THE MARINE FISH FAUNA, BASED PRIMARILY ON OTOLITHS, OF A LOWER PLEISTOCENE DEPOSIT AT SAN PEDRO, CALIFORNIA (LACMIP 332, SAN PEDRO SAND)

By John E. Fitch
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DAVID K. CALDWELL

Editor
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By John E. Fitch

ABSTRACT: Several hundred pounds of fossiliferous "dirt," from a San Pedro sand deposit, yielded 2,746 otoliths, 584 vertebrae, 324 teeth, and 105 miscellaneous other fish remains representing at least 10 species of elasmobranchs and 30 kinds of teleosts. Since many of these fishes typically inhabit waters to the north of San Pedro, the deposit is believed to have been laid down during a period when ocean temperatures were colder than they are today at the same latitude. This deposit, one of the few remaining surface outcrops of San Pedro sand, will be destroyed by freeway construction prior to 1970.

The Miraflores Street deposit at San Pedro, California (LACMIP 332), was first brought to the attention of the Los Angeles County Museum of Natural History in 1963 by Roger D. Reimer, a student of paleontology with an especially keen interest in the Pliocene and Pleistocene of southern California. Museum personnel, under the supervision of George P. Kanakoff, then Curator of Invertebrate Paleontology, sampled the site extensively during ensuing months, but it was Reimer who found the first otoliths and called them to my attention.

Permission to sample the site was graciously granted by Jack Bell, owner of the property, and approximately 300 pounds of fossiliferous dirt were removed during two visits. This deposit is exposed at the base of a north-facing cliff, possibly 8 to 10 feet above present-day sea level, in the 600 block, Miraflores Street, San Pedro, California. The layer I sampled is composed primarily of friable molluscan remains in a fine, clean sandy matrix; it measures approximately 50 feet in a horizontal (east-west) direction by 18 to 24 inches vertically. Unfortunately, the Miraflores Street deposit is doomed by the impending southerly extension of the Harbor Freeway which is scheduled for completion prior to 1970. Until this occurs, it affords one of the last opportunities for the paleontologist to sample the San Pedro sand, and to learn of the various faunas represented by the contained assemblages.

When I processed my 300-pound field sample, as explained in a previous publication (Fitch, 1966b), I found the identifiable remains of 10 species of elasmobranchs and 30 teleosts. In addition to 2,746 otoliths, there were 584 vertebrae (9 from elasmobranchs), 324 teeth (99 from elasmobranchs), and 105 miscellaneous items: bone fragments, fin spines, dermal denticles, etc. (Table 1).

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Table 1. Fish Remains Found in a San Pedro Pleistocene Deposit (Miraflores Street)

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Type and number of remains</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELASMOBRANCHS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carcharhinus sp.</td>
<td>requiem shark</td>
<td>1</td>
</tr>
<tr>
<td>Galeorhinus zyopterus</td>
<td>soupfin shark</td>
<td>9</td>
</tr>
<tr>
<td>Isurus oxyrinchus</td>
<td>mako</td>
<td>1</td>
</tr>
<tr>
<td>Myliobatis californicus</td>
<td>bat stingray</td>
<td>32</td>
</tr>
<tr>
<td>Notorynchus maculates</td>
<td>sevengill shark</td>
<td>6</td>
</tr>
<tr>
<td>Prionace glauca</td>
<td>blue shark</td>
<td>3</td>
</tr>
<tr>
<td>Rajia spp.</td>
<td>skates</td>
<td>12</td>
</tr>
<tr>
<td>Squalus acantius</td>
<td>spiny dogfish</td>
<td>19</td>
</tr>
<tr>
<td>Squatina californica</td>
<td>Pacific angel shark</td>
<td>10</td>
</tr>
<tr>
<td>Triakis semifasciata</td>
<td>leopard shark</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>unidentified elasmobranches</td>
<td>9</td>
</tr>
</tbody>
</table>

| **TELEOSTS**                     |                        |                            |
| Atherinops affinis               | topsmelt               | 6                          |
| Broscomysis marginata            | red brotula            | 1                          |
| Chitonotus pigetensis           | roughback sculpin      | 1                          |
| Citharichthys sordidus           | Pacific sanddab        | 22                         |
| Citharichthys stigmatus         | speckled sanddab       | 191                        |
| Citharichthys spp.              | sanddabs               | 795                        |
| Clupea pallasi                  | Pacific herring        | 29                         |
| Coryphopterus nicholsi          | bluespot goby          | 20                         |
| cottids                          | sculpins               | 25                         |
| Cymatogaster aggregata          | shiner perch           | 1,129                      |
| Engraulis mordax                 | northern anchovy        | 80                         |
| Enophtus taurota                 | bull sculpin           | 1                          |
| Eopsetta jordani                | petrales sole          | 20                         |
| Genyonemus lineatus             | white croaker          | 2                          |
| Glyptcephalus zachirus          | rex sole               | 17                         |
| Icelinus tenuis                 | spotfin sculpin        | 2                          |
| Ichthys lockingtoni              | medusafish             | 1                          |
| Leptocottus armatus             | staghorn sculpin       | 9                          |
| Lycodopsis pacifica             | blackbelly eelpout     | 12                         |
| Lyopsetta exilis                | slender sole           | 5                          |
| Microgadus proximus             | Pacific tomcod         | 1                          |
| Oxyjulis californica             | señorita               | 2                          |
| Porichthys notatus              | plainfin midshipman    | 148                        |
| Radulius asprellus              | slim sculpin           | 3                          |
| Rhamochilus vacca               | pile perch             | 7                          |
| Scorpaenichthys marmoratus      | cabezon                | 1                          |
| Sebastodes carinitus             | gopher rockfish        | 1                          |
| Sebastodes goodei               | chillipepper           | 30                         |
| Sebastodes spp.                 | rockfish               | 145                        |
| Seriphus politus                | queenfish              | 15                         |
| Spirinchus starksi              | night smelt            | 18                         |
| Stenobrachius leucopsarus       | northern lampfish      | 1                          |
| Trachurus symmetricus           | jack mackerel          | 3                          |
|                                 | unidentified teleosts   | 3 225 575 91†              |

*“wing” spines
**dermal denticles
†pharyngeals, fin spines, opercula, etc.
Woodring, Bramlette and Kew (1946), using molluscan data, postulated that the San Pedro sand represented a shallow-water habitat in some localities, but other deposits contained moderate-depth mollusks not found elsewhere. These localities were inferred to represent depths of 25 to 50 fathoms.

Among the mollusks they identified from the San Pedro sand were six locally extinct northern species, but there were no locally extinct southern species. In addition, these deposits contain both northern and southern species that are now at or close to the limits of their range at the latitude of San Pedro. Based upon these and similar data, most geologists and paleontologists are prone to interpret the San Pedro sand as representing a portion of the Lower Pleistocene when local ocean temperatures were considerably colder than they are today.

Deposits of the San Pedro sand generally lie unconformably below the Palos Verdes sand, and in terms of events that took place during the time interval represented by the unconformity, there was "deformation; almost complete submergence or probably complete submergence of the area now constituting the Palos Verdes Hills; and intermittent emergence during which the series of marine terraces were formed and the marine deposits now found on most of them were laid down, the Palos Verdes sand constituting the marine deposits on the lowest and most extensive terrace on the landward side of the hills." (Woodring, Bramlette, and Kew, 1946).

**Systematic Account**

Hexanchidae—cow sharks

*Notorynchus maculatus* Ayres—sevengill shark

Although sevengill sharks range from northern British Columbia to San Carlos Point, Baja California, they seldom are seen or captured south of Point Conception. They reportedly attain lengths of 15 feet, but 7- to 9-foot specimens are quite large for California. A 5-foot 7-inch male caught at Santa Rosa Island in 1961 weighed 41 pounds. In southern California waters, individuals that size and smaller usually are caught at or near the bottom in depths exceeding 400 feet. Teeth of this species have been found in several Pliocene and Pleistocene deposits in southern California and in an Indian midden at Ventura, California (Fitch, 1964, In press, and unpublished data; Kanakoff, 1956).

**Material:** 6 teeth.

Isuridae—mako sharks

*Isurus oxyrinchus* Rafinesque—mako

This world-ranging species is fairly common in our coastal waters between about San Francisco and Magdalena Bay, Baja California. Applegate (1966) reported an 11-footer from California that apparently represented a record
size for the species, but the usual mako in our waters is shorter than 8 feet. Mako remains, primarily teeth, have been found in numerous Pliocene and Pleistocene deposits in southern California (Fitch, 1964; and Kanakoff, 1956, as *I. glaucus*; Fitch, unpublished data) and in several coastal Indian middens (Fitch, In press; Follett, 1932, 1963a, 1963b).

*Material:* 1 tooth.
Carcharhinidae—requiem sharks
*Carcharhinus* sp.—requiem shark, species undetermined

At least four species of sharks belonging to the genus *Carcharhinus* have been captured off southern California at one time or another during the past four or five decades, but none of these tropical sharks occurs in any abundance north of about Magdalena Bay, Baja California. Although these sharks are rare visitors to our waters, all are common residents in tropical regions, especially around islands and offshore banks. A few members of this genus are pelagic forms, and some of these have worldwide distributions. Some species of requiem sharks may attain lengths of 15 feet, but others apparently never exceed 5. Because of confusion among taxonomists regarding speciation, it is difficult if not impossible to identify teeth beyond the generic level. *Carcharhinus* remains, mostly teeth, have been found in several Pliocene and Pleistocene deposits in southern California (Fitch, 1964, 1966b, and unpublished data; Fitch and Reimer, 1967; Kanakoff, 1956).

**Material:** 1 tooth.

*Galeorhinus* zyopterus Jordan and Gilbert—soupfin shark

The soupfin shark ranges from northern British Columbia to about Magdalena Bay, but is not abundant at the more southerly latitudes. Females occur principally south of Point Conception, where they often are caught in depths as shallow as 100 feet. A 6½-foot female may weigh as much as 100 pounds, but 50- to 70-pounders are the usual sizes caught. Soupfin shark remains, mostly teeth, have been found in a number of Pliocene and Pleistocene deposits in southern California (Fitch, 1964, and unpublished data; Fitch and Reimer, 1967; Kanakoff, 1956, as *Triakis semifasciata*) and in several coastal Indian middens (Fitch, In press; Follett, 1963b).

**Material:** 9 teeth.

*Figure 1.* Inner face, left sagitta of *Clupea pallasi* 3.7 mm long.
*Figure 2.* Inner face, left sagitta of *Atherinops affinis* 2.5 mm long.
*Figure 3.* Inner face, left sagitta of *Coryphopterus nicholsi* 3.8 mm long.
*Figure 4.* Inner face, left sagitta of *Engraulis mordax* 4.4 mm long.
*Figure 5.* Inner face, right sagitta of *Oxyjulis californicus* 1.7 mm long.
*Figure 6.* Inner face, right sagitta of *Brosmophycis marginata* 3.7 mm long.
*Figure 7.* Inner face, right sagitta of *Lycodopsis pacifica* 3.9 mm long.
*Figure 8.* Inner face, right sagitta of *Spirinchus starksi* 2.7 mm long.
*Figure 9.* Inner face, left sagitta of *Stenobrachius leucopsarit* 1.7 mm long.
*Figure 10.* Inner face, right sagitta of *Enophrys taurina* 4.3 mm long.
*Figure 11.* Inner face, left sagitta of *Chitonotus pugetensis* 2.8 mm long.
*Figure 12.* Inner face, right sagitta (badly worn, rostrum missing) of *Ichthys lockingtoni* 3.0 mm long.
*Figure 13.* Inner face, right sagitta of *Radulinus asprellus* 3.6 mm long.
*Figure 14.* Inner face, right sagitta (rostrum broken) of *Scorpaenichthys marmoratus* 3.7 mm long.
*Figure 15.* Inner face, right sagitta of *Icelinus tennins* 3.5 mm long.

*Photographs by Jack W. Schott.*
Prionace glauca (Linnaeus)—blue shark

The blue shark is a pelagic species occurring in tropical, subtropical, and warm temperate areas of all world seas. On our coast, individuals sometimes stray into shallow water just outside the surf zone, but most are seen swimming slowly at the surface considerable distances offshore. Small blue sharks are extremely abundant off the California coast during summer months, and almost invariably these small sharks are males, indicating a geographical
distribution by sex. Although blue sharks are reported to reach lengths of 20 feet, the largest verified record was 12 feet 7 inches (Bigelow and Schroeder, 1948). Twelve-footers have been caught off our coast, but the usual blue shark in our waters is shorter than 6 feet and weighs less than 50 pounds. Blue shark remains are not abundant in fossil deposits, being known from only one other southern California locality (Lomita Marl Pliocene; Fitch, unpublished data). Follett (1963b) reported blue shark remains from a coastal Indian midden in Los Angeles County.

Material: 3 teeth.

Triakidae—smoothhounds

*Triakis semifasciata* Girard—leopard shark

The leopard shark has been caught between Oregon and Mazatlan, Mexico. It usually frequents shallow areas where the bottom is sandy, but also abounds in shallow rocky areas around southern California's offshore islands. The females grow larger than males and may reach lengths of 7 feet, but a 5-footer can be considered large. Leopard shark remains have been found in several Pliocene and Pleistocene deposits (Fitch, unpublished data; Fitch and Reimer, 1967) and in a few coastal Indian middens (Fitch, In press; Follett, 1963a, 1963b, 1964).

Material: 6 teeth.

Squalidae—dogfish sharks

*Squalus acanthias* Linnaeus—spiny dogfish

The spiny dogfish abounds in the north Pacific Ocean (eastern and western), ranging south on our coast to Sebastian Viscaino Bay, Baja California. Females attain larger sizes than males, and are reported to reach 5 feet, but a 4-footer can be considered large. Trawling off southern California yields best spiny dogfish catches in 100 to 250 feet of water, but they have been

Figure 16. Inner face, right sagitta of *Seriphus politus* 7.1 mm long.
Figure 17. Inner face, right sagitta of *Genyonemus lineatus* 3.8 mm long.
Figure 18. Inner face, left sagitta of *Citharichthys sordidus* 5.2 mm long.
Figure 19. Inner face, right sagitta of *Sebastodes carnatus* 11.6 mm long.
Figure 20. Inner face, right sagitta of *Rhacochilus vacca* 7.8 mm long.
Figure 21. Inner face, left sagitta of *Citharichthys stigmatus* 3.2 mm long.
Figure 22. Inner face, right sagitta of *Sebastodes goodei* 12.1 mm long.
Figure 23. Inner face, right sagitta of *Cymatogaster aggregata* 4.7 mm long.
Figure 24. Inner face, right sagitta of *Glyptocephalus zachirus* 4.7 mm long.
Figure 25. Inner face, right sagitta of *Leptocottus armatus* 6.6 mm long.
Figure 26. Inner face, right sagitta of *Porichthys notatus* 5.4 mm long.
Figure 27. Inner face, left sagitta of *Eopsetta jordani* 4.7 mm long.
Figure 28. Inner face, left sagitta (rostrum missing) of *Trachurus symmetricus* 6.8 mm long.
Figure 29. Inner face, left sagitta of *Microgadus proximus* 6.8 mm long.
Figure 30. Inner face, left sagitta of *Lyopsetta exilis* 3.2 mm long.

Photographs by Jack W. Schott.
caught both shallower and deeper. Remains of *Squalus acantbias* have been found in numerous Pliocene and Pleistocene deposits in southern California (Fitch, unpublished data; Fitch and Reimer, 1967) and in an Indian midden at Ventura, California (Fitch, In press).

*Materiel*: 19 teeth.

**Squalinidae—angel sharks**

*Squatina californica* Ayres—Pacific angel shark

Although the Pacific angel shark ranges from southern Alaska into the Gulf of California, it apparently is not abundant north of Point Conception nor south of Magdalena Bay. Skin divers often observe them buried in sand or mud at depths of 8 to 150 feet or more, but greatest concentrations are noted in 50 to 70 feet. They are reported to attain lengths of about 5 feet, but the largest I have examined, a 44-inch female, weighed 31 pounds. Pacific angel shark remains have been found in numerous Pliocene and Pleistocene deposits in southern California (Fitch, 1964, and unpublished data) and in several coastal Indian middens (Fitch, In press; Follett, 1932, 1963a, 1963b).

*Materiel*: 10 teeth and 8 dermal denticles.

**Rajidae—skates**

*Raja* spp.—skates, species undetermined

Although six species of skates (at least) occur off California, I was unable to find foolproof characters for distinguishing the teeth of any one of these from those of the other five. By size alone, teeth of large *R. binoculata* can be distinguished if they are present, but no really large skate teeth were found in the Miraflores Street deposit. At various times, skates can be captured at all depths from the shallow subtidal to those exceeding several thousand feet. Skate remains have been found in numerous Pliocene and Pleistocene deposits in southern California (Fitch, 1964, and unpublished data) and in an Indian midden at Ventura, California (Fitch, In press).

*Materiel*: 12 teeth and 6 "wing spines."

**Myliobatidae—eagle rays**

*Myliobatis californicus* Gill—bat stingray

Bat stingrays range from Oregon to Magdalena Bay, occurring in shallow bays, along the mainland coast, and around offshore islands. A record specimen weighed 209 pounds, but individuals exceeding 50 pounds are rare. Remains of *M. californicus*, primarily teeth, have been found in many Pliocene and Pleistocene deposits in southern California (Fitch, 1964, and unpublished data; Fitch and Reimer, 1967; Kanakoff, 1956), and in several coastal Indian middens (Fitch, In press; Follett, 1963b; Harrington, 1928).

*Materiel*: 32 teeth.
Unidentified elasmobranchs

No effort was made to assign family or generic names to the nine small elasmobranch vertebrae recovered from this deposit. It is presumed that they came from some of the same species as the teeth that were found.

Clupeidae—herrings

*Clupea pallasi* Valenciennes—Pacific herring

The Pacific herring ranges throughout the north Pacific Ocean (western and eastern), but because of pollution and bay development, is no longer important on our coast south of Point Conception, although it may still occur in small numbers as far south as Ensenada, Baja California. They are said to attain lengths of 18 inches, but a 12- to 14-inch individual can be considered large; a fish of this size will weigh about a pound. Pacific herring otoliths have been found in several Pliocene and Pleistocene deposits in southern California (Fitch, unpublished data). The sagittae of a large, adult Pacific herring will exceed 5.0 mm in length.

*Material:* 29 otoliths 2.1 to 4.8 mm long (Fig. 1).

Engraulidae—anchovies

*Engraulis mordax* Girard—northern anchovy

The northern anchovy is a schooling fish that ranges from British Columbia to Magdalena Bay and offshore for more than 100 miles. They are reported to attain lengths of 9 inches, but a 7-inch individual can be considered unusually large. Otoliths of *E. mordax* have been found in many Pliocene and Pleistocene deposits in southern California (Fitch, 1964, and unpublished data; Fitch and Reimer, 1967), and in Indian middens at Ventura and Corona del Mar (Fitch, In press). The sagittae of a large, adult northern anchovy will exceed 4.5 mm in length.

*Material:* 80 otoliths 1.9 to 4.7 mm long (Fig. 4).

Osmeridae—smelts

*Spirinchus starksi* (Fisk)—night smelt

The night smelt ranges from Shelikof Bay, southeastern Alaska to Point Arguello, California. It is reported to attain a length of 9 inches, but individuals exceeding 7 inches are rarely encountered. McAllister (1963) in revising the smelt family (Osmeridae) mentions that only one genus (*Mallotus*) has a fossil record. I have found *S. starksi* remains only at one other site, a marine Pliocene deposit at Santa Barbara, California, but osmerid otoliths (apparently *Spirinchus* sp.) are abundant in a freshwater Pliocene deposit (Tulare formation) in Kettleman Hills, California (Fitch, unpublished data). The sagittae of a large, adult night smelt will exceed 4.5 mm in length.

*Material:* 18 otoliths 2.1 to 3.3 mm long (Fig. 8).
Myctophidae—lanternfishes

*Stenobrachius leucopsarus* (Eigenmann and Eigenmann)—northern lampfish

*S. leucopsarus* is one of the most abundant bathypelagic fishes in the eastern north Pacific, where it ranges from the Bering Sea to about Cedros Island, Baja California. A large individual might be 5 inches long and weigh about one-half ounce. Otoliths of this species have been found in many Pliocene and Pleistocene deposits in southern California, more than 1,000 having been recovered from a San Pedro, California, (Lomita Marl) deposit (Fitch, 1966b, and unpublished data). The sagittae of a large, adult northern lampfish will exceed 1.8 mm in length.

*Material:* 1 otolith 1.7 mm long (Fig. 9).

Gadidae—cods

*Microgadus proximus* (Girard)—Pacific tomcod

The Pacific tomcod ranges from Alaska to about Morro Bay, California, usually at depths of 200 feet or more, but sometimes in shallow water just outside the surf zone. They are reported to reach lengths of 12 inches, but no weights are available for such a fish; a 101/4-inch female weighed just under 6 ounces. *M. proximus* otoliths are rare in southern California Pliocene and Pleistocene deposits, but are abundant in the Pleistocene of Oregon (Fitch, unpublished data). The sagittae of a large, adult Pacific tomcod will exceed 14.0 mm in length.

*Material:* 1 otolith 6.8 mm long (Fig. 29).

Bothidae—left-eyed flounders

*Citharichthys sordidus* (Girard)—Pacific sanddab

Pacific sanddabs are reported to range from southern Alaska to about Magdalena Bay, but the occurrence of the species in central and southern Baja California needs to be verified. The maximum length and weight attributed to *C. sordidus* (16 inches and 2 pounds) also are questionable. A 12-inch female, the largest of several thousand Pacific sanddabs recently examined, weighed less than 10 ounces. *Citharichthys* otoliths are abundant in southern California Pliocene and Pleistocene deposits, and many of these are from *C. sordidus* (Fitch, 1964, and unpublished data; Fitch and Reimer, 1967). The sagittae of a large, adult Pacific sanddab will exceed 8.0 mm in length.

*Material:* 22 otoliths 2.5 to 5.9 mm long (Fig. 18).

*Citharichthys stigmatos* Jordan and Gilbert—speckled sanddab

Speckled sanddabs range along the coast from southeastern Alaska to Sebastian Viscaino Bay, Baja California, usually in depths shallower than 200 feet, and often just outside the surf zone. A large individual, about 5 inches long, would weigh less than an ounce. *C. stigmatos* otoliths have been found in many southern California Pliocene and Pleistocene deposits (Fitch, 1964,
and unpublished data; Fitch and Reimer, 1967), and in an Indian midden at Ventura (Fitch, in press). The sagittae of a large, adult speckled sanddab will exceed 3.5 mm in length.

**Material:** 191 otoliths 1.5 to 3.4 mm long (Fig. 21).

*Citharichthys* spp.—sanddabs, species undetermined

The otoliths of all three species of *Citharichthys* known to California are easily distinguished if they are in good condition, but most fossil sanddab otoliths are either worn, fragmented, or partially digested, making specific identification impossible. Some of the unidentified sanddab otoliths in this deposit could have been from *C. xanthostigma* (the third California species), but most of them probably were from Pacific and speckled sanddabs.

**Material:** 795 otoliths identifiable to genus only.

**Pleuronectidae—right-eyed flounders**

*Glyptocephalus zachirus* Lockington—rex sole

The rex sole ranges from the Bering Sea to Ensenada, Baja California (at least) in depths from shallow water to 2,100 feet. They are reported to attain lengths of 22 inches, but no weights are available for fish that size; a 15-inch female weighed just under 1½ pounds. Rex sole otoliths are abundant in some southern California Pliocene and Pleistocene deposits, more than 700 having been recovered from the Lomita Marl (Pliocene) at San Pedro (Fitch, unpublished data). The sagittae of a large, adult rex sole will exceed 7.0 mm in length.

**Material:** 17 otoliths 1.5 to 4.7 mm long (Fig. 24).

*Lyopsetta exilis* (Jordan and Gilbert)—slender sole

The slender sole ranges from southeastern Alaska to Cedros Island, usually in depths of 400 to 800 feet, but sometimes as shallow as 120 feet or as deep as 1,700. A large individual might exceed 12 inches in length, but probably would not weigh more than ¼ pound. Otoliths of *L. exilis* have been found in numerous southern California Pliocene and Pleistocene deposits (Fitch, 1964; Fitch and Reimer, 1967), more than 2,000 having been recovered from the Lomita Marl at San Pedro (Fitch, unpublished data). The sagittae of a large, adult slender sole will exceed 5.5 mm in length.

**Material:** 5 otoliths 2.6 to 4.2 mm long (Fig. 30).

*Eopsetta jordani* (Lockington)—petrale sole

The petrale sole ranges from northwestern Alaska to south of Ensenada, at least, migrating annually between deep and shallow water. They are reported to attain a length of 25½ inches and a weight of 8 pounds or more, but a 5-pounder is considered quite large by most commercial fishermen. The otoliths of *E. jordani* are difficult to distinguish from those of two other eastern Pacific flatfishes, *Parophrys vetulus* and *Lepidopsetta bilineata*, unless they
are in perfect or near perfect condition. Since several of the "Eopsetta" oto-
liths from this deposit were in relatively poor condition, a few may not be
properly assigned. The sagittae of a large, adult petrale sole will exceed 10.0
mm in length.

Material: 20 otoliths 2.0 to 5.8 mm long (Fig. 27).

Atherinidae—silversides

Atherinops affinis (Ayres)—topsmelt

Topsmelt range from the Straits of Juan de Fuca to and into the Gulf of
California. Various subspecies inhabit bays, kelp beds, and offshore island
areas where they live at or near the surface. A 14½-inch female weighing
slightly less than 12 ounces appears to be a record size. Topsmelt oto-liths have
been found in many southern California Pliocene and Pleistocene deposits
(Fitch, 1964, and unpublished data), and in an Indian midden at Ventura
(Fitch, In press). The sagittae of a large, adult topsmelt will exceed 5.0 mm
in length.

Material: 6 otoliths 1.7 to 4.0 mm long (Fig. 2).

Carangidae—jacks

Trachurus symmetricus (Ayres)—Pacific jackmackerel

The Pacific jackmackerel, a schooling fish, is perhaps one of the three
or four most abundant species off our coast, ranging from British Columbia
to Cape San Lucas and offshore for several hundred miles. The commercial
catch is comprised primarily of fish shorter than 15 inches, but jackmackerel
are known to attain lengths of 30 inches and weights of 5 pounds or more.
T. symmetricus oto-liths have been found in several southern California Plio-
cene and Pleistocene deposits (Fitch, 1966b, and unpublished data), and in
an Indian midden at La Jolla (Fitch, unpublished data). The sagittae of a
large, adult Pacific jackmackerel will exceed 10.0 mm in length.

Material: 3 otoliths longer than 6.0 mm (Fig. 28).

Centrolophidae—medusae-fishes

Icichthys lockingtoni Jordan and Gilbert—medusa-fish

The medusa-fish ranges throughout the offshore area between British
Columbia and central Baja California. Very young individuals (to perhaps
3 or 4 inches) usually accompany jelly-fishes, apparently enjoying some type
of commensal relationship. Large individuals (10 to 12 inches long) do not
seem to associate with medusae, solitary specimens occasionally being cap-
tured in mid-water trawls and other nets. I have not encountered I. lockingtoni
remains in any other fossil deposit. The sagittae of a large, adult medusa-fish
will exceed 10.0 mm in length.

Material: 1 otolith (Fig. 12) in poor condition, longer than 3.0 mm.
Sciaenidae—croakers

*Genyonemus lineatus* (Ayres)—white croaker

The white croaker ranges from Vancouver Island to Magdalena Bay, abounding in almost every type of habitat between the intertidal and depths of 600 feet. A near-record 14½-inch fish weighed 1.4 pounds. White croaker sagittae frequently are the most abundant fish remains in southern California Pliocene and Pleistocene deposits, comprising 6,409 of the more than 11,000 otoliths recovered from a San Diego Pliocene locality (San Diego Formation, unpublished data). They are also a common constituent of many coastal Indian middens: Fitch (in press) reports 7,655 *G. lineatus* otoliths from an Indian midden at Ventura. In view of their abundance in other deposits, their scarcity in this deposit (Miraflores Street) is difficult to explain. The sagittae of a large, adult white croaker will exceed 12.5 mm in length.

*Material:* 2 otoliths (Fig. 17) in poor condition, longer than 3.8 mm.

*Seriphus politus* Ayres—queenfish

Queenfish range from Yaquina Bay, Oregon, to San Juanico Bay, Baja California, living in much the same habitat as the white croaker. A near-record 12-inch female weighed just over 10 ounces. Queenfish otoliths have been found in many southern California Pliocene and Pleistocene deposits (Fitch, 1964, and unpublished data; Fitch and Reimer, 1967; Kanakoff, 1956), and in several coastal Indian middens (Fitch, in press). The sagittae of a large, adult queenfish will exceed 10.0 mm in length.

*Material:* 15 otoliths 2.7 to 7.1 mm long (Fig. 16).

Embiotocidae—surfperches

*Cynatogaster aggregata* Gibbons—shiner perch

The shiner perch ranges from Port Wrangel, Alaska, to Santo Tomas Point, Baja California, being restricted to the mainland coast, primarily in depths shallower than 50 feet, but occasionally trawled in 400 feet. A record-sized pregnant female 7 inches long, weighing just under 3 ounces, contained 16 young which were almost 2 inches long each. Although *C. aggregata* otoliths have been found in many southern California Pliocene and Pleistocene deposits (Fitch, 1964, and unpublished data; Fitch and Reimer, 1967), they usually comprise less than 10 percent of the total sagittae recovered. In this deposit, they made up almost 50 percent of the more than 2,700 otoliths found. The sagittae of a large, adult shiner perch will exceed 6.5 mm in length.

*Material:* 1,129 otoliths 2.0 to 6.4 mm long (Fig. 23).

*Rhachochilus vacca* (Girard)—pile perch

The pile perch ranges from Port Wrangel, Alaska, to San Martin Island, Baja California, primarily in shallow water around kelp beds, pier and dock pilings, breakwaters, and similar habitat. A near-record 17-inch female weighed just under 4 pounds. Pile perch remains, mostly otoliths and pharyn-
geal teeth, have been found in several southern California Pliocene and Pleistocene deposits (Fitch, unpublished data), and in an Indian midden at Ventura (Fitch, In press). The sagittae of a large, adult pile perch will exceed 9.5 mm in length.

**Material**: 7 otoliths 6.6 to 9.9 mm long (Fig. 20).

**Labridae**—wrasses

**Oxyjulis californica** (Günther)—señorita

The señorita ranges from Natural Bridges State Park to Cedros Island, inhabiting shallow areas of rocky substrate and similar relief where kelp beds and other vegetation grows. A near-record 9-inch male speared at Dana Point in January 1965 weighed 4 ounces. Señorita otoliths have been found in several southern California Pliocene and Pleistocene deposits (Fitch, unpublished data). The sagittae of a large, adult señorita will exceed 3.5 mm in length.

**Material**: 2 otoliths 1.7 to 2.2 mm long (Fig. 5).

**Scorpaenidae**—rockfishes

**Sebastodes carnatus** (Jordan and Gilbert)—gopher rockfish

The gopher rockfish ranges from Eureka, California, to San Roque, Baja California, living almost exclusively in areas of rocky substrate from the shallow subtidal to depths of 180 feet. The species is reported to attain a length of 15 inches, but the largest I have seen was a 12-incher that weighed an ounce over 1 pound. The otoliths of *S. carnatus* are not known from any other fossil deposit. The sagittae of a large, adult gopher rockfish will exceed 11.5 mm in length.

**Material**: 1 otolith 11.6 mm long (Fig. 19).

**Sebastodes goodei** Eigenmann and Eigenmann—chilipepper

The chilipepper ranges from Vancouver Island to Magdalena Bay, usually at depths greater than 600 feet. A 20½-inch female (1½ inches short of the reported maximum) caught at Cortez Bank in December 1964 weighed just under 4 pounds. *S. goodei* otoliths have been found in several southern California Pliocene and Pleistocene deposits (Fitch, unpublished data). The sagittae of a large, adult chilipepper will exceed 17.0 mm in length.

**Material**: 30 otoliths 6.0 to 12.1 mm long (Fig. 22).

**Sebastodes spp.**—rockfishes, species undetermined

The otoliths of most of the 52 members of the genus *Sebastodes* inhabiting the waters of California, can be distinguished one from the other if they are from adult fish, and if they are not worn or broken. Such characters as length and shape of rostrum, configuration of posterior end, presence or absence of marginal frills, angle of posterior taper, depth of sulcus, and number of growth zones (annuli) for otolith length are helpful for identify-
ing sagittae of the various species or species-complexes. Unfortunately, very few fossil otoliths are sufficiently well preserved to be identified to species.

**Material:** 145 otoliths, probably representing four or five species, at least.

**Cottidae**—sculpins

*Chitonotus pugetensis* (Steindachner)—roughback sculpin

The roughback sculpin ranges from northern British Columbia to Magdalena Bay, usually at depths of 100 to 350 feet, but sometimes shallower or deeper. A large individual might be 7 inches long and weigh about 2 ounces. *C. pugetensis* otoliths have been found in several southern California Pliocene and Pleistocene deposits (Fitch, 1964, and unpublished data). The sagittae of a large, adult roughback sculpin will exceed 6.0 mm in length.

**Material:** 1 otolith 2.8 mm long (Fig. 11).

*Enophrys taurina* Gilbert—bull sculpin

The bull sculpin ranges from Monterey Bay to Anacapa Island, usually at depths of 100 to 250 feet, but sometimes as shallow as 30 feet or as deep as 800. A 6-inch specimen (perhaps near maximum size) will weigh about 2 ounces. *E. taurina* otoliths have been found in several southern California Pliocene and Pleistocene deposits (Fitch, unpublished data). The sagittae of an adult bull sculpin will exceed 5.5 mm in length.

**Material:** 1 otolith 4.3 mm long (Fig. 10).

*Icelinus tenuis* Gilbert—spotfin sculpin

The spotfin sculpin ranges from Queen Charlotte to Guadalupe Island, Baja California, usually in depths of 100 to 400 feet, but some have been taken as shallow as 50 feet and as deep as 1,200. These small, slender fishes (4 inches might be about maximum length) probably never attain a weight of one ounce, even when full of eggs. Their otoliths are extremely difficult to distinguish from those of the yellowchin sculpin, *I. quadririseriatus*, but a critical comparison indicates *I. tenuis* sagittae are somewhat more pointed posteriorly, are more slender (height into length), and have a slightly less-pronounced rostrum. Since all of these characters are relative, it is necessary to compare each fossil otolith with an assortment of similar sized sagittae from living fishes before specific names can be assigned. Even with such critical evaluation, 100 percent accuracy is not assured. Otoliths of both these species of *Icelinus* are abundant in several southern California Pliocene and Pleistocene deposits (Fitch, unpublished data). The sagittae of a large, adult spotfin sculpin will exceed 4.5 mm in length.

**Material:** 2 otoliths 3.0 to 3.5 mm long (Fig. 15).

*Leptocottus armatus* Girard—Pacific staghorn sculpin

The Pacific staghorn sculpin ranges from northwestern Alaska to San Quintin Bay, Baja California, being particularly common in shallow outer
coast waters, and in bays and lagoons. It is reported to reach a length of 12 inches, but the largest I have seen was a 10-inch female netted in 1958 that weighed 8 ounces. *L. armatus* otoliths have been found in several southern California Pliocene and Pleistocene deposits (Fitch, unpublished data), and in an Indian midden at Ventura (Fitch, In press). The sagittae of a large, adult staghorn sculpin will exceed 9.0 mm in length.

*Material*: 9 otoliths 3.1 to 6.6 mm long (Fig. 25).

*Radulinus asprellus* Gilbert—slim sculpin

The slim sculpin ranges from Kodiak Island, Alaska, to about Ensenada, Baja California, usually at depths exceeding 150 feet. A 5½-inch fish (large for the species) will weigh about 1 ounce. Otoliths of *R. asprellus* have been found in a number of southern California Pliocene and Pleistocene deposits, over 1,300 having been recovered from a Pliocene site (Lomita Marl) at San Pedro (Fitch, unpublished data). The sagittae of a large, adult slim sculpin will exceed 4.0 mm in length.

*Material*: 3 otoliths 3.2 to 3.6 mm long (Fig. 13).

*Scorpaenichthys marmoratus* (Ayres)—cabezon

The cabezon ranges from northern British Columbia to Abreojos, Baja California, primarily in areas where the bottom is rocky, but often over sandy or sandy-mud substrate also. The cabezon is reported to reach a length of 39 inches (Miller, Gotshall, and Nitsos, 1965) and a weight of 20 to 25 pounds (Roedel, 1953), but individuals exceeding 25 inches and 10 pounds are rare. Cabezon otoliths have not been found in any other fossil deposit. The sagittae of a large, adult cabezon will exceed 6.5 mm in length.

*Material*: 1 otolith (Fig. 14), in poor condition, longer than 3.7 mm.

Unidentified sculpins

A number of otoliths and otolith fragments were identifiable as sculpins (family Cottidae), but were not in good enough condition to determine genus or species.

*Material*: 25 badly worn otoliths.

Gobiidae—gobies

*Coryphoenterus nicholsi* (Bean)—bluespot goby

The bluespot goby ranges from British Columbia to San Martin Island. Although the adults are bottom dwellers in the shallow subtidal and to depths of about 200 feet, larvae and juveniles sometimes are taken in plankton nets 100 miles or more offshore (Ebert and Turner, 1962). *C. nicholsi* seldom exceeds a length of 5 inches or a weight of 1 ounce. Their otoliths have been found in many southern California Pliocene and Pleistocene deposits, over 1,700 having been recovered from a Pliocene site (Lomita Marl) at San Pedro
(Fitch, unpublished data). The sagittae of a large, adult bluespot goby will exceed 3.0 mm in length.

Material: 20 otoliths 1.8 to 3.8 mm long (Fig. 3).

Batrachoididae—toadfishes

Porichthys notatus Girard—plainfin midshipman

The plainfin midshipman ranges from southeastern Alaska to Cedros Island, being one of the half-dozen most abundant species at depths of 300 to 750 feet. During spawning and “nesting” they often move into intertidal areas, but during other periods they may travel into depths of 1,200 feet or more. *P. notatus* is reported to attain a length of 15 inches, but the largest I have seen was a 13½-inch male weighing just over 14 ounces. Plainfin midshipman sagittae often are one of the most abundant otoliths in southern California Pliocene and Pleistocene deposits, nearly 700 having been recovered from a Pliocene site (Lomita Marl) at San Pedro (Fitch, 1964, and unpublished data; Fitch and Reimer, 1967). The sagittae of a large, adult plainfin midshipman will exceed 10.0 mm in length.

Material: 148 otoliths 0.7 to 7.9 mm long (Fig. 26).

Zoarcidae—eelpouts

Lycodopsis pacifica (Collett)—blackbelly eelpout

The blackbelly eelpout ranges from the Gulf of Alaska to Ensenada (at least), being very abundant in trawl catches made in depths of 100 to 800 feet or more. It is reported to attain a length of 18 inches and a weight of about 1/3 pound. *L. pacifica* otoliths have been found in several southern California Pliocene and Pleistocene deposits (Fitch, unpublished data). The sagittae of a large, adult blackbelly eelpout will exceed 5.0 mm in length.

Material: 12 otoliths 2.2 to 5.1 mm long (Fig. 7).

Brotulidae—brotulas

Brosmphycis marginata (Ayres)—red brotula

The red brotula ranges from southeastern Alaska to Ensenada, at least, mostly in depths of 60 to 400 feet in areas where a rocky bottom offers an opportunity for concealment. Although some individuals may reach lengths of 18 inches, few specimens are seen that exceed 16 inches or about 12 ounces. *B. marginata* otoliths have been found in several southern California Pliocene and Pleistocene deposits (Fitch, unpublished data). The sagittae of a large, adult red brotula will exceed 14.0 mm in length.

Material: 1 otolith 3.7 mm long (Fig. 6).

Unidentified teleosts

Three badly deteriorated otoliths, 225 teeth, 575 vertebrae, and 91 assorted bone fragments recovered from this deposit could not be identified at
Figure 31. Present-day distributions of the 28 non-bathypelagic bony fishes identified from the Miraflores Street, San Pedro, California deposit (lat. 33° 44.8' N.)
this time except as "teleosts." Most of these remains are presumed to have come from the same species that "left" their otoliths.

**DISCUSSION**

Possibly 5 of the 40 fish species identified from the Miraflores Street deposit might be considered northern forms, 1 a "southerner," and 3, offshore or pelagic species. Two of the northern species, *Notorynchus maculatus* and *Clupea pallasi*, occasionally have been noted south as far as the latitude of this deposit during modern times, but the known ranges of *Spirinchus starksii*, *Microgadus proximus*, and *Enophrys taurina* all terminate to the north of San Pedro (Fig. 31).

Several species of *Carcharhinus* are abundant in waters off southern Baja California, but only during warm summer months or years when local water temperatures are higher than normal do a few individuals stray into the southern California area.

Two of the three offshore species, *Prionace glauca* and *Ictiobus leucopsarus*, are captured in or near the surf zone, but all these may be sick individuals, because such behavior is not believed normal for either. Typically they are found in clear, blue offshore waters, generally in the upper 50 meters of the water column. *Stenobrachius leucopsarus*, the third “offshore” species, seldom is captured in water shallower than 1,000 feet, yet its otoliths were found in five of eight marine Pliocene and Pleistocene deposits. In three of these five deposits, only one *Stenobrachius* otolith was recovered, but in the other two, Timms Point silt and Lomita marl, they were more abundant.

In many respects, the Miraflores Street fish fauna is similar to what I found in both the Timms Point silt and the Point marl, yet in the proportion of surfperch otoliths (Embiotocidae) it is unique among all the deposits I have investigated. Three species, *Clupea pallasi*, *Radulina asperella*, and *Brosmophyctis marginata*, were present only in these three coldwater deposits. Four other species, *Stenobrachius leucopsarus*, *Trachurus symmetricus*, *Coryphopterus nicholsi*, and *Lycodopsis pacifica*, were present only in these same three deposits plus one or at most two other deposits. (All but *Trachurus* were in the San Diego Pliocene, and *Stenobrachius* and *Trachurus* were both in the Playa del Rey Pleistocene.) A similarity also is seen in the insignificant role of *Genyomus lineatus* and *Seriphus politus* otoliths in the Miraflores Street, Timms Point silt, and Lomita marl deposits. *Genyomus* contributed 0, 8, and 2 otoliths respectively to the total otolith yield for these three "coldwater" deposits, while only 15, 8, and 3 *Seriphus* otoliths were recovered. In the five "non-coldwater" deposits that were sampled extensively (Table 2), *Genyomus* otoliths were very important, comprising from 13 (Playa del Rey) to 55 (Signal Hill and San Diego Pliocene) percent of the total recovered. *Seriphus* otoliths were also very important in these same five deposits.
### Table 2. Otolith Yield from Eight Heavily-Sampled, Southern California Pliocene and Pleistocene Deposits

<table>
<thead>
<tr>
<th>Deposit Locality</th>
<th>Designation</th>
<th>Age</th>
<th>Otoliths recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal Hill (LACMIP 423)</td>
<td>?</td>
<td>Pliocene</td>
<td>1,230°</td>
</tr>
<tr>
<td>San Diego (LACMIP 305)</td>
<td>San Diego fm.</td>
<td>Pliocene</td>
<td>11,590°</td>
</tr>
<tr>
<td>Miraleste Canyon (LACMIP 435)</td>
<td>Lomita marl</td>
<td>Pliocene</td>
<td>24,299†</td>
</tr>
<tr>
<td>Timms Point (LACMIP 130)</td>
<td>Timms Point silt</td>
<td>Lower Pleistocene</td>
<td>2,370°*†</td>
</tr>
<tr>
<td>Miraflores Street (LACMIP 332)</td>
<td>San Pedro sand</td>
<td>Lower Pleistocene</td>
<td>2,746†</td>
</tr>
<tr>
<td>Playa del Rey (LACMIP 59)</td>
<td>Palos Verdes sand</td>
<td>Upper Pleistocene</td>
<td>2,591°**</td>
</tr>
<tr>
<td>500 block N. Pacific (LACMIP 131)</td>
<td>Palos Verdes sand</td>
<td>Upper Pleistocene</td>
<td>662†</td>
</tr>
<tr>
<td>700 block N. Pacific</td>
<td>Palos Verdes sand</td>
<td>Upper Pleistocene</td>
<td>282†</td>
</tr>
</tbody>
</table>

*recovered “by eye.”

**about one-half recovered “by eye” and one-half with microscope.

†recovered with microscope.

In view of the similarities between otoliths from the Miraflores Street deposit and those recovered from the Timms Point silt and Lomita marl, I feel certain that additional sampling would yield many more species, particularly such northern forms as are unique to Timms Point and Lomita marl (e.g., *Atheresthes stomias*, *Malacocottus zonurus*, *Icelinus burchami*, *Lyconectes aleutensis*, *Anmodytes hexapterus*, etc.).

No explanation is readily available as to why *Cymatogaster aggregata* otoliths comprised 41 percent of the total otolith yield of the Miraflores Street deposit. In no other deposit I have examined did surffish otoliths exceed 10 percent of the total; however, a high yield of *Cymatogaster* otoliths was obtained in a 4-quart sediment sample from Ship Rock, on the leeward side of Santa Catalina Island, California. Department of Fish and Game biologist-divers had scooped up this sample (representing a sheltered environment) in 125 feet of water during routine diving operations, and saved it for me to examine. Sediment samples from exposed coastal areas have never yielded a disproportionate number of embiotocid otoliths, so such a phenomenon may exemplify deposition in a sheltered environment at moderate depth.
Interestingly, otoliths of *Otophidium taylori* were entirely lacking in the Miraflores Street deposit, yet they were important or very important in every other Pliocene and Pleistocene deposit sampled, and a few were found in the sediment sample from Ship Rock. This is not a reflection of inadequate sampling or poor recovery techniques at Miraflores Street—*O. taylori* otoliths simply were not present! Since most fossil assemblages represent death associations, rather than life associations, the lack of *O. taylori* otoliths cannot be construed as positive proof the species was not an integral part of the fauna of the period, but it is a good indication that it was not.

I have referred to the Miraflores Street site as a coldwater deposit because the otoliths represent a fish fauna such as one would find off central and northern California today (Fig. 31). A deposit such as this could reflect from one to 1,000 years or more of geological history, and within such a period many temperature anomalies could have occurred. If ocean temperatures had fluctuated widely, an admixture of "northern" and "southern" species should have resulted. Radovich (1961) showed that widespread changes in ocean temperature will result in a temporary displacement or redistribution of marine animals beyond their normal range. When such conditions exist for lengthy periods, breeding communities often become established, at least among the vertebrates. Fast-moving organisms (e.g., fishes) can also reflect short-duration temperature anomalies wherein both "northern" and "southern" species invade an area almost simultaneously (Fitch, 1966a). The lack of remains from southern fishes in this deposit indicates conditions were relatively stable during the period of deposition (i.e., there was no intrusion of warm water), or if oceanic warming did occur, very few fishes took advantage of it.

**Acknowledgments**

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during his diving activities. My deepest appreciation goes to my wife, Arline, whose constant encouragement and helpful advice are always uncomplainingly available, even after weeks-on-end when she is unable to use the dining room table for its intended purpose because it is piled high with microscope, dirt samples, vials of otoliths and other fish remains, references, manuscripts, and similar miscellany which are vital in this work.

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