# New records of fish from northern exposures of the Imperial Formation of Riverside County, California

**Mark A. Roeder**
*San Diego Natural HIstory Museum, San Diego, CA 92112, maroeder1731@aol.com*

## Introduction

In Riverside County, outcrops of the Imperial Formation consist of Late Miocene and Pliocene marine siltstones and sandstones which are evidence of an extension of the ancient Gulf of California (Figure 1) into the northern portion of the Salton Trough, the Coachella Valley, and San Gorgonio Pass.

According to Carreno and Smith (2007), there were at least three Neogene marine incursions into this area of late Middle Miocene, Late Miocene and Pliocene age. Evidence of the earliest incursion, of which no marine sedimentary deposits exist, is based on rare and poorly preserved reworked nannofossils (microfossils) found within the Late Miocene age sediments named Imperial Formation in the Whitewater section near Cabazon, and date to the late Middle Miocene (McDougall et al. 1999). In the San Gorgonio Pass, late Miocene Imperial Formation sections are present near Whitewater, in Lion Canyon near Cabazon and on Garnet Hill near Palm Springs (Figure 2). On the eastern side of the Coachella Valley, Pliocene age Imperial Formation sections (Figure 2) are present at Willis Palms, at the mouth of Pushawalla Canyon and in the northwestern Indio Hills (Powell, et al 2011)2

Recent investigations of two localities in the Imperial Formation at Super Creek near Whitewater and Willis Palm near Thousand Palms, Riverside County, have yielded the first fossil records of fish. The fish remains consist of isolated fish otoliths (earstones) and fish and shark teeth. Fish otoliths, or earstones, are not skeletal elements, but calcium carbonate bodies with distinct

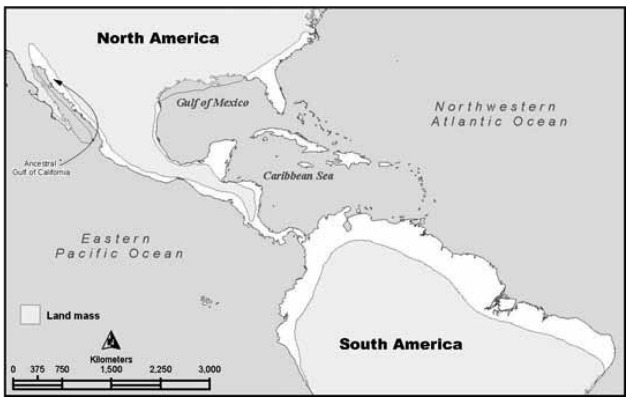



Figure 1. Late Miocene–Pliocene seas of North and Central America.

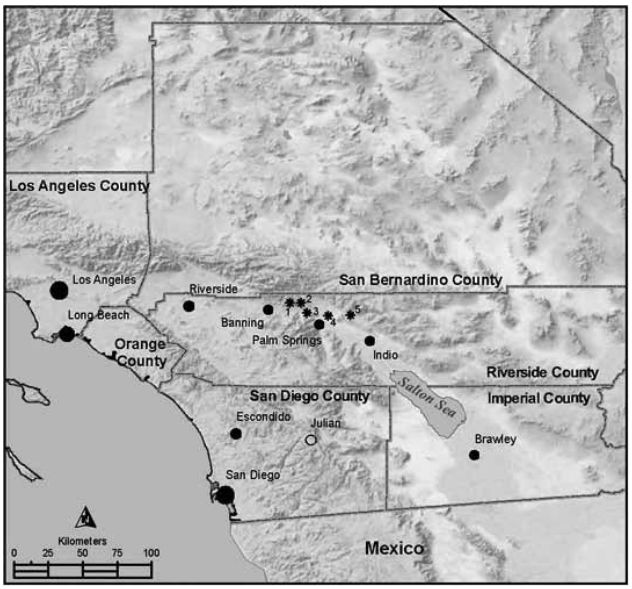



Figure 2. Northern exposures of the Imperial Formation, Riverside County, California. (1) Lion Canyon; (2) Whitewater; (3) Garnet Hill; (4) other sites.

shapes that form in the auditory capsules in the skulls of all Osteichthyes or bony fishes (Nolf 1985). Most actinopterygians, or ray-finned fishes, have three pairs of otoliths, three on each side of the base of the skull. These pairs are called the sacculith (=sagitta), utriculith (=lapillus), and lagenar (=astericus). In most fishes, the sacculith is the largest of the three otolith types. The geometric shape and other structures on the surface of the sacculith are most useful for family, genus, and species identifications.

The modern environmental information, ranges, and other data used in systematic accounts were taken from Castro 1983; Compagno et al. 2005; Eschmeyer and Herald 1983; Fitch and Lavenberg 1968; Goodson 1976,1988; Miller and Lea 1976; Nelson 1976; Randall 1968; Robins and Ray 1986; Thomson and McKibben 1986; Thomson et al, 1987.

## Super Creek locality

This locality (University of California, Riverside Geology Department Locality No. 7477) is north of the Banning Fault approximately one-half mile on the east bank of Super Creek where the creek cuts across the generally

NE–SW trending strike of the east dipping Imperial Formation at a slight angle. The abandoned Super Creek Mine is nearby.

The stratigraphy is this area consists of a lower member of the Imperial Formation which is a coarse to medium grained sandstone and conglomerate. This section is about 20 meters thick. Overlying the lower member is a one meter thick "worm tube bed" consisting of fossil marine mollusk (clam and snails) bearing siltstone and sandstone, separating the upper and lower members of the Imperial Formation (Carreno and Smith 2007).

The upper member consists of medium to fine-grained sandstones and siltstones about 75 meters thick.

It is from the "worm tube layer" that the matrix samples were collected and processed for fish remains. The lithology consists of a gray fossiliferous clayey siltstone with a diverse assemblage of marine invertebrates (bryozoans, corals, clams, snails) and fishes. This interval is within the part of the formation known as the "*Callianassa*" (shrimp) (Murphy 1986) or "worm tube" (McDougall 1999) bed because of abundant white calcareous tubes that are actually a gastropod (snail) (Vermetidae, *Thylacodes*) (LaFollette, this volume).

On the basis of foraminifers (microfossils), McDougall et al. (1999) and McDougall (2008) considered the age of this locality to be late Miocene, below but near the Miocene–Pliocene boundary (5.3 million years) and may date from 6.2 to 6.5 million years (McDougall el al 1999). McDougall (2008) noted that the benthic (bottom-dwelling) foraminifers indicate a rapid increase in water depth from approximately 37 m to 150 m in this stratigraphic interval. However, the tubes of this gastropod, *Thylacodes,* are the most abundant elements of the fauna and this gastropod is known to live only in the intertidal zone (LaFollete, this volume).

The fossil fishes described in this report were collected by the disaggregation of fossiliferous shell-bearing sediments in water, and the water screening of this material through 30-mesh (30 openings per inch) screen boxes. This removed most of the clay, silt and fine sands. The residue or concentrate remaining in the screens was carefully "dumped" on several layers of newspaper to dry in the sun. Once the concentrate was dry, it was gently sifted through three different size sieves (U. S. Standard Sieve Series 12 mesh, 16 mesh, and 20 mesh sieves). Then the concentrate in each sieve was searched for invertebrate and fish remains with the aid of a binocular microscope. In all, over 700 kilograms of matrix from this site were water screened. After the concentrate was picked of fish remains, the fish otoliths and teeth were compared to modern comparative material for identification. The author's private comparative collection and literature were utilized. Also, Mr. Richard W. Huddleston assisted the author in identification of some of the fish otoliths. At least 16 kinds of bony fishes (Table 1) were identified from the Super Creek locality.

Table 1. Fish Remains from the Super Creek (UCR 7477) Whitewater, Riverside County, California. Imperial Formation (late Miocene)

| Taxon | Otolith | Tooth |
|---|---|---|
| Atherinidae—silversides | 1 | |
| *Bregmoceras*—codlet | 1 | |
| *Diaphus*—headlightfish | 17 | |
| Myctophidae—lanternfish | 1 | |
| *Lepophidium*—cusk—eel | 12 | |
| Congridae—conger eels | 13 | |
| *Apogon*—cardinalfish | 1 | |
| *Gerres*—mojarra | 1 | |
| Gerreidae—mojarras | 1 | |
| *Lutjanus*—snapper | | 1 |
| Haemulidae—grunts | 1 | |
| *Orthopristis*—grunt | 1 | |
| *Umbrina* cf. *U. roncador*—yellowfin croaker | 1 | |
| Sciaenidae—croakers | 2 | |
| Gobiidae—gobies | 35 | |
| *Citharichthys*—sanddab | 2 | |
| Balistinae—triggerfishes | | 1 |
| Perciform fishes | 2 | |
| Unknown | 1 | |
| **Totals:** | **93** | **2** |

## Super Creek locality Systematic Accounts

### Atherinidae-silversides

These elongate silvery fishes are found in estuarine or marine waters in temperate and tropical seas worldwide (Figure 3). A few species are found in freshwater. Worldwide, there are about 29 genera with 156 species. Today in the northwestern Atlantic there are seven species of silversides, in the Gulf of California eight species, and off California three species (Figure 3)

Figure 3. Silverside.

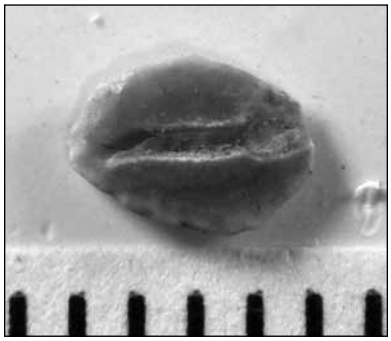


Figure 4. Silverside otolith.

### Atherinid—silverside

I compared the Super Creek fossil

otolith (Figure 4) with otoliths from three modern species off California, *Atherinops affinus* (topsmelt), *Atherinopsis californiensis* (jacksmelt), and *Leuresthes tenuis* (California grunion), and one species from the northern Gulf of California, *Colpichthyes regis* (false grunion). None of the species compare well with the fossil atherinid.

**Material**: left otolith

## Bregmacerotidae—codlets

This small relative of cods (usually less than four inches in length) is found in tropical and subtropical seas (Figure 5). Worldwide there is one genus, *Bregmaceros*, with eight species. In the northwest Atlantic, there are at least two species and in the eastern Pacific, one species. Codlets are found from the water surface to 1800 feet. At least one species makes diurnal migrations, living in deep water during the day and migrating to the water surface at night.

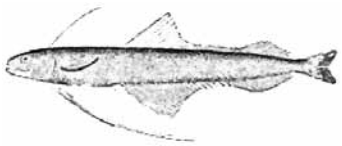


Figure 5. Codlet.

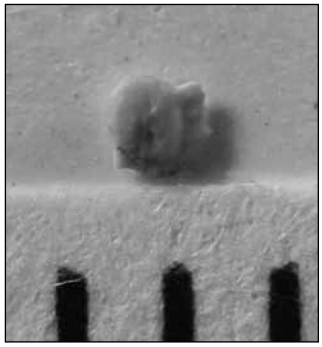


Figure 6. Codlet otolith.

*Bregmaceros*—codlet
There is only one genus, *Bregmaceros*, in the family Bregmacerotidae. Because of lack of comparative material, the single otolith (Figure 6) was only identified to the genus *Bregmaceros*.

**Material**: right otolith

## Myctophidae—lanternfishes

Lanternfishes is a large family of small deep sea fishes with light producing photophores. There are about 32 genera and 220 species. Most are oceanic, living at moderate to deep depths during the day and migrating near and to the water surface at night. More than 30 species of lanternfishes belonging to 20 genera inhabit the waters off California.

*Diaphus*—headlightfish
Today, four species of *Diaphus* inhabit deep waters off California (Figure 7). One species, *Diaphus theta* (California headlightfish) is found from the Gulf of Alaska to Cedros Island, central Baja California, Mexico (Fitch 1969). *D. theta* during daylight is found at depths of 1000 feet or more and at night migrates upward within 30 feet of the water surface (Fitch 1968). Fossil otoliths have been reported from localities in the middle Eocene of San Diego and the middle Miocene of Bakerfield (as *Diaphus)* and the Pliocene and Pleistocene of southern California (as *Diaphus theta*)(Fitch 1966).

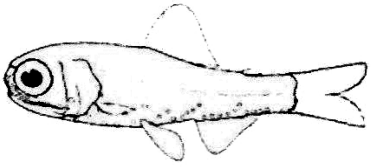


Figure 7. Headlightfish.

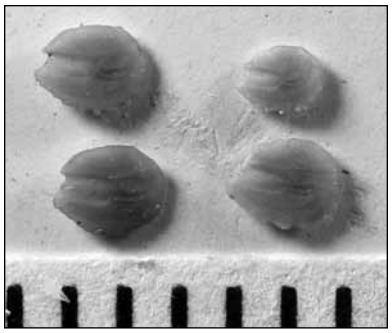


Figure 8. Headlightfish otoliths.

Until more comparative material becomes available, the fossil otoliths of *Diaphus* (Figure 8) from Super Creek will be assigned to generic level.

**Material**: 17 otoliths

### Myctophid—lanternfish

A single fossil lanternfish otolith was recovered. With more comparative material available, identification to genus and/or species level may be possible.

**Material**: otolith

## Ophidiidae—brotulas and cusk-eels

These long tapering fishes (Figure 9) are found in temperate and tropical seas with a few species in freshwater. Worldwide, there are about ten genera and 35 species of brotulas and cusk-eels. Cusk eels are found in shallow as well as deep marine waters. There are 14 species of cusk-eels in the northwestern Atlantic Ocean, at least two species in the Gulf of California, and five species off California.

*Lepophidium*—cusk eel
Today, one species, *Lepophidium negropinna* (giant cusk-eel) has not been captured north of Cedros Island, central Baja California, Mexico (Fitch 1964) and ranges throughout the Gulf of California to Talara, Peru. The giant cusk-eel is found in shallow water on firm smooth bottoms. Fitch (1970) reported fossil otoliths of *Lepophidium negropinna* from

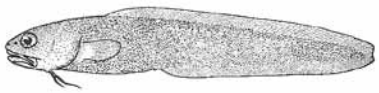


Figure 9. Cusk-eel.

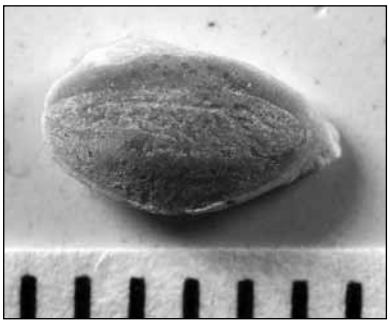


Figure 10. Cusk-eel otoliths.

localities in the Late Pleistocene (120,000 years ago) Palos Verdes Sand of southern California. There is a second species of *Lepophidium*, *L. stigmatistium,* in the Gulf of California (Aceves-Medina et al. 2003). Until comparative material of this species and other species of *Lepophidium*, becomes available, the Super Creek cusk-eel otoliths (Figure 10) can be only assigned to genus. There may be two species present.

**Material**: 12 otoliths

## Congridae—conger eel

This large family of eels (Figure 11) is found worldwide in tropical waters of all oceans. Congrid eels are found both in shallow and deep water, and usually inhabit burrows on soft bottoms. Worldwide, there are about 38 genera and 100 species.

Figure 11. Conger eel.

Fossil congrid otoliths are extremely abundant in North American Eocene deposits, and are present in later Oligocene and Miocene. However, it is very difficult to distinguish species from otoliths alone (Fitch and Lavenberg 1983). Comparative otolith material from recent conger species is not available, for the most part, because most congrid eels are secretive in their living habits and are rarely collected. Because of this, it is hard to place isolated fossil otoliths in a genus, and fossil conger eel material is usually only identified to family level. Until more comparative conger eel otolith material becomes available, either through papers that illustrate conger otoliths or actual identified conger otoliths, clarification of the fossil record of this family will remain uncertain (Fitch and Lavenberg 1983)

### Congrid—conger eel

As part of their study of the Pliocene Yorktown Formation fish otoliths recovered at the Lee Creek Mine, Aurora, North Carolina, Fitch and Lavenberg (1983) noted a number of congrid otoliths. They identified five types of congrid otoliths only to family level and labeled them Congrid species A through Congrid species E. None of the Super Creek congrids (Figure 12) have any resemblance to Lee Creek Mine Congrid otoliths. There may be at least two kinds of conger otoliths (Figure 12).

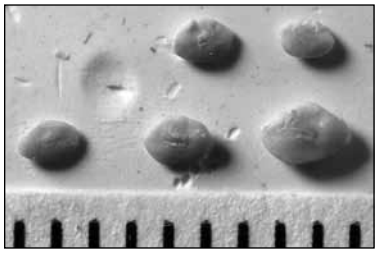


Figure 12. Conger eel otoliths.

**Material**: 13 otoliths

## Apogonidae—cardinalfishes

Cardinalfishes are small (usually less than 4 inches). During the day, these brightly colored fishes (Figure 13) are found hiding in the cracks and crevices of coral reefs, burrows, or empty shells. At night they are active, but rarely seen by underwater divers. Worldwide, there are 20 genera with about 170 species of cardinalfishes. In the northwestern Atlantic Ocean twenty shallow-water species are known, most of which occur in the Caribbean. Today in the Gulf of California there are four species of cardinalfishes, with only the barspot cardinal fish (*Apogon retrosella*) being common.

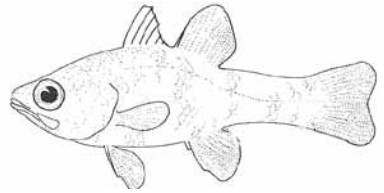


Figure 13. Cardinalfish.

*Apogon*—cardinalfish

The Super Creek fossil otolith (Figure 14) needs to be compared with modern species in order to place it in an existing species or to determine if it is a new species.

**Material**: left otolith

Figure 14. Cardinalfish otoloith.

## Gerreidae—mojarras

These small silvery fishes occur in shallow tropical and warm temperate coastal waters off North and South America, and in the western Pacific and Indian Oceans (Figure 15). Although most mojarras are marine, a few enter brackish or freshwater. Usually they are abundant in inshore areas over sand and sand-mud bottoms, but also are found over rocky bottoms with numerous sandy patches. Worldwide, there are seven genera and about 40 species. In the northwestern Atlantic Ocean, there is one species of *Gerres*. There are eight species of mojarras in the Gulf of California. There are a few records of two mojarras off southern California

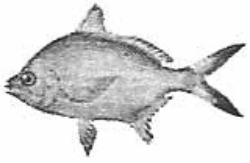


Figure 15. Mojarra.

Figure 16. Mojarra otolith.

(*Eucinostomis argenteus*—spotfin mojarra, *E. gracilis*—flagfin mojarra).

*Gerres*—mojarras
The Super Creek *Gerres* otolith (Figure 16) needs to be compared to otoliths of other modern species of this genus.

**Material**: right otolith

## Lutjanidae—snappers

Snappers are found in marine waters of the Atlantic, Pacific and Indian Oceans, and rarely in estuaries (Figure 17). Lutjanids are usually found in tropical shore waters. Several species are wide-ranging and oceanic, while others inhabit deeper waters or reefs. There are 32 genera and about 230 species. In the northwestern Atlantic Ocean, there are four species, and in the Caribbean at least 18 species. In the Gulf of California, there are nine species of snappers.

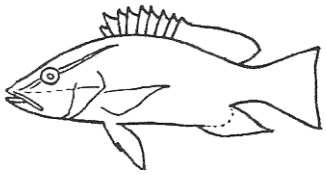


Figure 17. Snapper.

Figure 18. Snapper tooth.

*Lutjanus*—snapper
A single canine-like jaw tooth was recovered. *Lutjanus novemfasciatus* (dogtooth snapper) has the largest canine of any of the Pacific snapper. And with more comparative material, the isolated fossil snapper tooth (Figure 18) may be identified to this species.

**Material**: A single "canine" jaw tooth

## Haemulidae—grunts

Grunts are found in subtropical and tropical coastal waters of the Atlantic, Indian and Pacific Oceans. A few occur in temperate seas. A small number of species is present in brackish water and few in freshwater. During the day, grunts are found on reefs and other sheltered areas, while at night they feed over open sandy, muddy and grassy areas. Worldwide, there are twenty-one genera with about 175 species.

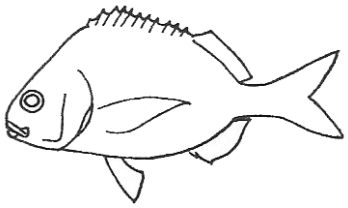


Figure 19. Grunt.

In the northwestern Atlantic, there are 20 species of grunts, while in the Caribbean 17 species are present. In the Gulf of California, there are 25 species (Figure 19).

*Orthopristis*—grunt
In the Atlantic Ocean, there are two species of the genus *Orthopristis, O. chrysoptera* (pigfish) and *O. ruber* (Corocoro), while in the Gulf of California there is one species, *O. reddingi* (bronzestriped grunt), which is present from Bahia Sebastian Viscaino, Baja California, Mexico and throughout the Gulf of California. This species is abundant over muddy and sandy bottoms. With more comparative material, assignment of this otolith (Figure 20) to a modern species or even a fossil species may be possible

Figure 20. Grunt otolitith.

**Material**: left otolith

## Sciaenidae—croakers

These elongate, usually silvery fishes are found in Atlantic, Pacific and Indian Oceans in marine and brackish waters. But a few species are found in freshwater, particularly in South America. Croakers are abundant shore fishes in tropical and temperate seas, with fewer species in cold waters. There are 28 genera of sciaenids with about 160 species. In the northwestern Atlantic, there are twenty-two species of croakers, while in the Gulf of California there are 28 species.

*Umbrina cf. U. roncador*—yellowfin croaker
Today, there are at least two species of *Umbrina* in the Gulf of California (*U. xanti and U. roncador)*—yellowfin croaker (Figure 21). The partial fossil otolith compares favorably with *Umbrina roncador*

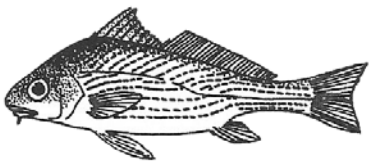


Figure 21. Yellowfin croaker.

Figure 22. Yellowfin croaker otolith.

(Figure 22). In southern California, the yellowfin croaker prefers the very shallow waters in the surfzone, near rocks, in bays and tidal sloughs over sandy bottoms, from the shore to 25 feet. Fossil otoliths of *Umbrina roncador* have been recovered from the late Pleistocene of southern California (Fitch 1970).

**Material**: partial left otolith

### Sciaenid—croaker

Two juvenile croaker otoliths were also recovered, but they are too small to identify to genus or species level.

**Material**: two otoliths

## Gobiidae—gobies

One of the most speciose of fish families, gobies number more than 2000 species worldwide. These very small bottom-dwelling fish are found in marine, brackish, and occasionally freshwater environments (Figure 23). Gobies are found over a wide range of habitats from deep water to high tide pools, and from ocean reefs to hypersaline lagoons. Although most gobies are found on the bottom, some are mid-water swimmers and substrate-burrowing species.

Figure 23. Goby.

In the northwestern Atlantic Ocean, there are at least 79 species of gobies, while the Gulf of California has at least 60 species.

### Gobiid—goby

Because of lack of comparative material, the goby otoliths (Figure 24) are only assigned to family level. There may be at least two species.

**Material**: 35 otoliths

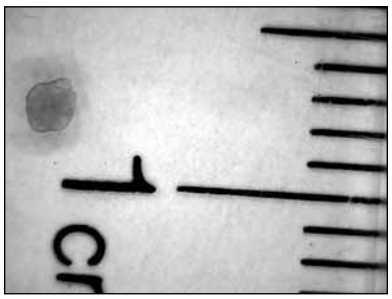


Figure 24. Goby otolith.

## Bothidae—lefteye flounders

Lefteye flounders are abundant in temperature and tropical waters with a few species in cold waters. Most are found in bays, lagoons, and shallow coastal waters with a few species in brackish and freshwater. Worldwide, bothids are found in the Arctic, Pacific and Atlantic Oceans with 41 genera with about 99 species.

### Citharichthys—sanddab

In the northwestern Atlantic Ocean, there are five species of *Citharichthys* (sanddabs) and at least three species in the Gulf of California (Figure 25).

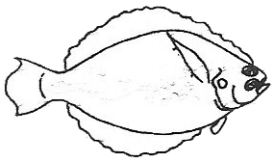


Figure 25. Sanddab.

A comparison with the two species of *Citharichthys* (*C. sordidus, C. stigmaeus*) found off California to southern Baja California, Mexico, and with *C. xanthostigma* found off southern California into the Gulf of California, indicates that Super Creek specimens are not among these species. Today, there are three species of *Citharichthys* (*C. fragilus, gordae, platophrys*) in the Gulf of California. Schwarzhans (1999) only illustrates otoliths of *C. fragilus*. But the Super Creek specimen (Figure 26) is more like the otoliths of the northwestern Atlantic species, *C. spilopetrus* (bay swiff) (Schwarzhans 1999). Until otoliths of *C. gordae and C. platophrys*, and other species of *Citharichthys* become available, identification can only be taken to the genus level.

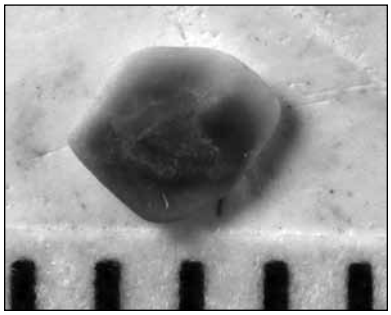


Figure 26. Sanddab otolith

**Material**: two otoliths

## Balistidae—filefishes and triggerfishes

The family Balistidae is sometimes split into two families, filefishes (one or more families) and triggerfishes (one family). Triggerfishes are deep-bodied and compressed fishes with three dorsal spines (Figure 27). The first dorsal spine can be locked in the upright position, deterring predators from attempting to swallow this fish. Triggerfishes are found in the Atlantic, Pacific, and Indian Oceans with seven genera with 35 species. They occur in warm seas over rocky areas and reefs, but a few are found over soft bottoms. In the northwestern Atlantic Ocean, there are six species of

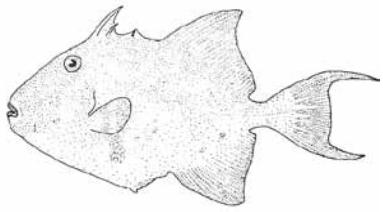


Figure 27. Triggerfish.

Figure 28. Triggerfish tooth.

triggerfishes, while in the Gulf of California, two species.

**Balistinae—triggerfish**

Until more comparative material becomes available, the Super Creek triggerfish tooth (Figure 28) will be assigned to the subfamily, Balistinae (triggerfishes)

**Material**:"canine" tooth fragment

## Willis Palm locality

This locality (Charles Powell Field Locality CP01172011) is located near Willis Palms Oasis in the Indio Hills, Riverside County, California. The Imperial Formation in this area has been correlated to the Pliocene part of the Imperial Formation to the south in Imperial and San Diego counties (Powell, et al 2011). These deposits may date to 3.1 to 3.2 million years (Powell 1987). Environmental data on extant marine mollusks collected at this site indicate water depth of between 5 and 30 meters in a low-energy, protected, marine environment (Powell, et al 2011). Benthic foraminifers (microfossils) from this site indicate inner neritic (shallow inshore) water depths (0–50m) (Powell, et al 2011).

A section measured consisted of 53 meters of very pale medium to fine-grained sandstone, with three fossil shell-bearing horizons near the base of the unit. A 200-kilogram sample was collected and processed from the third highest bed, which was 15 meters above the base of the section and consisted primarily of a white shell-bearing oyster bed.

At least three kinds of bony fishes and four kinds of sharks and rays were identified from the Willis Palm locality (Table 2).

Table 2. List of fish remains from the Willis Palm site (Field Locality CP01172011), Riverside County, California Imperial Formation (Pliocene)

| Taxon | Otolith | Tooth |
|---|---|---|
| *Mustelus*—smoothhound | | 1 |
| *Carcharhinus*—requiem shark | | 1 |
| Rhinobatidae—guitarfish | | 1 |
| Dasyatidae—round stingrays | | 1 |
| Myliobatoidea—large stingrays | | 3 |
| *Cynoscion*—corvina | 5 | |
| Sciaenidae—croakers | 8 | |
| Kyphosidae—sea chubs | | 1 |
| Gobiidae—gobies | 3 | |
| Osteichthys—bony fish | | 2 |
| **Totals:** | **16** | **10** |

## Triakididae—smoothhounds

Smoothhounds are small to moderately large sharks that occur in all oceans, usually in temperate and tropical waters. They are mainly continental in range, inhabiting inshore and near shore environments. Smoothhounds are also common in shallow bays. Worldwide, there are 11 genera with about 35 species. Within the genus *Mustelus* (Figure 29) in the northwestern Atlantic there are at least four species, in the Eastern Pacific eight species, and in the Gulf of California three species.

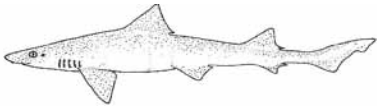


Figure 29. Smoothhound.

*Mustelus*—smoothhound

Fossil teeth of *Mustelus* have been reported from the middle Miocene of Orange County (Lander 2003).

Fossil smoothhound teeth (*Mustelus californicus*—gray smoothhound, *Mustelus henlei*—brown smoothhound) have been reported from the Late Pleistocene Palos Verdes Sand of Orange County, California (Long 1993). The Super Creek tooth (Figure 30) compares favorably to the teeth of the gray smoothhound, but until comparative material of other species of *Mustelus* from the eastern Pacific and western Atlantic Oceans is available, identification will be to the generic level.

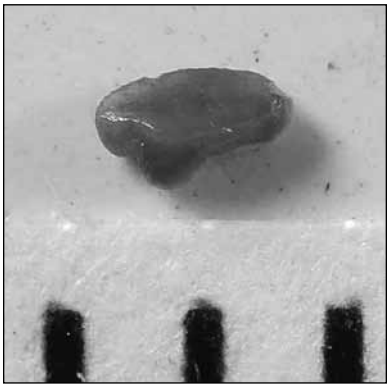


Figure 30. Smoothhound tooth.

**Material**: tooth

## Carcharhinidae—requiem sharks

Requiem sharks are a large and diverse family of small to large sharks. These sharks are the dominant shark of the tropics and are found in all oceans. A few species are found in cold waters.

Requiem sharks occur on continental shelves, around islands, and on the high seas. Within this family, there are nine genera with about 45 species

*Carcharhinus* sp.—requiem shark

Within Carcharhinidae, the genus *Carcharhinus* makes up over half of the species of this family (Figure 31). In the northwestern Atlantic Ocean, there are at least 14 species; in the eastern Pacific, there are at least 16 species of *Carcharhinus;* and in the Gulf of California, six species (Kato et al. 1967). Fossil teeth of *Carcharhinus* has been reported the middle Miocene of California and Baja California (Mitchell, 1965; Demere et al. 1984). The single *Carcharhinus* tooth (Figure 32) recovered may be assigned to a modern species or a fossil species as more comparative material becomes available.

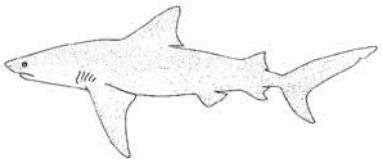


Figure 31. Requiem shark.

Figure 32. Requiem shark tooth.

**Material**: one tooth

## Rhinobatidae—guitarfishes

Guitarfishes have a body shape midway between a shark and a skate and are found in the Atlantic, Pacific and Indians Oceans (Figure 33). These medium sized fishes are found in tropical and temperate shore waters, sometimes entering tropical rivers. Worldwide, there are three genera of guitarfishes. In the northwestern Atlantic Ocean, there is one species of Rhinobatos, and three species in two genera in the Gulf of California, *Rhinobatos* and *Zapteryx*.

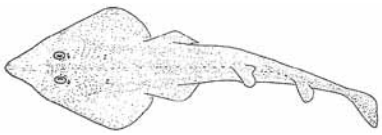


Figure 33. Guitarfish.

### Rhinobatid—guitarfish

Until comparative material becomes available, the single very small fossil guitarfish tooth is identified to the family level (Figure 34) .

**Material**: one tooth

Figure 34. Guitarfish tooth.

## Myliobatoidea—eagle and cownose rays

Worldwide, there are five genera of myliobatoid rays: *Aetobatis, Aetomylaeus, Pteromylaeus, Rhinoptera, and Myliobatis* (Figure 35) and 25 species.

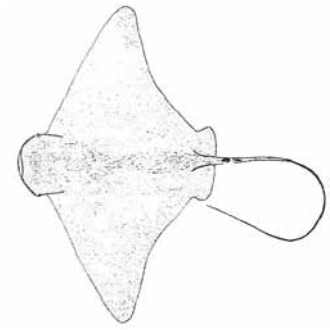
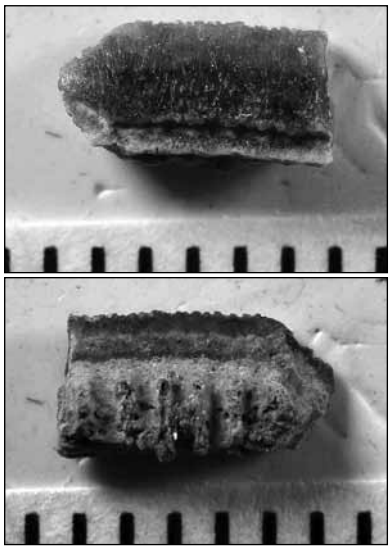


Figure 35. Eagle ray.

### Myliobatoidea—eagle and cownose rays

A preliminary analysis of over 300 individual jaws of modern California bat stingray *Myliobatis californicus* revealed that morphology of teeth is highly variable and "transcends virtually all supposed generically distinct dental patterns of other myliobatid rays" (Welton and Zinsmeister 1980). In the northwestern Atlantic Ocean, three genera, *Aetobatus, Myliobatis, Rhinoptera*, are present, while in the eastern Pacific, *Pteromylaeus, Myliobatis,* and *Rhinoptera* are known. The Willis Palm ray teeth (Figures 36, 37) can be identified only to the superfamily level.



Figures 36 and 37. Eagle ray tooth, top and bottom.

**Material**: two broken medial teeth

## Dasyatididae—stingrays

These rays have a thin whiplike tail with one or more venomous barbed spines near the base (Figure 38). Worldwide, there are seven genera and 45 species. In the western Atlantic and eastern Pacific Oceans, there are three genera, *Dasyatis*—stingray, *Gymnura*—butterfly ray, and *Urolophus*—round sting ray.

### cf. Dasyatid?

A single very small ray tooth was assigned to this family (Figure 39).

**Material**: tooth

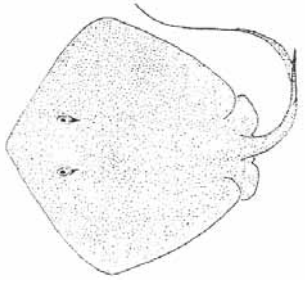


Figure 38. Stingray.

### Sciaenidae—croakers

*Cynoscion*—corvinas

"The genus *Cynoscion* (Figure 40) is one of the many speciose in the family Sciaenidae" (Schwarzhans 1993). In the northwestern Atlantic, there are 13 species of *Cynoscion* while in the Pacific Ocean, 9 species. Most bonyfish have a juvenile otolith form that is morphologically distinct from the adult shape. Unfortunately,

Figure 39. Ray tooth.

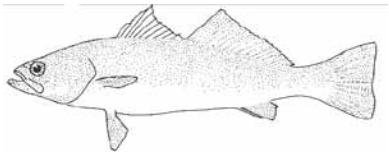


Figure 40. Corvina.

all of the Willis Palm *Cynoscion* otoliths (Figure 41) are from juveniles, precluding identification to the species level. Because the modern *Cynoscion* otoliths are well documented (Schwarzhans 1993), if larger fossil (adult form) otoliths are recovered with additional sampling of this site, it would allow identification to a modern species or possibly an extinct species.

**Material**: five juvenile otoliths

Figure 41. Corvina otolith.

#### Sciaenid—croaker

Eight juvenile croaker otoliths were also recovered, but they are too small to identify to genus or species level.

**Material**: eight juvenile otoliths

### Kyphosidae—sea chubs

Sea chubs are deep-bodied, oval-shaped, and omnivorous fishes found in the Atlantic, Pacific, and Indian Oceans (Figure 42). They feed on benthic algae, plankton, and small invertebrates with their small mouth and fine jaw teeth. Sea chubs are found in temperate and warm seas inshore over rocky bottoms and coral reefs.

There are two species of sea chubs in the northwestern Atlantic Ocean, seven species in the Gulf of California, and three species off southern California.

#### Kyphosid—sea chub

Because of lack of comparative material, the jaw tooth (Figure 43) could be identified only to family level.

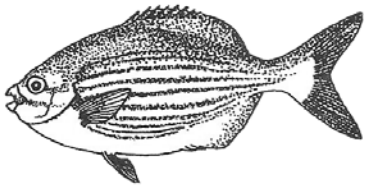


Figure 42. Sea chub.

**Material**: "incisor-like" jaw tooth

Figure 43. Sea chub tooth.

### Gobiidae—gobies

(Figure 44)

#### Gobiid—goby

Because of lack of comparative material, the Willis Palm goby otoliths (Figure 45) are only assigned to family level.

**Material**: two otoliths

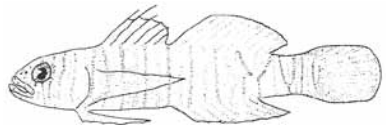


Figure 44. Goby.

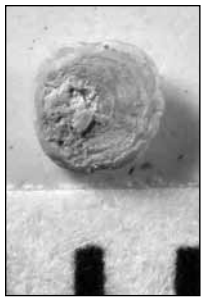


Figure 45. Goby tooth.

## Discussion

### Super Creek

Early work on the northern exposures of the Imperial Formation, including Super Creek, by Bramkamp (1935) identified many species of marine corals and mollusks (clams and snails).

Recently there has been renewed interest in the paleontology of Whitewater area. Research has been conducted on microfossils (McDougal et al 1999; McDougal), bryozoans (Wilson and Cuffey 1998) mollusks (Schremp 1981; Carreno and Smith 2007; Powell 1985, 1986, 1987, 1988: LaFollette, this volume), crabs (Tucker et al 1994), and whales (Thomas and Barnes 1993).

Roeder and Huddleston (2011) reported the first fossil records of marine fish from the Imperial Formation of the Super Creek area.

The fish remains, primarily otoliths, chronicle the fish fauna of the ancestral Gulf of California some 6 million years ago.

Except for the *Diaphus* (headlightfish) and *Bregmaceros* (codlet), the fossil fish species recovered from this site indicate a very shallow marine paleoenvironment.

Today, the cardinalfish (*Apogon*), mojarra (*Gerres*), grunt (*Orthopristis*), and snapper (*Lutjanus*) are considered warm water species. Records off southern California are either rare or nonexistent.

Today some species of *Diaphus* and Bregmaceros make diural migrations from fairly deep water to shallow waters at night. The presence of these fish in the Super Creek fauna may indicate the presence of a nearby offshore deep water basin.

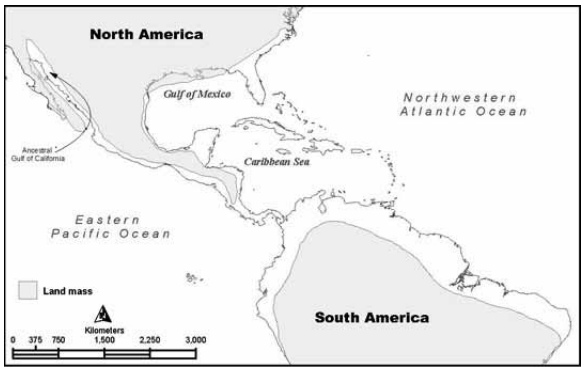



Figure 46. Late Miocene–Pliocene seas of North and Central America..

During the Late Miocene, a seaway existed across what is today Panama, until closure in the middle Pliocene (Figure 46). Prior to its closure, there was free exchange of marine waters of the eastern Pacific and Caribbean Sea. Early work on the northern exposures the Imperial Formation by Bramkamp (1935) identified a number of marine corals and mollusks (clams and snails) that today are not present in the eastern Pacific, but are living in the Caribbean Sea. Herein lies the challenge in the identification of the fish species from the Super Creek locality. For example, in comparing the fossil otoliths of *Citharichthys* (sanddab) with illustrations of sanddab otoliths from the eastern Pacific and western Atlantic Oceans (Schwarzhans 1999), the Super Creek otoliths are more like the western Altantic species of sanddabs. There is a possibility that many of the fish otoliths and teeth belong to Caribbean species, like earlier identified species of fossil bryozoans, corals and mollusks. Collections of comparative otoliths and osteological material from the Caribbean Sea are incomplete. Even if some of the fossil fish material is eastern Pacific Ocean species, comparative material is lacking. Because of this many of the otoliths and teeth from the Super Creek can only be identified to family and/or genus level

But at least one species of fish, *Umbrina* cf. *U. roncador* (yellowfin croaker) was identified to a modern species. It is possible that with more comparative material, many of the fish otoliths and teeth can be identified to modern species. Because of the age of the Super Creek locality, which is over 6 million years, there may be several species that are extinct.

Water screening and sorting of 700 kilograms of fossil-bearing sediment from the Super Creek locality yielded at least 16 taxa of bony fish. Surprisingly, no shark or ray remains were recovered.

Additional processing of fossiliferous sediments from the Super Creek locality should yield additional material of known taxa as well as records of new species. Although for the most part fish remains are scarce, I have averaged one new taxa for every 100 kg of sediment processed (water screened and sorted).

## Willis Palm

The Willis Palm locality, which is Pliocene (Powell, et al 2011) in age, gives us an opportunity to look at fish faunas from a younger exposure of the Imperial Formation. Even though sediments were deposited in shallow marine environments like the older Super Creek locality, the fish fauna is very different. For one thing, there are sharks and rays, which are absent at Super Creek. With more investigation, the Willis Palm locality fish may be more like the fish faunas of the present-day northern Gulf of California. Today, there are several species of croaker of the genus *Cynoscion* (corvina) in the northern Gulf and up until recently they were very abundant. Even though the fossil *Cynoscion* otoliths recovered from Willis Palm were from juveniles, with additional sampling and processing of fossiliferous sediments from this site there is an excellent chance to recover adult *Cynoscion* and other croaker otoliths which could be speciated.

**Acknowledgements**—I would like to thank Edward Wilson, curator emeritus of the Invertebrate Paleontology Section of Natural History Museum of Los Angeles County, for his encouragement and advice on this project. Ed, Pat LaFollette, and Diane Jovee accompanied me in the field, helping with the collection of the samples. Special thanks to Diane Jovee, who picked the concentrate from Super Creek and found many of the fish species described in this report. Also, all materials were collected under Charles L. Powell, II, of the U. S. Geological Survey, Menlo Park permits. Special thanks to Bob Reynolds for making the guidebook possible. Pat LaFollete took the photographs of the fish remains. And finally, Mr. Richard W. Huddleston of Scientific Research Systems assisted the author in identification of some of the fish otoliths.

## References

Aceves-Medina, G., Jimenez-Rosenburg, S. P. A., Hinojosa-Medina, A., Funes-Rodriguez, R., Saldierna, R. J., Lluch-Belda, D., Smith, P. E., and W. Watson, 2003, Fish larvae from the Gulf of California. Scientia Marina. Volume 67. Number 1. p. 1-11.

Carreno, A. L. and J. T. Smith, 2007, Stratigraphy and Correlation of the Ancient Gulf of California and Baja California Peninsula, Mexico. Bulletin of American Paleontology. Number 372. p. 1-146.

Castro, J. I., 1983, The Sharks of North America. The W. L. Moody, Jr., Natural History Series, No. 5. Texas A&M University Press, College Station, Texas. 180p.

Compagno, L., Dando, M. and S. Fowler, 2005, Sharks of the World. Princeton Field Guides. Princeton University Press. Princeton and Oxford. 368p.

Demere, T. A., Roeder, M. A., Chandler, R. M., and J. A. Minch, 1984, Paleontology of the Middle Miocene Los Indios Member of the Rosarito Beach Formation, Northwestern Baja California in Minch, J. A. and J. R. Ashby, editors, *Miocene and Cretaceous Depositional Environments, Northwestern Baja California, Mexico.* Published by the Pacific Section, American Association of Petroleum Geologists, Los Angeles. Volume 54, p. 47-56.

Eschmeyer, W. N. and E. S. Herald, 1983, A Field Guide to Pacific Coast Fishes of North America. The Peterson Field Guide Series Houghton Mifflin Company, Boston. 336p.

Ebert, D. A., 2003, Sharks, Rays and Chimaeras of California. California Natural History Guide No. 7. University of California Press. Berkeley and Los Angeles, London. 285p.

Fitch, J. E., 1964, The Fish Fauna of the Playa Del Ray Locality, a Southern California Marine Pleistocene Deposit. Natural History Museum of Los Angeles County Contributions in Science. Number 82. p.1-35p.

___, 1968, Otoliths and other Fish Remains from the Timms Point Silt (Early Pleistocene) at San Pedro, California. Natural History Museum of Los Angeles County Contributions in Science. Number 146. p.1-29.

___, 1969, Fossil Lanternfish Otoliths of California, with notes on Fossil Myctophidae of North America. Natural History Museum of Los Angeles County. Number 173. p. 1-20.

___, 1970, Fish Remains, mostly otoliths and teeth from the Palos Verdes Sand (Late Pleistocene) of California. Natural History Museum of Los Angeles Contributions in Science. Number 199. p. 1-41.

Fitch, J. E. and R. J. Lavenberg , 1968, Deep-water Fishes of California. California Natural History Guide No. 25. University of California Press. Berkeley and Los Angeles. 155p.

___, 1983, Teleost Fish Otoliths from the Lee Creek Mine, Aurora, North Carolina (Yorktown Formation: Pliocene) in Ray, C. E., editor, *Geology and Paleontology of the Lee Creek Mine, North Carolina, I.* Smithsonian Contributions to Paleobiology. Smithsonian Institution Press, Washington. Number 53. p.509-529.

Goodson, G., 1985, Fishes of the Atlantic Coast. University of Stanford Press. Stanford. 202p.

___, 1988, Fishes of the Pacific Coast. University of Stanford Press. Stanford. 267p.

Kato, S., Springer, S., and M. H. Wagner, 1967, Field Guide to Eastern Pacific and Hawaiian Sharks. U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries. Washington, D.C. Circular No. 271. 47p.

Lander, E. B., 2003, Eastern Transportation Corridor, Paleontologic Resource Impact Mitigation Program, Final Technical Report of Results and Findings: Part 1 of 2 (text and Appendices A to D). Submitted to the Foothill/Eastern Transportation Corridor Agency, Irvine, California, prepared by E. Bruce Lander, Paleo Environmental Associates, Inc, Altadena, California.

Long, D. J., 1993, Preliminary List of Marine Fishes and Other Vertebrate Remains from the Late Pleistocene Palos Verdes Sand Formation at Costa Mesa, Orange County, California. PaleoBios. Volume 15. Number 1. p. 9-13.

McDougall, K, Poore, R. Z., and J. Matti,1999, Age and Paleoenvironment of the Imperial Formation near San Gorgonio Pass, Southern California. Journal of Foraminiferal Research. Volume 29. Number 1. p. 4-25

Miller, D. J. and R. N. Lea, 1976, Guide to the Coastal Fishes of California. Fish Bulletin 157. California Department of Fish and Game. 249p.

Mitchell, E., 1965, History of Research at Sharktooth Hill, Kern County, California. Special Publicationof the Kern County Historical Society and the County of Kern through its Museum. 45p.

Murphy, M. A., The Imperial Formation at Painted Hill, near Whitewater, California. In Geology Around the Margins of the Eastern San Bernardino Mountains, M. A. Kooser and R. E. Reynolds, editors. Publication of the Inland Geological Society, Redlands, California. 1: p. 63-69

Nelson, J. S., 1976, Fishes of the World. A Wiley-Interscience Publication. John Wiley and Sons. New York, London, Sydney, and Toronto. 416p.

Nolf, D., 1985, Otolithi piscium. In H. Schultze, editor, Handbook of Palaeoichthyology, Volume 10. New York:Gustav Fisher Verlag. 145p.

Powell, C. L, II, 1985, Bivalve molluscan paleoecology of northern exposures of the marine Neogene Imperial Formatin in Riverside County, California. Western Society of Malacologists Annual Report, August 1985. Volume 17 for 1984.

___, 1986, Stratigraphy and bivalve molluscan paleontology of the Neogene Imperial Formation in Riverside County, California. San Jose, California. M. S. Thesis, San Jose State University, 325p.

___, 1987, Correlation between sea level events and deposition of marine sediments in the proto-Gulf of California during the Neogene. Geological Society of America, Abstracts with program, 19(7): p.809

___, 1988, The Miocene and Pliocene Imperial Formation of Southern California and its molluscan fauna. Western Society of Malacologists. San Diego, California. Annual Report, Volume 20, p. 11-18.

Powell, C. L., II, Roeder, M. A., and K. McDougall, 2011, A Preliminary Report on the Paleontology of the Imperial Formation (Ancestral Gulf of California:Pliocene) in the Indio Hills, Riverside County, Southern California. CalPaleo 2011 abstracts with program, p. 22.

Randall, J. E., 1968, Caribbean Reef Fishes. T. F. H. Publications. Jersey City. 318p.

Robins, C. R. and G. C. Ray, 1986, A Field Guide to Atlantic Coast Fishes of North America. The Peterson Field Guide Series. Houghton Mifflin Company, Boston. 354p.

Roeder, M., 2005, Fossil Fishes of the Anza-Borrego Region in Program and Abstracts for Fossil Treasures of the Anza-Borrego Desert. Anza-Borrego Institute, California State Parks, and Sunbelt Publications, San Diego. P. 16-17.

Roeder, M. A. and R. W. Huddleston, 2011, First records of fossil fish remains from northern exposures of the marine Imperial Formation, Riverside County, California. Annual Meeting, Abstract No. 133, Bulletin of the Southern California Academy of Sciences, Volume 110, p. 115-116.

Schremp, L. A., 1981, Archaeogastropoda from the Pliocene Imperial Formation of California. Journal of Paleontology. Volume 55, Number 5, p. 1123-1136.

Schwarzhans, W., 1993, A Comparative Morphological Treatise of Recent and Fossil Otoliths of the Family Sciaenidae (Perciformes). Part Otolithi Piscium. Volume 1. Piscium Catalogus. Editor Dr. Friedrich Pfeil. Munchen, Germany. 245p.

___, 1999, A Comparative Morphological Treatise of Recent and Fossil Otoliths of the Order Pleuronectiformes, Part Otolithi Piscium, Volume 2, Piscium Catalogus. Editor Dr. Friedrich Pfeil., Munchen, Germany. 391p.

Thomas, H. W., 1993, Discoveries of fossil whales in the Imperial Formation, Riverside County, California: possible further evidence of the northern extent of the proto-Gulf of California. In Ashes, Faults, and Basins, edited by R. E. Reynolds and J. Reynolds, San Bernardino County Museum Association Special Publication 93(1): 34-36.

Tucker, A. B., Feldmann, R. M., and C. L. Powell, II, 1994, *Speocarcinus berglundi* n. sp. (Decapods:Brachyura), a new crab from the Imperial Formation (late Miocene-late Pliocene) of southern California. Journal of Paleontology, volume 68, number 4, p. 800-807.

Thomson, D. A., Findley, L. T. and A. N. Kerstitch, 1987, Reef fishes of the Sea of Cortez. University of Arizona Press. Tucson.

Thomson, D. A. and N. McKibben, 1986, Gulf of California Fishwatcher Guide. Golden Puffer Press. 75p.

Wilson, Edward Carl and Roger J. Cuffey (1998). "The Early Pliocene Caribbean bryozoan *Acanthodesia savarti monilifera* in the Imperial Formation near Whitewater, Riverside County, California." San Bernardino County (California) Museum Association Quarterly 45(1-2): 108.