the 11 southern forms could be considered indicator species for this period of the Pleistocene.

Critical examination of additional deposits of Palos Verdes Sand in northern California undoubtedly would lengthen the list of species (Table 4) exclusive to this stratum, but examination in northern California and Oregon of Pliocene and Pleistocene deposits representing other time periods would shorten the Crannell Road list of "exclusives" by possibly 50 percent.

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LITERATURE CITED

- ARNOLD, RALPH. 1903. The paleontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California. Mem. Calif. Acad. Sci. 3:1-420.
- CARLISLE, JOHN G., JR. 1969. Results of a six-year trawl study in an area of heavy waste discharge: Santa Monica Bay, California. Calif. Fish and Game 55(1):26-46.
- CARLISLE, JOHN G., JR., J. W. SCHOTT, AND N. J. ABRAMSON. 1960. The barred surfperch (*Amphistichus argenteus* Agassiz) in southern California. Calif. Dept. Fish and Game, Fish Bull. 109:1-79.



Fitch, John E. 1970. "Fish remains, mostly otoliths and teeth, from the Palos Verdes Sand (Late Pleistocene) of California." *Contributions in science* 199, 1-41. <https://doi.org/10.5962/p.241186>.

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