A Fossil Blue Marlin (*Makaira nigricans* Lacépède) from the Middle Facies of the Trinidad Formation (Upper Miocene to Upper Pliocene), San José del Cabo Basin, Baja California Sur, México

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Abstract.—A large fossil skull and several rostra of *Makaira nigricans* Lacépède, 1802 (Perciformes: Istiophoridae), as well as some less diagnostic istiophorid remains, have been recovered from the middle facies of the Trinidad Formation near Rancho Algodones, San José del Cabo Basin, Baja California Sur, México. These are the only billfish specimens known from fossiliferous deposits located between southern California and Panama. Based on published accounts of the presence of nannofossils and planktonic foraminifera, and additional field work, we conclude that the age of the study area is late Miocene to late Pliocene. Based on the habitat preferences of recent *M. nigricans* and on the type of sediments, we conclude that the middle facies of the Trinidad Formation was deposited far offshore at a water depth of at least 100 m in a bottom environment that was poorly oxygenated and without currents.

The blue marlin, *Makaira nigricans* Lacépède, 1802, is an important commercial and recreational fish species that inhabits the tropical and temperate Atlantic, Indian, and Pacific oceans favoring depths of over 100 m and temperatures of approximately 24°C (Nakamura 1983, 1985). Blue marlin are usually distributed from about 45°N latitude to 35°S latitude in the Pacific Ocean (Nakamura 1983), although in the far Eastern Pacific blue marlin generally range only from 23°N to 3°S (Rivas 1975). *Makaira nigricans* is occasionally observed off southern California, but only during periods of anomalously high sea surface temperatures (National Marine Fisheries Service [The Southwest Fisheries Science Center’s 1996 Billfish Newsletter], unpublished).

Fossil remains of blue marlin or blue marlin-like fish (e.g., *Makaira* sp., cf. *M. nigricans*) are reported from the middle Miocene of Belgium, from the late Miocene of Panama, southern California and Virginia, and from the early Pliocene of North Carolina (Fierstine 1998, 1999, 2001). Discovery of a large skull and several rostra of *M. nigricans*, as well as some less diagnostic istiophorid remains, in the middle facies of the Trinidad Formation (late Miocene to late Pliocene) in the San José del Cabo Basin, Baja California Sur, México, offers the first opportunity to examine billfish specimens from fossil deposits located between southern
California and Panama and to discuss the paleoecology of the Trinidad Formation based on the habitat preference of a still extant bony fish. Interpretations of the stratigraphy, ages and depositional environments of the rocks near Rancho Los Algodones are equivocal (Espinosa-Arrubarrena 1979; McCloy 1984; Martínez-Gutiérrez and Sethi 1997) and we offer our own conclusions based on additional field work and information from recent publications.

Materials and Methods

The materials and methods used in this study, particularly for the rostrum, have been described fully in Fierstine and Voigt (1996) and Fierstine (1998, 1999, 2001), but some of it is repeated here for convenience. Approximately 160 whole and partial skeletons of Recent specimens representing seven species of the family Istiophoridae were examined and used for comparisons with the fossil material. The museum number, geological age, and locality are given in the text for each fossil specimen that was used as comparative material.

Anatomical abbreviations: A, articular; DE, dentary; LA, lacrimal; LE, lateral ethmoid; M, maxillary; NA, nasal; NC, nutrient canal; PD, predentary; PM, premaxilla; PN, prenasal; S, sclerotic; † denotes extinct taxon.

Institutional abbreviations: IGM, Instituto de Geología, Ciudad Universitaria, Universidad Nacional Autónoma de México, D.F., México; LACM, Natural History Museum of Los Angeles County, Los Angeles, California, U.S.A.

Characters and their definitions for each bone or structure are as follows:

**Rostrum.**—Fierstine (1998, 1999) and Fierstine and Voigt (1996) emphasized two regions of the rostrum in Recent specimens (Fig. 1): 0.5L, or one-half the distance between the distal tip and the orbital margin of the lateral ethmoid bone (L); and 0.25L, or one-fourth the distance between the distal tip and the orbital margin of the lateral ethmoid bone. Six morphometric characters were studied in each region (Fig. 1): depth (D) and width (W) of rostrum; height (H) and width (N) of the left nutrient canal (as seen in cross-section); distance (IC) between the right and left nutrient canals (as seen in cross-section); and distance (DD) of the left nutrient canal from the dorsal surface of the rostrum (as seen in cross-section). Characters studied without reference to region were: distribution of denticles on the dorsal surface of the rostrum measured from the distal tip (DZ); length from distal tip where denticles are absent from the ventral mid-line (DVS); length from the distal tip to the distal extremity of the prenasal (P); length from tip where fused premaxillae divide into separate bones (VSPM); and presence or absence of denticles on the prenasal.

In the fossil specimens from San José del Cabo (Figs. 2–3; Table 1); the exact position of 0.5L or 0.25L was unknown and cross-sections were studied at broken end(s) or from computer tomography images. No transverse cuts were made of the specimens. Using the techniques of Fierstine and Crimmen (1996) and Fierstine (2001), a cross-section was estimated to be at 0.5L if the prenasal bone was large, and at 0.25L if the prenasal bone was tiny or absent. Because of the fragmentary nature of the fossil rostra, DZ was the only character available to study in each estimated region.

**Predentary.**—Fierstine (1998, 2001) studied three morphometric characters in Recent and fossil specimens: length along the ventral mid-line (PL), width across the widest expanse of the denticulated surface (PW), and depth perpendicular to
Fig. 1. *Makaira nigricans* Lacépède. A. Skull, left lateral view. Drawing is a composite of two Recent specimens (LACM 25491 and 46023-1). B. Enlarged cross-section of generalized istiophorid rostrum at one-half bill length (0.5L). C. Enlarged cross-section of generalized istiophorid rostrum at (0.25L). See text for definition of abbreviations (modified from Fierstine, 1999:fig. 3 and Fierstine and Voigt, 1996:fig. 2).
Fig. 2. *Makaira nigricans* Lacépède, upper Miocene-late Pliocene, middle facies of the Trinidad Formation, San José del Cabo Basin, Baja California Sur, México. A. Proximal rostrum (IGM 7888), left lateral view. B. Partial skull (IGM 7889), left lateral view. Dotted lines indicate probable attachment of A with B. C. Partial rostrum (IGM 7884), posterior view. D. Lateral view of C. E. Partial rostrum (IGM 7893), anterior view. F. Lateral view of E (IGM 7893). Scale bar equals 5 cm (A, B), 2 cm (D), and 1 cm (C, E, and F).
Fig. 3. Istiophorid billfish fossils, upper Miocene-late Pliocene, middle facies of the Trinidad Formation, San José del Cabo Basin, Baja California Sur, México. A. Istiophoridae gen. and sp. indet., partial predentary, dorsal view (IGM 7887). B. Istiophoridae gen. and sp. indet., partial predentary, dorsal view (IGM 7885). C. Istiophoridae gen. and sp. indet., partial ?dorsal pterygiophore (IGM 7894), anterior view. E. Makaira sp., cf. M. nigricans Lacépède, partial rostrum, posterior view (IGM 7883). F. Lateral view of E (IGM 7883). Scale bar equals 1 cm (A–E) or 2 cm (F).
Table 1. Measurements and ratios of partial rostra of five specimens of the Family Istiophoridae from the San Jose del Cabo Basin, Trinidad Formation (upper Miocene to late Pliocene), Baja California Sur, México. Measurements taken from computer tomography images are indicated with a pound sign (#) and measurement and ratio estimates are indicated with an asterisk (*). Region refers to whether the bill was studied as part of 0.25L or 0.5L (see text for definitions).

<table>
<thead>
<tr>
<th>Specimen number</th>
<th>Locality number</th>
<th>Region</th>
<th>Overall length</th>
<th>Measurements (in mm)</th>
<th>Ratios</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>W</td>
<td>D</td>
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<tr>
<td>IGM 7882</td>
<td>IG 95</td>
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<td>159.0</td>
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<td>60.5</td>
<td>37.0</td>
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</tr>
</tbody>
</table>
the long axis from PW to the ventral surface of the bone (PD). The San José del Cabo specimens (Fig. 3) were too fragmentary to obtain any of the three morphometric characters.

**Skull.**—Although there are published descriptions available of a typical or specific istiophorid skull (Gregory and Conrad 1937; Schultz 1987; Davie 1990), there are no comparative osteological studies that are useful in determining the species represented by the partial skull from the San José del Cabo Basin (Fig. 2B). Nakamura (1983, 1985) compared complete neurocrania of Recent istiophorid species and found generic differences in overall proportions. Fierstine (1998, 2001) found specific differences among three isolated skull bones (articular, maxilla, and parasphenoid) of Recent and fossil istiophorids, but those features are not preserved in the fossils from the San José del Cabo Basin. Identification of the skull is based on overall size and its possible attachment to one of the rostra (IGM 7888).

**Pterygiophore.**—Potthoff et al. (1986:672, fig. 14) described the development of pterygiophores in the anal and dorsal fins of istiophorids, but we are not aware of any published morphological accounts of individual pterygiophores in the adult Istiophoridae. Identification of the partial pterygiophore (IGM 7894) from San José del Cabo Basin (Fig. 3) is based on comparison with pterygiophores in the dorsal and anal fins of three Recent istiophorids, LACM 46023-1 (M. nigricansi), LACM 25509 (M. indica), and LACM 25499 (T. angustirostris).

**Regional Geology**

The Buena Vista-San José del Cabo Basin is located near the southern end of the Baja California Peninsula between the Sierra La Laguna and Sierra La Trin­idad mountain ranges (Fig. 4). Both ranges are composed of crystalline and metamorphic rocks. Based on evidence from fission-track thermochronology, Fletcher et al. (2000) suggested that the uplift of the Sierra La Laguna Mountains along the San José del Cabo fault started approximately 10–12 Ma. The basin covers approximately 2,000 km² and contains both terrestrial and marine strata that range in age from early middle Miocene to Recent (McCloy 1984; Martínez-Gutiérrez and Sethi 1997). Martínez-Gutiérrez and Sethi (1997) considered the basin to have formed in association with the opening of the Gulf of California and formation of the Baja California Peninsula, and proposed a general model for its evolution. The sedimentary rocks of the basin filling are mainly dipping to the southwest or west, and for this reason the oldest sedimentary rocks are exposed along the eastern margin of the basin, becoming younger to the southwest and west. The presence of faults complicates this general picture.

The Calera Formation (Fig. 5) is the oldest sedimentary and non-marine unit in the basin (Martínez-Gutiérrez and Sethi 1997), and is composed of sandstones and conglomerates deposited in an alluvial fan environment. Its age is uncertain due to the lack of fossils, but McCloy (1984) assigned an age of no younger than middle Miocene, and Martínez-Gutiérrez and Sethi (1997) considered the beds to be middle Miocene to late Miocene, an age range that essentially agrees with the fission-track data of Fletcher et al. (2000), if the basin began to fill with deposits soon after uplift of the Sierra La Laguna Mountains. The superposed Trinidad Formation (Fig. 5) was deposited in a nearshore to basinal marine setting during the middle Miocene to upper Pliocene (see discussion below). The marine Refugio
Formation (Fig. 5) overlies the Trinidad Formation and the contact between them is transitional as well as erosional (Martínez-Gutiérrez and Sethi 1997). The Refugio Formation is composed of siltstones, sandstones, and limestones. Many sandstones are cross-bedded and fossiliferous, indicating nearshore depositional settings. McCloy (1984) suggested a late Pliocene age for the Refugio Formation, whereas Smith (1991) and Martínez-Gutiérrez and Sethi (1997) considered it to be early Pliocene.

The Trinidad Formation

The Trinidad Formation is the oldest marine stratigraphic unit in the Buena Vista-San José del Cabo basin. McCloy (1984) estimated its thickness to be between 700 and 1000 m, whereas Martínez-Gutiérrez and Sethi (1997) estimated its thickness at 400 m. McCloy (1984) informally divided the formation into four lithologic subunits (A to D). Subunit A is generally a sequence that grades upward from course to fine and is composed of cross-bedded or planar-bedded sandstone, siltstones, and fissile and laminated shales. These beds may have alternating tan to buff siltstones and gray shales with sandstone intercalations. Fossils (mainly mollusks) are common and McCloy (1984) interpreted the unit as inner to outer
shelf deposits. Subunit A is well-exposed around Rancho Lengua de Buey (N 23°
20.318', W 109° 33.910'). Subunit B, a succession of sandstone, siltstone, and
alternating beds of sandstone and mudstone, is related to an outermost shelf to
upper shelf depositional environment. Sedimentary structures (graded beds, cross-
bedding) indicate traction and downslope transport of sandy sediments (McCloy
1984). We found outcrops of this unit at Rancho El Bosque (N 23° 20.53', W
109° 36.378'). Subunit C is a succession of mudstones, diatomaceous shales, and
diatomite that displays a transitional or marked rhythmic cyclicity often with fine
laminae. McCloy (1984) and Carreno (1992) found massive diatomites in the
central part of the basin, and McCloy (1984) proposed that they were deposited
in a partially aerated to anoxic environment. We found good outcrops of subunit
C in Cañada del Enmedio. Subunit D consists of greenish, laminated, non-bio-
turbated, clayey siltstones that grade upward into massive to cross-bedded bio-
turbated, fossiliferous sandstones. McCloy (1984) suggested these sediments were
deposited in an outer shelf environment. Subunit D is well-exposed near Rancho
La Calabaza (N 23° 20.71', W 109° 38.252').

Martínez-Gutiérrez and Sethi (1997) subdivided the Trinidad Formation into
three vertically stacked lithofacies. The basal facies is approximately equivalent
to McCloy’s (1984) subunit A and was interpreted as representing nearshore to
lagoonal, brackish-marine deposits. The middle facies is equivalent to McCloy’s
subunits B and C, and was interpreted as having been deposited in “shelf depths
slightly greater than that of normal wave base” (Martínez-Gutiérrez and Sethi
1997). We believe the middle facies was deposited in much deeper water that was
influenced initially by turbidity currents (subunit B). The presence of non-biotur-
bated diatomaceous sediments in subunit C indicates a low sedimentation rate in
a basinal setting. The upper facies corresponds to McCloy’s (1984) subunit D,
and Martínez-Gutiérrez and Sethi (1997) suggested that it was deposited in a high
energy, shallow marine depositional environment, an interpretation that is consis-
tent with our observations.

The Trinidad Formation has been assigned different ages. McCloy (1984) con-
sidered it to span middle Miocene to late Pliocene. She gave a late Pliocene age
for subunit C based on microfossils. Carreno (1992) demonstrated an uppermost
Miocene/early Pliocene to middle Pliocene age for beds exposed near the town
of Santiago that approximately correspond to McCloy’s subunits B and C. How-
ever, according to Berggren et al. (1995), the microfossils reported by Carreno
extend into the late Pliocene. In contrast, Martínez-Gutiérrez and Sethi (1997)
suggested an age from late Miocene to early Pliocene, but did not present new
evidence for their conclusion. In conclusion, the total stratigraphic range for the
Trinidad Formation probably spans from middle Miocene to upper Pliocene.

The billfish fossils described herein were recovered from several localities.
Locality IGM 95 (N 23° 20.400', W 109° 36.931') is located in a westward
dipping sequence, known informally as La Angostura, that is exposed west of
Rancho El Bosque (Fig. 4). It consists of 40 m of diatomaceous mudstone and
clayey siltstone that probably correspond to McCloy’s (1984) subunit C. In the
upper part of the outcrop there are abundant large, yellow-weathering limestone
concretions that contain the billfish fossils that we report here.

Locality IGM 240 (N 23° 20.550', W 109° 39.537') is located in a westward
dipping sequence that is exposed in Cañada del Enmedio (Fig. 4). A 55 m thick
stratigraphic section contains diatomaceous mudstone at its base and is transitional upward to clayey siltstone and then to siltstone at the top. These beds mark the transition between McCloy’s (1984) subunits C and D. The upper part of this stratigraphic section has yellow-weathering concretions some of which contain remains of fossil billfish similar to those collected at locality IG 95.

Other fossil localities are located in the area around Rancho Algodones (N 23° 13.200’, W 109° 38.450’) (Fig. 4). Locality IGM 92 (Los Algodones) includes exposures distributed southwest of the ranch. Locality IGM 93 (Los Dientes Grandes) is situated about 1 km southwest of the ranch, and corresponds to locality BCS-7 of Espinosa-Arrubarrena (1979). Barnes (1998) reported that locality IGM 92 has yielded the remains of mysticete and odontocete whales, and locality IGM 93 has yielded mysticete whales and a possible odobenine walrus. The rocks exposed in this region have been reported as Refugio Formation (formerly called Salada Formation) by Espinosa-Arrubarrena (1979), Espinosa-Arrubarrena and Applegate (1981), and Barnes (1998), but for reasons given below, we now believe they are part of the Trinidad Formation. The geologic map of Martínez-Gutiérrez and Sethi (1997:figs. 2, 11) only shows the Refugio Formation in this region although a stratigraphic section made near the ranch includes the Trinidad Formation in its lower part. In our field work we noted that the strata in this area generally dip 10–20°W. There are no major faults. The ranch rests on beds of the lower or lower middle Trinidad Formation and lithologic features exposed near the ranch fit subunit B of McCloy (1984). Topographically higher areas are partly covered by Pleistocene terrace deposits that earlier workers might have confused with the Refugio Formation. East of the Rancho Algodones the Trinidad Formation disconformably overlies granitic basement rocks. The gradational contact with the superposed Refugio Formation is well exposed 2 km to the west and southwest of the ranch and, because of the striking lithologic differences between the two formations, the Refugio and Trinidad Formations are easily separated in the field. The general lithology of the Trinidad Formation, dominated by greenish shale and siltstone, agrees with differences noted in the more northerly areas. However, we did not observe the diatomites that are typically found in the middle part of the formation.

Espinosa-Arrubarrena (1979) and Espinosa-Arrubarrena and Applegate (1981) suggested a late Pliocene age for the selachian fauna of locality IGM 92 (Los Algodones) based on the stratigraphic ranges of the shark species, and a similarity between the invertebrate fauna that was collected at Espinosa-Arrubarrena’s locality BCS-43 and faunas in the Imperial Formation in California and the San Marcos Formation near Santa Rosalía, Baja California. However, the Imperial Formation is now thought to range from the late Miocene to late Pliocene in age (McDougall et al. 1999) and the San Marcos Formation is now known to be late Miocene based on radiometric data (Smith, 1991). The selachian fauna by itself offers little help in determining the exact age of the Trinidad Formation in the Los Algodones area because it includes species that range from the late Miocene and Pliocene to Recent (Espinosa-Arrubarrena 1979; Espinosa-Arrubarrena and Applegate 1981:table 1).

In conclusion, the fossils described below came from the middle to upper part of the Trinidad Formation, probably corresponding to McCloy’s (1984) subunits B and C. We can not give a precise age, but believe the age for these subunits
in our study area to be late Miocene to late Pliocene. The specimens probably settled to the bottom in a poorly oxygenated environment that lacked bottom currents.

Systematic Paleontology
Class Actinopterygii (sensu Nelson, 1994)
Division Teleostei (sensu Nelson, 1994)
Order Perciformes (sensu Johnson and Patterson, 1993)
Suborder Scombroidei (sensu Carpenter et al., 1995)
Family Istiophoridae (sensu Robins and deSylva, 1960)
Istiophoridae, genus and species indet.
Figs. 3A–D

Specimens.—Locality IGM 92: numerous fragments of a large rostrum, uncatalogued; partial pterygiophore (?dorsal fin), IGM 7894. Locality IGM 95: three predentaries, IGM 7885–7887; two median fin spine fragments, IGM 7890–7891; pectoral fin spine fragment, IGM 7892. IGM 240: distal rostral fragments, uncatalogued.

Discussion.—These bones are too fragmentary to be positively identified to genus, however, the rostra, pterygiophore, fin spines, and two predentaries are from fish of large size, a factor that favors their identification as belonging to the genus *Makaira* or *Tetrapturus audax*, and not to the genus *Istiophorus* nor to *T. albidus*, *T. angustirostris*, *T. belone*, or *T. pfluegeri*. The pterygiophore is a distal fragment. Its shield-like shape, the stellate pattern on its anterior and posterior surfaces for articulation with the pterygiophore anterior and posterior to it, and the broad articular surface for the fin spine, are characteristic features of a pterygiophore from the anterior part of the dorsal or anal fin in the Istiophoridae. It is similar in morphology to the pterygiophore that supports the 3rd or 4th dorsal spine, but because of a lack of comparative skeletal material, we can not eliminate the possibility it supported an anal spine. The uncatalogued specimens from localities IGM 92 and IGM 240 were examined by one of us (HLF) in 1984, but subsequently were discarded, lost, or misplaced before they could be accessioned by IGM.

*Genus Makaira* Lacépède, 1802
*Makaira* sp., cf. *M. nigricans* Lacépède, 1802
Figures 3E, F

Specimens.—Locality IGM 95: distal rostrum, IGM 7883.

Discussion.—Although two ratios (D/W and DD/D) fall only within the observed range of values computed for *M. nigricans* and not within the range of any other Recent istiophorid (Table 1), the rostrum was not positively identified as belonging to *M. nigricans*. The dorsal surface of the rostrum was completely covered with denticles, yielding a very large DZ/W value, a feature unknown in any Recent or fossil *M. nigricans* (Fierstine 1999: Tables 2, 3).

*Makaira nigricans* Lacépède, 1802
Figures 2A–F

Specimens.—Locality IGM 93: distal rostrum, IGM 7893. Locality IG 95: two distal rostra, IGM 7882, 7884; proximal rostrum, IGM 7888; partial skull, IGM 7889.
**Table 1.** Stratigraphic column of beds near Rancho Algodones, San José del Cabo Basin, Baja California Sur, México.

**Fig. 5.** Stratigraphic column of beds near Rancho Algodones, San José del Cabo Basin, Baja California Sur, México.

**Discussion.**—All ratios (Table 1) computed for the above rostra are within the range of values observed for Recent *M. nigricans* with one exception, ratio IC/W for IGM 7888. Specimen IGM 7888 was identified as belonging to *M. nigricans* for two reasons: 1) ratio IC/W is not within the observed range of values of any fossil or Recent istiophorid, but is closest to the value of Recent *M. nigricans* (Fierstine 1999: Tables 2, 3), and 2) ratio DD/D is only within the
observed range of Recent *M. nigricans*. The partial skull (IGM 7889) has no osteological feature that is diagnostic of *M. nigricans*, however, its identification is based on our belief that both rostrum IGM 7888 and the skull are from the same individual. The skull and rostrum belong to a similar-sized fish and both were encased in a sandy matrix that contained small veins of calcite.

The partial skull is a fully articulated unit from mid-orbit to the base of the rostrum and it has an overall length of 308 mm and a posterior width of 245 mm. The left side is more complete than the right side. The neurocranium contains the anterior-most part of the frontals, lateral ethmoids, nasals, and posterior parts of the prenals. The olfactory foramen of the lateral ethmoid is visible in the nasal fossa. The thin portion of the frontals that covers the pineal apparatus (Rivas 1953) on the mid-dorsal surface of the skull is not preserved and the pineal fossa is exposed. The left orbit contains the anterior half of the sclerotic.

The maxillary segment contains its anterior articulation with the prenasal, dorsal articulation with the lacrimal, and ventral articulation with the premaxilla. The lower jaw contains the entire articular-dentary suture. Denticles are visible on both the dentary and premaxilla.

Both the dorsal-ventral diameter (115 mm) of the sclerotic (IGM 7889) and the width of the skull (IGM 7889) across the lateral ethmoids (248 mm) are approximately 1.4 times greater than similar measurements of a 181 kg Recent *M. nigricans* (LACM 46023-1). Assuming that IGM 7889 came from a specimen with a length (tip of bill to fork of caudal fin) that was 1.4 times longer than LACM 46023-1 (3280 mm), then the skull (IGM 7889) and rostrum (IGM 7888) probably are remains of a fish larger than 500 kg, based on the length-weight curve published in Strasburg (1969). Individuals of Recent *M. nigricans* that are larger than 160 kg are always females (Hopper 1986:60).

Discussion and Conclusions

The presence of *M. nigricans* in a marine upper Miocene or Pliocene deposit in Baja California Sur is not surprising because it has been the most common billfish identified in Neogene deposits bordering the eastern North Pacific Ocean from southern California to Panama (Fierstine and Applegate 1968; Fierstine and Welton 1988; Fierstine, 1999), and it is commonly caught off Cabo San Lucas, Baja California Sur today. What is surprising is that no species of billfish other than *M. nigricans* has been positively identified in fossil deposits bordering the eastern North Pacific even though other Recent istiophorids (especially *I. platypterus* and *M. indica*, and *T. audax*) now inhabit the same waters at least during part of the year [Gottfried (1982) identified *I. platypterus* in the upper Pliocene San Diego Formation based on a fragmentary vertebra, but after examination of the specimen we believe it should be identified as Istiophoridae genus and species indeterminate]. Perhaps the absence of other istiophorids as fossils in the eastern North Pacific realm is due in part to our inability to accurately identify billfish from partial remains. Identifications are based primarily on comparing rostral fragments with complete rostra from Recent fish where emphasis is placed on cross-sectional morphology at 0.25L and 0.5L, two areas that must be estimated in fossil fragments. Fierstine and Voigt (1996) noted another limitation in their statistical study of rostra of Recent billfish; the lack of large-sized *M. nigricans* and *M. indica*. Species identifications of Recent billfish from vertebrae and other
bones are based on small sample sizes as well (Fierstine 1998, 2001) and in most cases have not proven to be diagnostic (except for the predentary).

As noted above, Martínez-Gutiérrez and Sethi (1997) concluded that the middle facies (subunits B and C) of the Trinidad Formation were deposited in "shelf depths slightly greater than normal wave base", but that we concluded that the middle facies was deposited in much deeper water based on type of sediments. Because *M. nigricans* favors depths of over 100 m (Nakamura 1983, 1985), its presence in the Trinidad Formation supports a greater water depth and more open-ocean environment, assuming that fossil and Recent blue marlin have similar ecological preferences. Two of the specimens, a predentary (IGM 7885) and a rostral fragment (IGM 7893), are badly eroded (possibly by stomach acid) and may have been transported into the San José del Cabo Basin as stomach contents of a more shallow-dwelling animal.

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Literature Cited


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