Santa Monica Mountains National Recreation Area Paleontological Survey

Alison L. Koch, Vincent L. Santucci, and Ted R. Weasma

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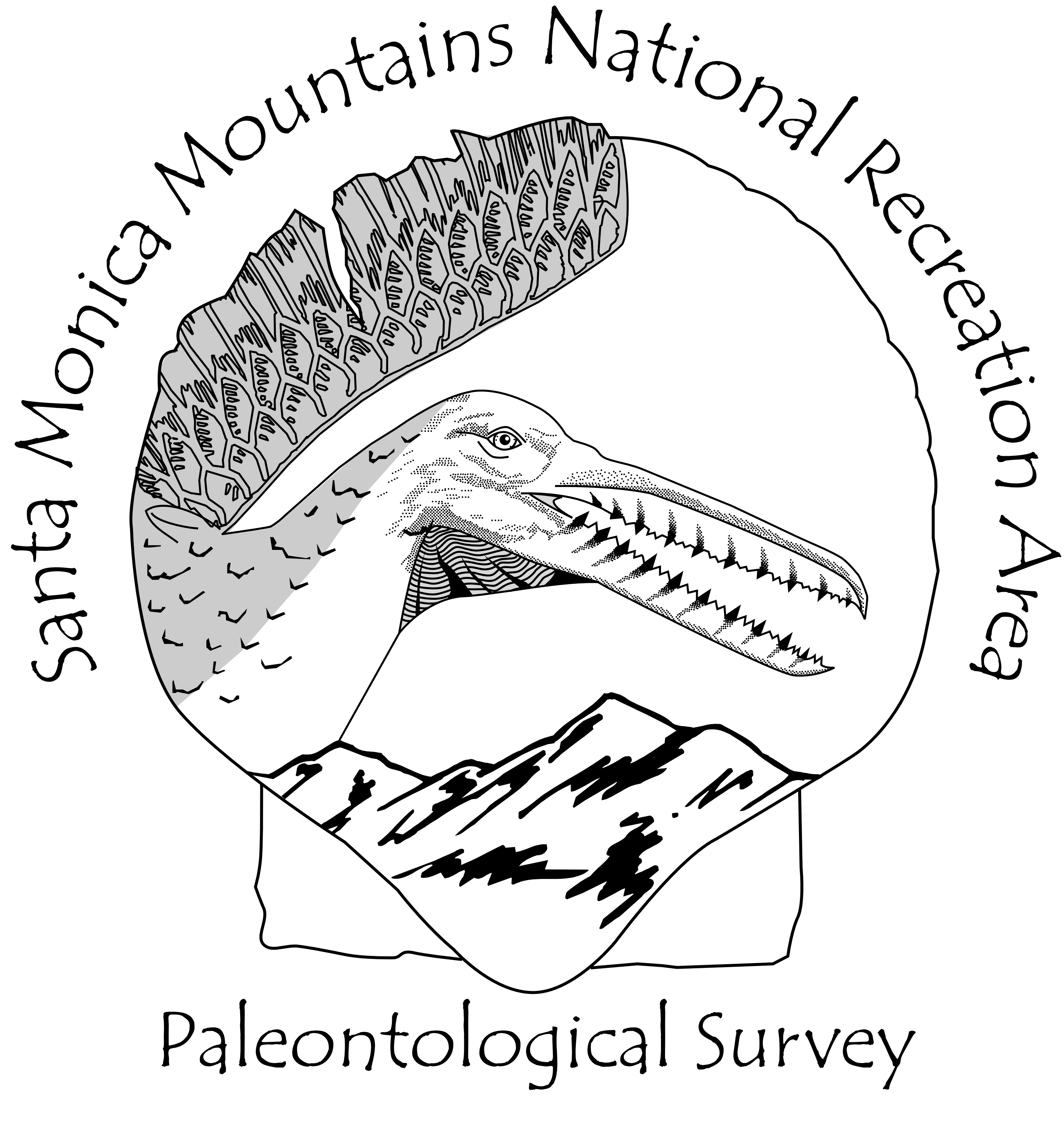

United States Department of the Interior - National Park Service - Geologic Resources Division

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Dedicated to Norma Agusta Steiner and Margaret Llewellyn Koch

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INTRODUCTION

The large number and wide variety of fossils found throughout Santa Monica Mountains National Recreation Area (SAMO) contribute to one of the richest fossil areas preserved within the National Park Service. This project represents the fourth park-specific comprehensive paleontological resource inventory in the National Park Service, following Yellowstone National Park, Death Valley National Park, and Arches National Park. SAMO has been widely known to contain significant paleontological resources; however, this survey has expanded our understanding of just how rich and diverse the fossils from the park are.

Santa Monica Mountains National Recreation Area was established in 1978 to preserve a portion of the rugged mountains, a coastline with sandy beaches and rocky shores, and chaparral canyons.

The park encompasses an area with a myriad of different landowners and jurisdictions (Figure 1). The national recreation area includes a total of 150,050 acres, with 21,500 discontinuous acres directly controlled by the National Park Service. Therefore, SAMO management consistently considers the actions of neighboring landowners. Currently, the largest landowner within the SAMO boundary is the California State Parks with 42,000 acres. Approximately 6,000 acres of private recreation and local public parkland exist, and once acquisitions are complete, a total of 50,000 acres will reside in private ownership. In addition to multiple landowners, over 70 governmental entities share jurisdiction within the SAMO boundary, including the city of Malibu. This report summarizes data on the known paleontological resources from all the lands within the over-arching boundary (150, 050 acres) of the Santa Monica Mountains National Recreation Area. This is necessary as the fossil resources are found throughout the area and resource impacts, such as non-permitted collecting and erosion, are occurring regardless of the land ownership.

Significance of Paleontological Resources

Santa Monica Mountains National Recreation Area contains one of the most extensive and diverse assemblages of fossil material known in the National Park Service. There are at least 2,300 known fossil localities, representing over a dozen fossiliferous geologic formations. Invertebrate, vertebrate, paleobotanical, protista, and trace fossils occur, ranging in age from the Late Jurassic to Pleistocene. The diversity of the fauna, both marine and terrestrial, is extraordinary with many new species named from the Santa Monica Mountains. The quality of preservation is remarkable in many specimens, especially the fully articulated skeletons of fossil fish that can be compared to the caliber of the world- famous Eocene Green River Formation fossil fish from Wyoming, Utah, and Colorado.

SAMO has the opportunity to assess fossil flora and fauna with the modern in neighboring locations. For example, many of the fossils are marine and can be compared with the modern ocean system. This provides a wealth of exciting interpretive prospects.

Additionally, the fossils from SAMO have historical and cultural significance. The local community has roots in fossil collecting since the turn of the 20th century, with many adults maintaining their enthusiasm for fossils from childhood visits to localities in the Santa Monica Mountains.

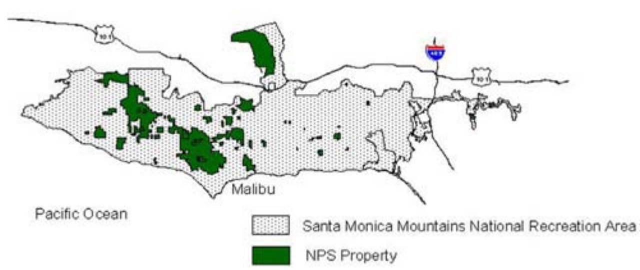

Figure 1. Location Map of the Santa Monica Mountains National Recreation Area.

Historical Background

One of the earliest accounts of paleontological research within the Santa Monica Mountains is a 1907 article in the Proceedings of the U. S. National Museum by Ralph Arnold, a U. S. Geological Survey paleontologist. Marine invertebrate species lists from Topanga and Temescal Canyons were included in his publication. Although no longer valid practice, Arnold indicated the importance of the local fossils when he stated that, "the differentiation of the various geologic formations in the southern Coast Ranges of California depends almost entirely upon their paleontology..."

Charles Waring described many new invertebrate species in a 1917 report that focused on localities within the Martinez, Tejon, and Chico Formations.

Loye Holmes Miller described bird material from the Santa Monica Mountains area in the 1920s. A Pleistocene diving goose, *Chendytes*, and a new Miocene cormorant were the topics of study (Miller, 1925 and 1929).

H. W. Hoots, U. S. Geological Survey, described the geology of the eastern Santa Monica Mountains (1930). During this project, Hoots, with help from W. P. Woodring, made mention of numerous fossils, the localities, and also made collections. This report is still one of the most comprehensive documents regarding the paleontology of the Santa Monica Mountains.

Grant and Hertlein (1938) studied the echinoids of Cenozoic Western America, Compton (1944) focused on Paleocene gastropods from southern California, and Popenoe (1954 and 1973) researched a variety of Mesozoic invertebrates from southern California.

Both Cretaceous and Tertiary fossil fishes were the topic of study for French paleontologist Lore Rose David (1939, 1941, 1943, and 1948; David and Stock, 1939). She reported on a number of localities within the current Santa Monica Mountains National Recreation Area boundary and hundreds of her specimens are held at the Natural History Museum of Los Angeles County.

Takeo Susuki researched the stratigraphic paleontology of the Topanga Formation for his UCLA Master's Thesis (1951) and published some of the work in a Geologic Society of America abstract (1952) and in a Topanga Canyon Historical Society book (1992). Susuki's extensive collections are housed at the Natural History Museum of Los Angeles County.

Richard Pierce, in association with the Richfield Oil Corporation, reported on Miocene foraminifera and fishes from the Benedict Canyon in the eastern Santa Monica Mountains. This 1956 report focuses on analyzing many of the fish scales that were originally collected in 1943 by Tom Baldwin, a senior geologist with the Monterey Oil Company.

Tatsuro Matsumoto (1959) reported on the Upper Cretaceous ammonites of California, including a spectacular specimen from the Santa Monica Mountains.

Figure 2. Avian Paleontologist, Dr. Hildegarde Howard, analyzing fossil bird collections in 1939. Photo courtesy of the Natural History Museum of Los Angeles County Museum Archives.

The Cretaceous *Eupachydiscus lamberti* is an extraordinarily large ammonite (approximately 2ft. x 1.5ft.) collected from the Tuna Canyon Formation in Santa Ynez Canyon. The specimen is currently housed at the Natural History Museum of Los Angeles County (see Figure 5).

Marine mammals (Sirenia and Desmostylia) from the Santa Monica Mountains region were studied by Roy Reinhart in 1959 and again by Mitchell in 1963.

A variety of Miocene seabirds were the focus of Hildegarde Howard's work in the late 1950s and early 1960s (see Figure 2). Most notable is the publication related to the second record of the Miocene "toothed" bird, *Osteodontornis* (Howard and White, 1962). This bird had a 15-foot wingspan and large bony "teeth" in the upper and lower jaws. Howard's collections are stored at the Natural History Museum of Los Angeles County.

Ralph Imlay (1963) remarked upon the Jurassic invertebrate fossils from the Santa Monica Slate near Mandeville Canyon.

W. O. Addicott (1964), U. S. Geological Survey in Menlo Park, California, studied the Pleistocene invertebrates from the Dume terrace, approximately 2 miles from Point Dume. These fossil invertebrates included gastropods, bivalves, echinoderms, and crustaceans.

Further work on fossil fish from the area was conducted by Jules Crane (1966) in a study of viperfish radiation, comparing Recent and Miocene species. Additionally, a report on the fish family Moridae was written by John Fitch and Lloyd Barker (1972).

Lawrence Barnes (1977 and 1985) researched cetacean assemblages, including a report on the late Miocene dolphin *Pithanodelphis*.

Yerkes and Campbell (1979 and 1980), U.S. Geological Survey scientists, discovered fossils while conducting geologic mapping projects in the Santa Monica Mountains. Many of these fossil localities were marked on their geologic maps. The most recent geologic map (1994) by Yerkes, Campbell, and Alderson covers the Topanga Quadrangle.

Ronald Fritzsche (1980) discussed both Recent and fossil forms of the eastern Pacific fish family Syngnathidae, which includes seahorses and pipefishes.

Fossil mammals gained attention in the Santa Monica Mountains area in the late 1980s from Hutchison (1987) and Jefferson (1989). Hutchison reported on Pliocene and Pleistocene moles and Jefferson described Late Cenozoic tapirs.

Comprehensive mapping and compilations of geologic mapping of the Santa Monica Mountains, including identification of fossil localities, has been published by the Dibblee Foundation (Dibblee, 1991a, 1991b, 1991c, 1991d, 1992a, 1992b, 1992c, 1992d, and 1993; Dibblee and Ehrenspeck, 1990a, 1990b, 1992, 1993a, and 1993b).

Carol Stadum and Peter Weigand (1999) reported on fossil wood from the Miocene Conejo Volcanics within the Santa Monica Mountains. During this work, fossil coniferous and dicotyledonous woods were collected and later identified by thin-section analysis. Additionally, this report is the first record of fossil trees in a tuff breccia from the Los Angeles basin region.

LouElla Saul, now a Research Associate at the Natural History Museum of Los Angeles County Invertebrate Paleontology, has conducted extensive research in the Santa Monica Mountains. Reports have been published on Cretaceous bivalves from the Pacific (Saul, 1978; and Saul and Popenoe, 1992), as well as on Paleogene molluscan faunal sequences (Saul, 1983a and 1983b).

Richard Squires, currently at California State University, Northridge, has worked extensively on the invertebrate fauna of the Santa Monica Mountains. Since the 1980s, Squires has researched and published primarily on Cretaceous, Paleocene, and Eocene gastropods and Paleocene crabs and bivalves (1980, 1990, and 1993; Squires and Kennedy, 1998). Squires and Saul have also co-written many articles relating to the invertebrate fauna of the Santa Monica Mountains (1998, 2000, 2001, and 2002).

Lindsey Groves, Natural History Museum of Los Angeles County, Malacology Collection Manager described the only cowry specimen (Family Cypraeidae) from the Topanga Formation in 1994 and is currently working with John Alderson and LouElla Saul on Late Cretaceous abalone specimens from Topanga Canyon.

John Alderson, Research Associate at the Natural History Museum of Los Angeles County Invertebrate Paleontology section, has worked extensively in the Santa Monica Mountains, investigating the geology and paleontology of the area. Detailed geologic maps and age assignments (1988), as well as many significant fossil discoveries, have resulted from Alderson's research. Alderson has been a co-author on numerous articles involving Cretaceous mollusks and Oligocene to Miocene land plants, land mammals, continental vertebrates, and marine invertebrates (Saul and Alderson, 2001; Fisk, et al., 2001; Lander, et al., 2001, 2003; and Shapiro, et al., 2001a, 2001b).

Administrative History

Scope of Collections (1996)

This document is currently being revised to further incorporate the significance of SAMO's fossil resources.

Draft Comprehensive Design Plan, Simi Hills, Environmental Assessment (1996)

Five paleontological resource localities are described in a cultural resource section, and the potential to discover additional localities is also mentioned.

Calabasas Landfill Special Use Permit, Environmental Assessment (1997)

Although included in the cultural resource section, this assessment notes a study area with a description of the geologic units and associated fossils.

Water Resources Management Plan (1997)

This plan briefly mentions fossils in two of the geologic units that are described.

Land Protection Plan (1998)

There is no mention of paleontological resources.

Resource Management Plan (1998)

Paleontological resources are included in the Natural Resource Descriptions, Baseline Information, and Collections sections of the Resource Management Plan.

Museum Management Plan (1999)

This plan includes paleontological resources and outlines the reasoning for housing collections.

General Management Plan (2002)

Fossils are included in the geology sections of the plan. Additionally, from the Analysis of Impacts section, the plan states, "Mitigation measures for impacts to non-renewable paleontologic resources are directed at recovering the scientific data and educational values that have been recognized as constituting the intrinsic properties that make the resources important."

Fire Management Plan (2003)
The Environmental Impact Statement that accompanies the Fire Management Plan considers paleontological resources and discusses the threshold criteria of varying impacts.

Draft Long - Range Interpretive Plan (2004)
Paleontological sites and fossils are briefly mentioned; however, they are included in a cultural resources section.

Trail Management Plan
The Trail Management Plan will be drafted over the next year along with the associated compliance documents: Environmental Impact Statement and Environmental Impact Report. These documents will include environmental analysis of potential paleontological resource impacts.

GEOLOGY

Geologic History

The Santa Monica Mountains are the southcentral mountain chain in the Transverse Ranges of southern California (Figure 3). There has been periodic uplift in the area since the Oligocene collision of the Pacific Plate and the North American Plate. However, the mountain building of the Santa Monica Mountains ocurred in the last few million years, due to north -south compression from plate movement. As a result, complex geologic structures of folding and faulting characterize these east -west -trending mountains.

Thick marine sedimentary sequences of sandstone, siltstone, and mudstone, as well as volcanic deposits, primarily compose the rocks found within the Santa Monica Mountains (Figure 4). Although less abundant, terrestrial deposits also exist. The rocks exposed in the mountains range in age from the Jurassic to the Quaternary. There is variation in stratigraphic nomenclature when characterizing Santa Monica Mountains geology. This report will not attempt to resolve differences or choose preferential terminology, but rather gather information on and summarize the pertinent stratigraphic units.

The Jurassic Santa Monica Slate is only found toward the eastern boundary of SAMO. Rocks are exposed in and around the areas of Topanga State Park, Mission Canyon, and Encino Reservoir.

Cretaceous deposits are found in various areas within SAMO. Significant exposures are known in the vicinity of Topanga State Park, Ahmanson Ranch, Cheeseboro Canyon, Palo Camado Canyon, and Tuna Canyon, as well as in Malibu and inland from Point Dume.

Paleocene rocks are found within a few areas of the park, including Ahmanson Ranch, Topanga State Park, Tuna Canyon, Malibu, and Trancas Canyon.

The region of Malibu Creek State Park and Trancas Canyon contain exposures of the Eocene Llajas Formation.

Oligocene to Miocene deposits can be found in Malibu, Malibu Creek State Park, Zuma Canyon, and Trancas Canyon. Additionally, the Sespe Formation can be found in the Red Rock Canyon and Topanga State Park areas, and the Vaqueros Formation is also in Point Mugu State Park.

The Miocene Topanga stratigraphic unit is the most common and extensive geologic unit within SAMO. These varied deposits can be found in most areas of the national recreation area. Other Miocene rocks are known from Point Dume and Malibu. In addition, the Modelo Formation is widely exposed in the northern and north - eastern areas of SAMO.

Pliocene deposits are found only in the Pacific Palisades area of the park.

Lastly, the more recent Quaternary deposits are found in small exposures scattered throughout the Santa Monica Mountains.

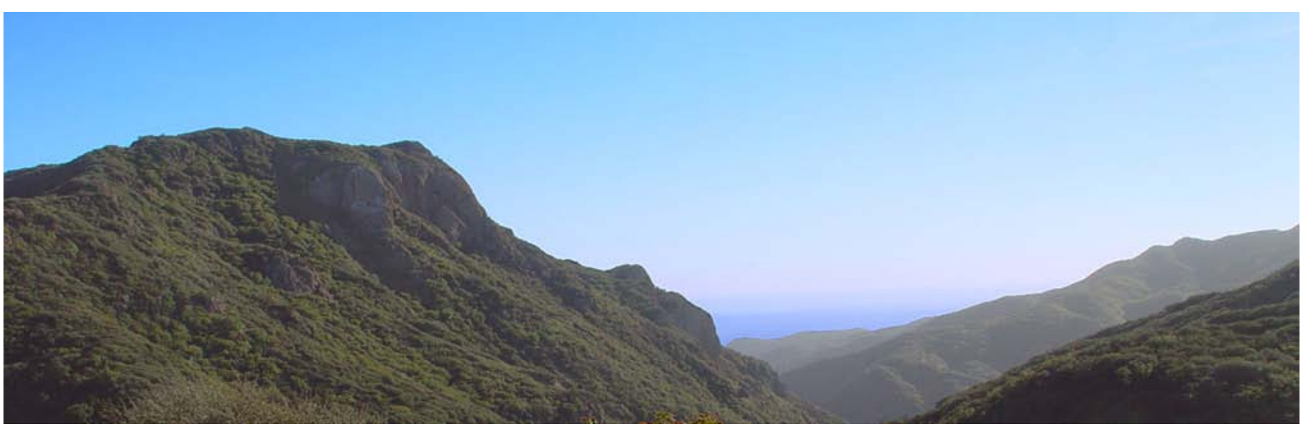

Figure 3. Scenic view of the Santa Monica Mountains. Photo by Alison Koch.

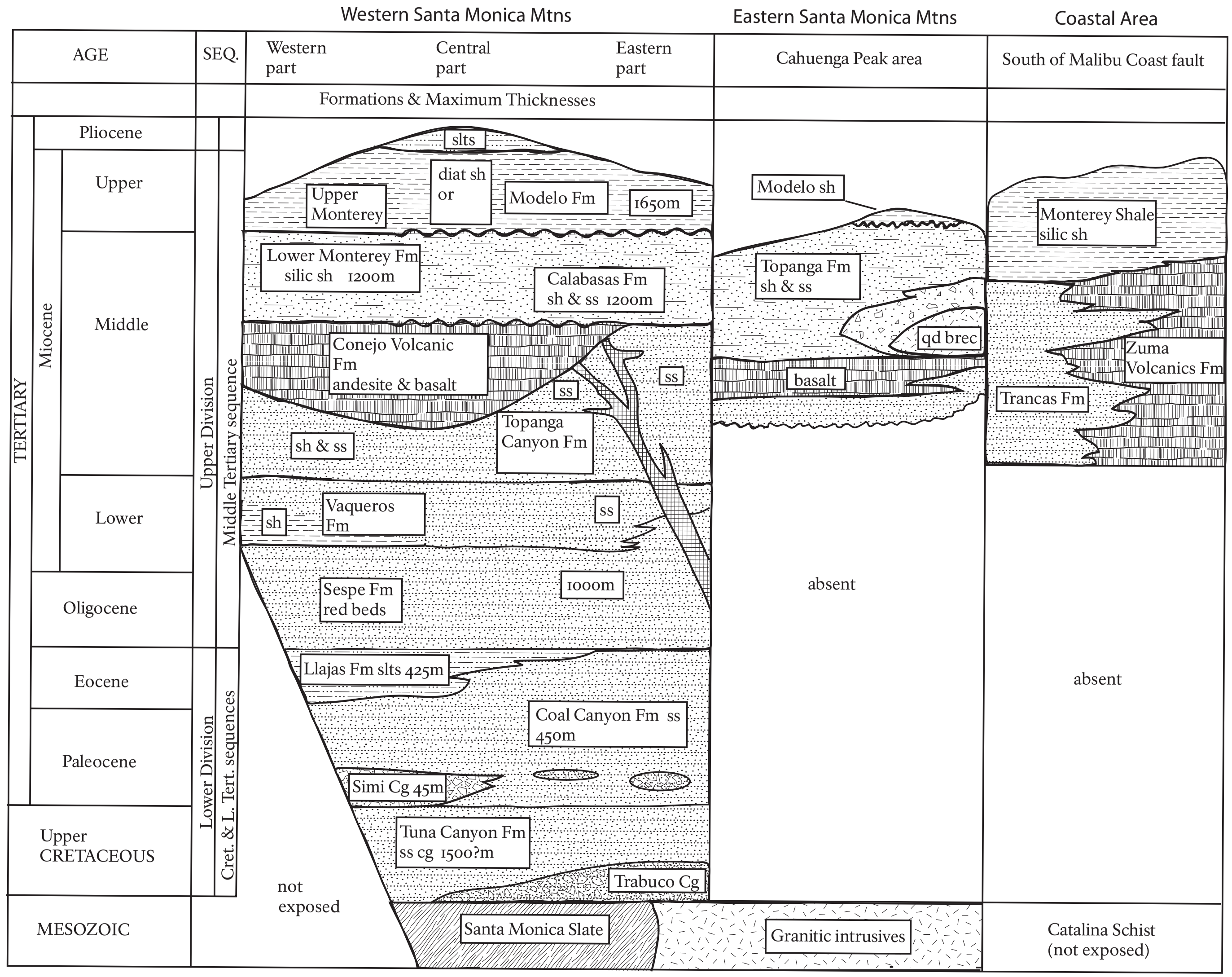

Figure 4. Stratigraphic column for the Santa Monica Mountains, showing some of the rock formation names (no preference intended) that have been used (recreated from Dibblee, 1982).

Fossiliferous Rock Formations

Late Jurassic: Santa Monica Slate
Lithology: Dark-gray and bluish-gray-to-black slate, well-developed slaty cleavage, fissile nature, and abundant jointing. Altered areas due to contact metamorphism.
Fossils: Imlay (1963) reported "Jurassic fossils from the Santa Monica Slate were discovered recently by C. E. Corbató and Barry Raleigh of the University of California at Los Angeles near Mandeville Canyon...". There is mention of the fossils resembling the pelecypod *Buchia*.

Cretaceous: Tuna Canyon Formation and/or Chatsworth Formation and/or Chico Formation
Lithology: Marine sequence of sandstone, siltstone, and conglomerate, ranging in color from olive-gray to grayish-red (Yerkes and Campbell, 1979). Light-gray to brown, medium-grained micaceous sandstones with thinly bedded siltstones. Gray metavolcanic and granitic cobble conglomerate and gray clay shales with weathered ellipsoidal fractures. In Topanga, Santa Ynez, and Temescal Canyons, exposures are hard, massive, coarse brown conglomerates with associated dark gray shale and hard gray sandstone, which can be highly fossiliferous.
Fossils: Abundant fossil mollusks, including the age-diagnostic ammonite species *Metaplacenticeras pacificum*. Although less common, microfossils of foraminifera exist (Yerkes and Campbell, 1979). Hoots (1930) reported on approximately 30 different species from localities within the undivided Chico and Martinez formations.

Paleocene: Coal Canyon Formation and/or Santa Susana Formation and/or Martinez Formation
Lithology: Marine sequence of sandstone, pebble conglomerate, and siltstone. Basal cobble conglomerate member including thin red clay lenses. White algal limestone beds, shales with intercalated sandstones, some massive beds of poorly sorted arkosic sandstone and conglomerate.
Fossils: Abundant mollusks and foraminifera (Yerkes and Campbell, 1979). Calcareous lenses with the gastropod *Turritella pachecoensis* (Dibblee, 1993; Dibblee and Ehrenspeck, 1993a).

Eocene: Llajas Formation
Lithology: Gray micaceous claystones and siltstones; some brown sandstone beds; and granitic, metavolcanic, and quartz detritus cobble conglomerate.
Fossils: Abundant mollusks, including *Ectinochilus supraplicatus* and *Turritella buwaldana* (Yerkes and Campbell, 1979).

Oligocene to Early Miocene: Sespe Formation
Lithology: Mostly non-marine redbed sequences of sandstone and claystone. Gray-white, tan-to-pink, medium-to-coarse-grained conglomerate.
Fossils: Paleobotanical material (J. Alderson, personal communication, 2003) and fossil land mammals (Lander et al., 2001).

Late Oligocene to Early Miocene: Vaqueros Formation and/or lower part of the Lower Topanga Formation
Lithology: Marine sequence of dark platy or shaly siltstones, medium-to coarse-grained sandstones, and greenish to reddish mudstones (Yerkes and Campbell, 1979).
Fossils: Characteristically contains *Turritella*, as well as other gastropods, bivalves, foraminifera, and fossil wood (Yerkes and Campbell, 1979; and J. Alderson, personal communication, 2003).

Early Miocene: Topanga Canyon Formation and/or upper part of the Lower Topanga Formation
Lithology: Clay shale to siltstone, thick bedded sandstone, conglomerate (Dibblee, 1993).
Fossils: One of the most fossiliferous units within the Santa Monica Mountains. It is well known for marine invertebrates and a plethora of species have been identified from this formation. In 1930, Dr. W. P. Woodring stated that the gastropod *Turritella ocoyana* is the most widespread species in the Topanga Formation. Additionally, foraminifera, plant fragments, bivalves, oysters, gastropods, sand dollars, barnacles, crab claws, invertebrate burrows, algae, fish scales, shark gill-rakers, whale bones, and sea lion bones have been noted (Hoots, 1930; Susuki, 1951; J. Alderson, personal communication, 2003; and Yerkes and Campbell, 1979).

Early Miocene: Conejo Volcanics and/or Middle Topanga Formation
Lithology: Volcaniclastic rocks and extrusive flows of andesite and basalt; conglomerates and breccias. Sequence of sandstone, siltstone, and sedimentary breccia (Yerkes and Campbell, 1979). Clay shale and sandstone (Dibblee, 1993).
Fossils: Sparse fauna (Yerkes and Campbell, 1979) and fossil wood (Stadum and Weigand, 1999) have been found in the volcanics.

Early Miocene: Trancas Formation
Lithology: Sandstones, claystones, shales, and breccia.
Fossils: "...contains a microfauna diagnostic of Saucesian to Luisian age" (Dibblee, 1982).

Middle Miocene: Calabasas Formation and/or Upper Topanga Formation
Lithology: Light gray to tan sandstone, blueschist breccia, clay shale, conglomerate (Dibblee, 1993; Dibblee and Ehrenspeck, 1993a; Yerkes and Campbell, 1979).
Fossils: Foraminifera, molluscan fauna, and fish scales (Yerkes and Cambell, 1979).

Middle to Late Miocene: Modelo Formation and/or Monterey Formation
Lithology: Massive units of coarse gray and brown sandstones, calcareous and siliceous shales, soft white punky diatomaceous shale. Calcareous lenses or concretions that weather to yellow in color.
Fossils: A large diversity of fossils occurs within the formation, including gastropods, bivalves, echinoids, whale bones, sharks teeth, horse remains, well-preserved fish, terrestrial plants, and foraminifera (Hoots, 1930 and David, 1943).

Pliocene: Repetto Formation and/or Pico Formation and/or Fernando Formation
Lithology: Clastic marine sediments, soft claystone, siltstone, and commonly fossiliferous sandstones. Intensely deformed and faulted (Dibblee, 1982).
Fossils: Shark teeth, brachiopods, gastropods, and bivalves (J. Alderson, personal communication, 2003).

Quaternary Deposits
Lithology: Alluvial fill, gravels, and shallow marine sand.
Fossils: Amphibians, reptiles, 20 species of birds, rodent, camel, bison, tapir, mammoth, mastodon, and giant ground sloth.

TAXONOMY

(See also Appendix A: Paleontological Species List.)

Microfossils

Kingdom Protoctista
Phylum Protozoa

Microfossils in the Santa Monica Mountains have been collected for age -dating purposes, and have primarily consisted of foraminifera.

Fossil Plants

Kingdom Plantae

Paleobotanical material is less abundant than invertebrate and vertebrate fossils. This observation may also be impacted by fewer researchers interested in pursuing fossil plant studies in the park. Although some leaf material has been discovered in the Vaqueros Formation, as well as leaf and kelp fossils within the Modelo Formation, the bulk of known paleobotanical resources are fossil wood. Stadum and Weigand (1999) discussed fossil wood from the Conejo Volcanics; SAMO's museum collections contain a significant number of fossil wood specimens; and additional resources are known from within the Topanga Stratigraphic unit (J. Alderson, personal communication, 2003). Lastly, pollen and spore samples have been collected for analysis from Santa Ynez Canyon for Paleocene and Eocene deposits.

Fossil Invertebrates

Kingdom Animalia
Phylum Mollusca

Bivalves, cephalopods, and gastropods are found in many areas throughout the park (see Figure 5). These specimens are certainly the most abundant within SAMO. Specimens can be found from all of the fossiliferous deposits, except for the Sespe Formation, ranging from the Cretaceous to the Recent. Hundreds of species are known from SAMO, mostly within the classes Bivalvia (clams) and Gastropoda (snails). The known cephalopods are restricted to Cretaceous rocks, including the very large specimen of *Eupachydiscus lamberti* from Santa Ynez Canyon.

Phylum Arthropoda

Miocene deposits have produced arthropod specimens that are housed at the Natural History Museum of Los Angeles County. Additionally, the new arthropod *Cyclocorystes aldersoni* was found from Paleocene deposits within SAMO.

Phylum Echinodermata

Echinoderm specimens from Miocene deposits are housed at the Natural History Museum of Los Angeles County.

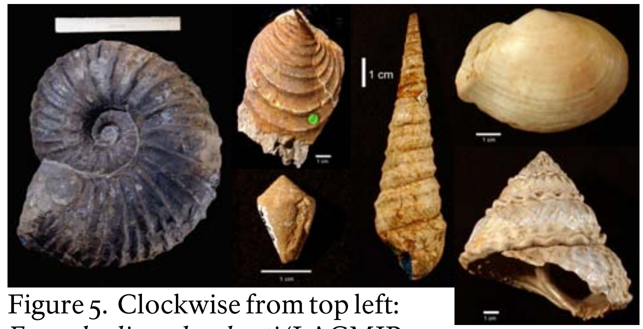

Figure 5. Clockwise from top left: *Eupachydiscus lamberti* (LACMIP hypotype 9786), *Inoceramus subundatus* (LACMIP hypotype 8387), *Turritella infra granulata pachecoensis* (LACMIP hypotype 10316), *Macoma secta* (LACMIP hypotype 8151), *Pomaulax undosa* (LACMIP hypotype 8103), and *Conus owenianus* (LACMIP hypotype 8158). Photos by Caitlin De La Cruz.
Top left scale bar = 30cm, all other scale bars =1 cm

Fossil Vertebrates

Kingdom Animalia
Phylum Chordata

The bulk of vertebrate material in SAMO is fossil fish. The classes of Chondrichthyes (cartilaginous fish) and Osteichthyes (bony fish) are both represented. Some undetermined sharks and bony fish were discovered in Late Cretaceous deposits, including a nearly complete long, slender skull of a bony fish (S. McLeod, personal communication, 2003). Aside from a few Quaternary specimens, the remaining fish material has been discovered from various Miocene rocks. Many of these specimens exhibit remarkable preservation and should be considered highly significant. French paleontologist Lore Rose David conducted the most extensive research on these Miocene fishes in the 1940s.

The only known fossil amphibian from SAMO is a Quaternary frog specimen that is housed at the Natural History Museum of Los Angeles County.

The majority of reptile fossils are from Quaternary deposits, although one specimen housed at the Natural History Museum of Los Angeles County is a Miocene turtle. The Quaternary fossil reptiles consist of two lizards and two snakes. No formal reports have been published on these specimens.

Apart from one Quaternary specimen of a flightless bird, fossil birds have been found from three different localities within the Modelo and/or Monterey Formation. Two species of boobies, one shearwater, and one cormorant were found within SAMO (Howard, 1958; Howard, 1962; and Miller, 1929) (see Figure 6). Additionally, Howard and White (1962) discuss the remarkable large -"toothed" bird, *Osteodontornis orri*, found in the Sherman Oaks area.

Figure 6. Fossil birds of SAMO: *Osteodontornis orri* (LACM 1267/2707 Figured) showing large "teeth" (left) and *Phalacrocorax femoralis* (LACM 6092/133076 [cast of HOLOTYPE UCLA VP-2754]) (right). Photos by Alison Koch.

Mammals from the Santa Monica Mountains have been found in both Miocene and Quaternary deposits. Published specimens from the Miocene include a large marine mammal and dolphin from the Modelo and/or Monterey deposits (Reinhart, 1959; Mitchell, 1963; Barnes, 1977; and Barnes, 1985). Additional Miocene material includes remains of a sea lion ancestor, whale, sea cow, and 3-toed horse (see Figure 7). Significantly more mammal specimens have been recovered from the Quaternary deposits. Although only two specimens have been published -a mole (Hutchison, 1987) and a tapir (Jefferson, 1989), additional exciting specimens exist. Camel, bison, rabbit, mastodon, mammoth, horse, mouse, gopher, rat, and giant ground sloths have been found in various sites within Quaternary sediments.

Figure 7. Sea lion ancestor remains (top left) (LACM 6186/135825), whale teeth (top right) (LACM 1408/3864), and mammoth bone (LACM 1225/3662) (bottom). Photos by Alison Koch.

Trace Fossils

Trace fossils discovered in SAMO have consisted of invertebrate burrows. *Ophiomorpha* from the Santa Monica Mountains were figured by Flack (1993) from the "Topanga Formation" and were also mentioned by Oborne (1993) from the Vaqueros Formation.

LOCALITIES

There are over 2,300 known fossil localities within the SAMO boundary. Some of these sites no longer exist due to building construction, while others continue to be extremely productive. It is certain that more localities will be discovered in the future. Below are two summaries of Santa Monica Mountains' most noteworthy fossil localities.

Old Topanga Canyon (Amphitheater)

This fossil site occurs in the Old Topanga Canyon area, where there is a large portion of the Topanga Formation exposed. Research and recreational collecting have produced significant finds, making this locality the most prolific site in SAMO, and have contributed to the nationwide popularity of the area. No less than 133 species have been identified from this site, and there is high potential to discover many more. *Turritella* snail shells are the most common fossils from the Amphitheater, producing countless numbers of specimens. There are a multitude of other fossils known from the site, including other snail shells, clams, shells covered with coralline algae, barnacles, sand dollars, invertebrate burrows, plant fragments, fish scales, whale bones (including the earliest record of a pygmy baleen whale), beds of shark gill rakers, and sea lion bones.

Currently the locality is privately owned. The owner has been amenable to collecting in the past, but due to a request from the Department of Public Works, "No Trespassing" and "No Parking" signs have been posted, thereby closing the site to collecting. However, there is a good possibility that this important locality could one day be managed by a public lands agency.

Due to the high rates of erosion, concerns of the Public Works, and popularity, this site is in need of some active resource management from a land conservancy agency. Natural erosion is an immediate impact that is threatening the stability of these fossils. Wind, rain, and steep slopes contribute to high erosion, while direct human impacts add to this. New fossil material, and potentially significant new finds, are rapidly weathering out from the rock. To minimize this loss of scientific data, researchers should be allowed, through a permit system, to investigate this locality. Measures should be taken to reduce eroded material entering the roadway to appease the concerns of the Public Works Division. Natural hazards to any visitor at this site include steep slopes, regular "mini" rock falls of pebbles, and one section that shows signs of large fracturing. The local community has had roots in fossil collecting at this particular site since the 1930s, and although public removal of specimens from the area is not desirable, there is a large potential for interpretive programming.

Figure 8. Fossil fish from various localities within the ModeloFormation. Clockwise from top left: *Sarda stocki* (LACM 1035 / 1059 HOLOTYPE), *Hipposyngnathus imporcitor* (LACM 326/12055 HOLOTYPE), *Decapterus* sp. (LACM 317-a/25089), *Lompoquia* sp. (LACM 1938/11675), *Chalcidichthys malacopterygius* (LACM (CIT) 317/10228 HOLOTYPE), *Xyne grex* (LACM 5768/150210), and *Scorpaena ensiger* (LACM (CIT) 317/10226 Figured). Photos by Alison Koch.

Fossil Fish Localities in the Modelo Formation

The Modelo Formation preserves isolated fish scales and skeletons, as well as mass mortality layers. These layers contain abundant fish and can be found in very soft, crumbly sediments and in harder sandstone. The preservation, especially in the harder sediments, can be outstanding. The Natural History Museum of Los Angeles County houses several fully articulated fish specimens (Figure 8).

Many of the fossil fish localities have been destroyed or made inaccessible due to private construction. However, some fossiliferous beds can be reached along neighborhood streets and in Fossil Ridge Park, controlled under the Santa Monica Mountains Conservancy Zone Parkland. This park was established for the abundant fossil fishes; however, the entrance was blocked when a neighboring housing development gated the entrance. In order to provide a new source of access, the Conservancy established the Oak Forest Canyon Park, which adjoins the park. Currently there is no established continuous trail that joins the two parks; therefore, accessing Fossil Ridge Park is arduous, and involves penetrating dense brush.

PALEONTOLOGICAL RESOURCE MANAGEMENT

National Park Service Policy

Fossils are non -renewable natural resources that are protected by the National Park Service. Both human and natural factors impact fossil stability, thus requiring consideration within resource management. Perhaps the most complex issues surrounding paleontological resource management lie within effectively caring for *in situ* fossil specimens.

Fossils become exposed at the surface by natural and human activities, including natural erosion, storm events, fires, and building construction. These processes and events aid in the discovery of fossils, but can also lead to their alteration and destruction.

It is therefore vital that management know where the fossils are located and how they are being impacted. To mitigate paleontological resource degradation, resource management actions may be implemented to help reduce the threats to these valuable non-renewable resources. National Park Service paleontological resource management guidance has been developed within the Natural Resource Management Guideline (DO-77).

Monitoring

An important aspect of paleontological resource management is establishing a long -term paleontological resource monitoring program. National Park Service paleontological resource monitoring strategies were developed by Santucci and Koch (2003). This monitoring strategy should incorporate the measurement and evaluation of the factors stated below.

Climatological Data Assessments

These assessments include measurements of factors such as annual and storm precipitation, freeze/thaw index (number of 24-hour periods per year where temperature fluctuates above and below 32° F), relative humidity, and peak hourly wind speeds.

Rates of Erosion Studies

These studies require evaluation of lithology, slope degree, percent vegetation cover, and rates of denudation around established benchmarks.

Assessment of Human Activities, Behaviors, and Other Variables

These assessments involve determining access/ proximity of paleontological resources to visitor use areas, annual visitor use, documented cases of theft/ vandalism, commercial market value of the fossils, and amount of published material on the fossils.

Condition Assessment and Cyclic Prospecting

These monitoring methods entail visits to the locality to observe physical changes in the rocks and fossils, including the number of specimens lost and gained at the surface exposure. Paleontological prospecting would be especially beneficial during assessments after wildfires.

Periodic Photographic Monitoring

Maintaining photographic archives and continuing to photo -document fossil localities from established photo -points enables visual comparison of long -term changes in site variables.

Stabilization/Reburial (DO -77)

Significant specimens that cannot be immediately collected may be stabilized using the appropriate consolidants, and reburied. Measures to mitigate erosion may also be used for stabilization.

Shelters (DO -77)

Sites or specimens that are to be exhibited *in situ* will usually require protective shelters. Structures range from small plastic domes to large buildings with attendant exhibits and research facilities. However, the use of structures may invite theft or vandalism and present problems of temperature and humidity control and specimen degradation.

Excavation (DO -77)

Excavation may be partial (such as the collection of a particular specimen in a fossil reef or the emergency collection of bones in imminent danger of destruction) or complete (an entire skeleton or an entire microvertebrate locality).

Closure (DO-77)

Closure may be temporary (such as while an excavation is in progress) or permanent (such as for areas with abundant significant fossil resources that are easily pilfered). Closed areas may be completely withdrawn from public use or restricted to ranger -led activities, such as guided hikes.

Patrols (DO -77)

Important sites or areas may be in the area of existing patrol routes and should be brought to the attention of patrol rangers. Other areas may require the modification of patrol routes. Patrols may be important in preventing or reducing theft and vandalism.

Alarm Systems / Electronic Surveillance

Seismic monitoring systems can be installed to alert rangers of disturbances to sensitive paleontological sites. Once the alarm is engaged, a ranger can be dispatched to investigate. Motion -sensory activated cameras may also be mounted to visually document human activity in areas of vulnerable paleontological sites.

Baseline Paleontological Resource Inventories

Santucci (1998) piloted a prototype for the first comprehensive paleontological resource inventory for the National Park Service in Yellowstone National Park. A baseline inventory of paleontological resources within a park is fundamental for any paleontological resource management program. In order to proceed with science -based decision -making, managers must be aware of the “where” and “what” details of the park’s paleontological resources.

PALEONTOLOGICAL RESOURCE PROTECTION

The protection of fossil resources not only from the elements, but also from looting and vandalism, is vital to preserving the scientific value associated with a specimen. To remove a fossil from its geographic and/or stratigraphic context without documentation is equal to discarding volumes of information that can aid in the understanding of a fossil's place in time and space.

It is widely known throughout the Santa Monica Mountains that hobby fossil collecting has and continues to occur, regardless of land -ownership.

Some of the more vulnerable fossil -rich areas within the over -arching boundary of SAMO are not under direct NPS control. Perhaps the most efficient means of protecting some of these resources is to include the fossil-rich areas into the NPS -governed lands. There are a number of potential regions that could profit from the additional protection that the Park Service would provide.

An additional concern for the paleontological resources within SAMO is the occurrence of illegal encroachment activity. Any land disturbance for the purpose of cutting trails or providing access within the park can result in adverse affects to fossils. Direct damage as well as increased erosion destroys or destabilizes the fossils.

SAMO rangers should continue to search for evidence of disturbance to paleontological resources when investigating a case and contact a specialist to conduct a field assessment and provide a report for a 19jj case if necessary. Staff at the Natural History Museum of Los Angeles County may be able to provide this assistance.

Recommendations for Paleontological Resource Protection

- Conduct regular patrols of known sites;
- Continue cooperation with state parks, conservancies, museums, and universities;
- Develop a PMIS statement for paleontological resource protection;
- Assess commercial values of paleontological resources preserved within the park;
- Provide paleontological resource protection training for park staff; and
- Increase public awareness of NPS regulations regarding fossils.

RESEARCH

The National Park Service Natural Resource Management Guidelines (DO-77) state, "paleontological research by the academic community will be encouraged and facilitated under the terms of a permit..." Paleontological research has been conducted in the area since before the establishment of the Santa Monica Mountains National Recreation Area and continues today, although no official research permits have been issued by the National Park Service. It is fortunate that a tremendous wealth of paleontologic information exists for the Santa Monica Mountains, although the park has not previously been aware of much of this information.

There are a number of reasons that permits have not been obtained by paleontological researchers in the area. First, many researchers are not conducting paleontological investigations on the National Park Service controlled portions of land, and it is therefore not required that they possess a permit. However, many researchers have not been alerted to the fact that it is a requirement to have a permit to conduct paleontological research on Park Service land. Due to the rich tapestry of land ownership within the boundary, some researchers have difficulty identifying which agency is responsible for the locality in question.

Although illegal collecting and unpermitted research must not be tolerated in the National Park Service, there are some things that SAMO can do to help "encourage and [facilitate research] under the terms of a permit." Providing local museums and universities with information and links to the NPS permitting website could be a first step to informing the academic community. SAMO can also approach these institutions with potential research opportunities and projects that the park would like to see accomplished. Making copies of detailed land-ownership maps for the entire recreation area available to the general public would help identify park lands until greater signage can be installed. Also, the park has a wealth of resources, GIS capabilities, detailed maps, and road access, in particular, which would be beneficial for a researcher to utilize. Reaching out to the academic community in this way may encourage communication between researchers and the park. This in turn could open the doors for additional valuable research within SAMO under the terms of NPS permitting regulations.

Current Research

John Alderson, LouElla Saul, and Takeo Susuki are investigating the fauna from the Amphitheater site. This work is a comprehensive look at the variety and distribution of fossils from this locality.

John Alderson, Bruce Lander, and Don Prothero are researching the Sespe Formation and Vaqueros Formation in the Saddle Peak area. Fossils and microfossils of land mammals, land plants, and marine invertebrates are being studied. Additionally, paleomagnetic investigations, in conjunction with fossil dating, are being used to determine ages for the rocks.

Potential Research

Old Topanga Canyon (Amphitheater)

Although many specimens, including new species, were collected from this area by researchers and hobbyists, many other specimens will likely continue to emerge. Due to the high rates of erosion at this site, new specimens may be appearing regularly, and they should be documented before they are altered, destroyed, or removed by natural and human processes. Future studies of this locality would be extremely valuable due to the wealth of paleontological resources and the popularity they have received nationwide.

Further Investigation of Fossil Fish Beds

Preservation of fossil fish from within SAMO is so good that it can be compared to that of the Wyoming's Green River Formation. Fully articulated specimens are housed at the Natural History Museum of Los Angeles County, and others may be housed at a variety of institutions. Although some previously identified fossil fish localities are now inaccessible due to building construction, there is the potential for recovery of new specimens within SAMO.

Inventory of Fossil Wood Deposits

There are significant fossilized wood deposits within and surrounding SAMO. Some of this material has been identified. In addition to identification, locality data should be documented, along with GPS information and photographic images.

Permit System

A research permit serves as an administration tool to help ensure resource protection by defining limitations on and responsibilities of researchers working in the park. Park management should ensure that information gained through research (field notes and photographs) is obtained by the park, and that any specimens collected under a permit remain accessible and properly cataloged into a museum collection - the park's or otherwise. For further information on NPS permit regulations and applications, consult the U. S. National Park Service Research Permit and Reporting System website, http://science.nature.nps.gov/permits/servlet/PubIndexServlet

Funding

Funding for paleontological research has traditionally been difficult to secure within the National Park Service. Fossils lack specific legislation for appropriation of funds to support paleontological resource projects. Most of the financial support for paleontological resource projects has come from park cooperating associations, park donation accounts, or academic institutions. With limited funding for paleontological resource projects, the training and utilization of volunteers can be a valuable way to accomplish management objectives.

The National Park Service has moved toward greater recognition of paleontological resources within the last few years. A staff position in Washington, D. C. has been created to oversee geologic and paleontologic resource issues. The Geologic Resources Division in Denver, Colorado has also had a staff position since 1998 and is able to secure some funding to support paleontological research in the national parks.

Santa Monica Mountains National Recreation Area may also be able to utilize funds and support for paleontological projects through the newly instituted Center for Teaching New America.

Literature Survey

As a part of the Santa Monica Mountains National Recreation Area Paleontological Survey, background searches into existing geologic and paleontologic publications were conducted, with the purpose of finding all information pertaining to known Santa Monica Mountains paleontological resources. The cooperation of the Natural History Museum of Los Angeles County and the Invertebrate Paleontology staff and research associates was very much appreciated in this effort. Additionally, GeoRef databases and the National Park Service databases "PaleoBib" and "NatureBib" were searched.

The majority of papers mention vague and/or specific site and specimen data without specific reference to the presence of the recreation area. Therefore, there was some approximation for determining whether references pertain to specimens and localities inside the park boundaries.

MUSEUM COLLECTIONS / CURATION

The paleontology collections at Santa Monica Mountains National Recreation Area are very limited, except for a large (approximately -150 -specimen) collection of unidentified fossil wood and a few invertebrate specimens (Figure 9). These specimens are accessioned in the National Park Service ANCS+ system, but very few are catalogued. The museum facility itself is in compliance with all National Park Service guidelines for maintaining collections.

Paleontology is mentioned in the park's Scope of Collections (SOC). Additionally, the SOC is currently being revised and updated to accomodate the increased breadth of paleontological potential.

The Museum Management Plan identifies the philosophy behind the scope of the collections. This broad scope of the collections is not intended to compete with other repositories, but rather to house any specimens that are needed for interpretation and to preserve any material that is threatened or has been stumbled upon within the park. Due to the limited space available for park collections, most collected specimens will remain in outside repositories. However, there is some vacant space in the museum collections that could be used for fossil specimens. SAMO museum curator Phil Bedel states, " I would like to see our paleontological collections grow. They are an important theme for the mountains, but we are not trying to duplicate work that has already been done."

SAMO has the opportunity to house a variety of representative and rare specimens for their collections. These specimens could be used for exhibits, interpretation, staff training, research, and resource protection. The Natural History Museum of Los Angeles County has a multitude of representative fossils that may be loaned to the park. In addition, casts of rare or otherwise significant specimens can be made for the park. SAMO should maintain contact with this museum to obtain updates on new specimens, preparation procedures, and potential curatorial cooperative projects. Due to the overwhelming abundance of fossil material within the Santa Monica Mountains, new specimens could be collected from the field and curated directly into the park's museum. Associated field records should also reside in the park collections.

In addition to housing specimens, SAMO has the facilities to maintain an extensive photographic archive of paleontological material. By retaining photographs,

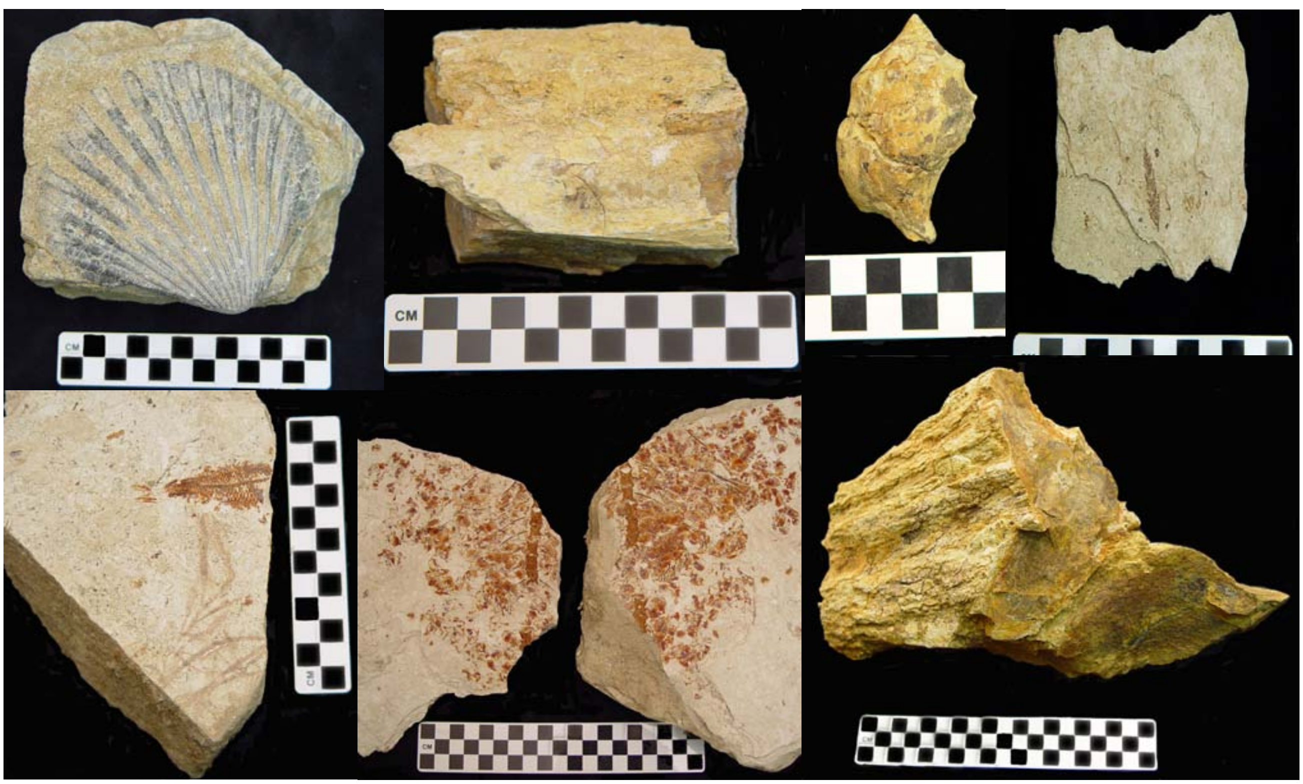

Figure 9. Specimens housed at the museum facility of the Santa Monica Mountains National Recreation Area. Clockwise from top left: Pectinidae (clam) (SAMO245), unidentified marine mammal*, *Bruclarkia* sp. (snail) (SAMO3204), unidentified leaf (SAMO3210), fossilized wood*, Carangidae (fish) (SAMO3221), and Clupeidae (fish) with plant material (SAMO3213). Photos by Alison Koch.

*represent part of the backlog of uncataloged specimens in the park collections the park saves museum drawer space, while keeping a useful record of the local paleontology on site.

Security for the collections at Santa Monica Mountains National Recreation Area is excellent. The relative remoteness and unidentifiable nature of the building add to security by decreasing access to the general public. Any person visiting the museum building must be escorted through the collections.

INTERPRETATION

Current Efforts

Interpretation of SAMO paleontological resources is primarily informal at present. Most educational and interpretive information regarding fossils and paleontology is presented during interpretive programming, and not within exhibits. Although not a primary interpretive theme, there is one unidentified fossil replica on display in the NPS visitor center. During a guided hike previously conducted at SAMO, visitors stopped at a fossil locality to see an *in situ* (in place) fossil. Most visitors receive little paleontological information from park staff unless specific questions arise during interpretive programs. These questions are most often asked by school children. Visitors with a particular interest in fossils are usually referred to the neighboring La Brea Tar Pits of the Page Museum of the Natural History Museum of Los Angeles County for additional paleontological information.

Paleontological Themes

As part of a National Park Service servicewide survey of paleontological interpretive themes, SAMO reported on a number of paleontological topics that have been utilized by the staff. These topics include Definition of a Fossil, Fossilization Processes, Curation, Paleoenvironmental Reconstruction, Earth History, Evolution, Geologic Time, Values of Fossils, Threats to Fossils, Paleontology vs. Archeology, Fossils and Culture, and Misconceptions in Paleontology (J. Kenworthy, personal communication, 2003).

Interpretive Potential

Due to the richness and significance of paleontological resources at SAMO, the interpretive potential is great. The following are a few recommendations that could be used to incorporate paleontological resource information into interpretation.

Some of the range of possible interpretive activities and programs could include SAMO -specific programs or activities relating to this area's rare opportunity to compare the modern -day fauna to the similar fossil specimens that are both currently found within the park and the Los Angeles area. Matching cards, touch boxes, programs, exhibits, or other tools could be used to present this topic. Quarry or field programs, exhibits, waysides, or site bulletins could be created to help locals identify the fossils "in your own backyard." Another way to involve the local community would be to have rotating field trips or talks lead by local scientists to explain the geology and paleontology. Utilizing a paleontologist through the GeoScientist -in -the - Parks, Student Conservation Association, and/or other volunteer venues may be an inexpensive way to develop specific programs. Cooperating with the Center for Teaching New America may also provide support for paleontological interpretive programming. Hosting school groups or visiting the schools to present local paleontological topics, including conducting art/essay contests, could be another way to inform local communities about the neighboring paleontological resources. If there were space to be made available, the visitor center could provide a "rubbing plate station" for visitors (especially kids) to make crayon rubbings of local fossils with their associated scientific names. Any paleontological interpretation at SAMO should also have a protection message included in the interpretive programming, due to the illegal collecting in the past and present, and the difficulties in determining land ownership within the entire park boundary.

Recommendations for Paleontological Interpretation

- Update interpretive planning documents to include paleontological resources and issues;
- Incorporate significant park paleontological resources in interpretive exhibits and displays;
- Develop geologic/paleontologic resource components for education programs;
- Provide paleontological resource training for interpretive staff;
- Continue park policy of not divulging paleontological localities to park visitors; and
- Update interpretive slide collection to incorporate significant fossil specimens.

SUMMARY OF RECOMMENDATIONS

Resource Management

Incorporate all backlog paleontological localities into the paleontology database and GIS layer. Conduct site assessments to evaluate the productivity for future occurrences of specimens. Conduct scheduled monitoring of fossil localities. Continue to cooperate with other land agencies to ensure appropriate management and increase recognition of the valuable paleontological resources that occur throughout the mountains.

Resource Protection

Provide paleontological resource protection training for park staff. Continue to work with paleontologists on 19jj cases (Natural History Museum of Los Angeles County staff may be consulted). Develop a PMIS statement for paleontological resource protection. Include paleontological resources in the conservation criteria for the Land Protection Plan.

Research

Conduct outreach to encourage the scientific community to maintain a working relationship with the park about their research and provide information about the NPS permitting system. Communicate SAMO research needs to local universities for potential projects.

Museum Management and Collections

Maintain a working relationship with the Natural History Museum of Los Angeles County for preparation, identification, and curation needs. Continue to provide park staff and outside visitors and researchers access to the collections. Acquire funding to catalog the backlog specimens within the collections. Investigate other repositories that contain SAMO fossils, especially the University of California, Berkeley paleontology collections.

Interpretation

Provide paleontological resource training for interpretive staff. Move paleontological resources into the natural resources of the Long - Range Interpretive Plan and incorporate the significance of SAMO fossil resources. Utilize a GeoScientist - in - the - Parks intern to create an interpretive product or program regarding paleontological resources at SAMO. Provide resource protection message with all paleontological interpretation and continue park policy not to divulge fossil localities to visitors.

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APPENDICES

A: PALEONTOLOGICAL SPECIES LIST

Geologic Time Codes:

[K]	Cretaceous
[P]	Paleocene
[E]	Eocene
[M]	Miocene
[Q]	Quaternary

Fossils Examined in LACM Repositories

Invertebrates

Mollusca

Bivalvia

Anadara topangensis [M]
Chione triangulata [M]
Clementia temblorensis [M]
Clementia pertenuis [M]
Cymbophora triangulata [K]
Dosinia ponderosa [M]
Glycymeris veatchii [K]
Inoceramus subundatus [K]
Macoma cf. *nasuta* [M]
Macoma secta [Q]
Macrocallista stantoni [E]
Martesia sp. [P]
Miltha pertenuis [M]
Miltha santaecrucis [M]
Mytilus mathewsoni [M]
Nototeredo sp. [P]
Ostrea sp. [M]
Pinna sp. [M]
Plicatula lapidicina [P]
Plicatula trailerensis [P]
Propeamusium cowperi [K]
Saxidomus nuttallii [M]
Solena stantoni [P]
Spisula hemphilli [Q]
Teredo sp. [M]
Trachycardium sp. [Q]
Venericardia mulleri [P]
Vertipecten bowersi [M]
Yaadia robusta [K]

Cephalopoda

Eupachydiscus lamberti [K]
Metaplacenticeras sanctaemonicae [K]
Metaplacenticeras pacificum [K]
Pachydiscus catarinae [K]

Gastropoda

Anchura phaba [K]
Bittium topangensis [M]
Bruclarkia barkerianum [M]
Bursa californica [Q]
Calyptraea costellata [M]
Calyptraea mamillaris [M]
Campanile greenellum [P]
Cancellaria sp. [M]
Conus owenianus [M]
Deussenia californiana [K]
Diodora sp. [P]
Fusinus sp. [P]
Gyrodes robustus [P]
Haliotis palaea [M]
Neverita reclusiana [M]
Ocenebra topangensis [M]
Penion titan [P]
Perissitys pacifica [K]
Pomaulax undosus [Q]
Spinigeropsis calafia [E]
Tenagodus californiensis [P]
Terebralia susana [P]
Trophon bartoni [M]
Turritella chicoensis [K]
Turritella infragranulata [P]
Turritella ocoyana [M]
Turritella pachecoensis [P]
Turritella peninsularis [P]
Turritella temblorensis [M]
Velates perversus [E]
Zonaria emmakingae [M]

Arthropoda

Crustacea [M]
Rhyssematus miocenae [M]
Cyclocorystes aldersoni [P]

Echinodermata

Astrodapsis hootsi [M]
Vaquerosella norrisi [M]

Vertebrates

Chondrichthyes

Carcharhinidae

Galeocerdo aduncus [M]
Hemipristis sp. [M]

Cetorhinidae

Cetorhinus sp. [M]

Lamnidae

Carcharocles angustidens [M]
Isurus hastalis [M]
Isurus planus [M]

Myliobatidae

Myliobatis sp. [M]

Osteichthyes	
Atherinidae	
Atherinops barkeri	[M]
Atherinopsis sp.	[M]
Exocoetidae	
Euleptorhamphus sp.	[M]
Scomberesocidae	
Scomberesox edwardsi	[M]
Diretmidae	
Absalomichthys velifer	[M]
Chalcidichthys malacopterygius	[M]
Clupeidae	
Etringus scintillans	[M]
Ganolytes cameo	[M]
Sardinella sp.	[M]
Xyne grex	[M]
Bregmacerotidae	[M]
Gadidae	
Eclipes santamonicae	[M]
Eclipes veternus	[M]
Gasterosteidae	[Q]
Myctophidae	
Lampanyctus bolini	[M]
Lampanyctus petrolifer	[M]
Halosauridae	
Laytonia californica	[M]
Carangidae	
Decapterus agilis	[M]
Pseudoseriola gillilandi	[M]
Gempylidae	
Thyrsocles kriegeri	[M]
Zaphlegulus venturaensis	[M]
Priacanthidae	[M]
Sciaenidae	
Lompoquia sp.	[M]
Scombridae	
Sarda stocki	[M]
Scomber grex	[M]
Scomber sanctaemonicae	[M]
Serranidae	
Stereolepis sp.	[M]
Sparidae	
Plectrites classeni	[M]
Zaproridae	
Araeosteus rothi	[M]
Bathylagidae	
Bathylagus angelensis	[M]
Quaesita angelensis	[M]
Quaesita quisquilia	[M]
Salmonidae	
Oncorhynchus rastrosus	[M]
Smilodonichthys sp.	[M]
Scorpaenidae	
Scorpaena ensiger	[M]
Sebastodes porteousi	[M]
Chauliodontidae	
Chauliodus barbatus	[M]
Chauliodus eximius	[M]
Gonostomidae	
Cyclothone solitudinis	[M]
Gonostoma sp.	[M]
Sternoptychidae	
Argyropelecus bullockii	[M]
Stomiatidae	
Stomias sp.	[M]
Syngnathidae	
Hipposyngnathus imporcitor	[M]
Syngnathus avus	[M]
Caproidae	[M]
Amphibia	
Ranidae	
Rana sp.	[Q]
Reptilia	
Dermochelyidae	
Psephophorus sp.	[M]
Anguidae	
Gerrhonotus sp.	[Q]
Colubridae	
Tantilla sp.	[Q]
Thamnophis sp.	[Q]
Iguanidae	
Uta sp.	[Q]
Aves	
Falconiformes	[Q]
Anatidae	
Anas americana	[Q]
Aythya affinis	[Q]
Aythya marila	[Q]
Bucephala albeola	[Q]
Chendytes lawi	[Q]
Melanitta perspicillata	[Q]
Oxyura jamaicensis	[Q]
Ardeidae	
Ardea herodias	[Q]
Alcidae	
Synthliboramphus antiquus	[Q]
Uria aalge	[Q]
Laridae	
Larus canus	[Q]
Larus occidentalis	[Q]
Meleagridae	
Parapavo californicus	[Q]
Phasianidae	
Lophortyx californica	[Q]
Gaviidae	
Gavia stellata	[Q]
Rallidae	
Fulica americana	[Q]
Corvidade	
Corvus corax	[Q]
Phalacrocoracidae	
Phalacrocorax femoralis	[M]
Phalacrocorax penicillatus	[Q]

Pseudodontornithidae
Osteodontornis orri [M]
Sulidae
Sula pohl [M]
Sula willetti [M]
Podicipedidae
Podiceps caspcus [Q]
Procellariidae
Fulmarus glacialis [Q]
Puffinus diatomicus [M]
Puffinus griseus [Q]
Puffinus puffinus [Q]

MAMMALIA
ARTIODACTYLA
Bovidae
Bison antiquus [Q]
Camelidae
Camelops hesternus [Q]
Cervidae
CARNIVORA
Desmatophocidae
Allodesmus sp. [M]
CETACEA
Cetotheriidae
Nannocetus sp. [M]
Kentriodontidae
Pithanodelphis nasalis [M]
Phocoenidae [M]
Physeteridae
Scaldicetus sp. [M]
DESMOSTYLIA
Desmostylidae
Paleoparadoxia sp. [M]
INSECTIVORA
Soricidae
Sorex sp. [Q]
Talpidae
Scapanus latimanus [Q]
LAGOMORPHA
Leporidae
Sylvilagus sp. [Q]
PROBOSCIDEA
Proboscidea
Mammutidae
PERISSODACTYLA
Tapiridae
Tapirus californicus [Q]
Equidae
Equus sp. [Q]
Parapliohippus carrizoensis [M]
RODENTIA
Cricetidae
Microtus sp. [Q]
Peromyscus sp. [Q]
Geomyidae
Thomomys bottae [Q]
Heteromyidae
Dipodomys sp. [Q]
Perognathus sp. [Q]
SIRENIA
Dugongidae [M]
XENARTHRA
Mylodontidae
Glossotherium harlan [Q]
Paramylodon sp. [Q]

Paleobotany

Unidentified fossil wood [M]

FOSSILS HELD IN SAMO REPOSITORY

Invertebrates

MOLLUSCA
BIVALVIA
Macoma sp. [M]
Ostrea sp. [M]
Pecten sp. [M]
GASTROPODA
Bruclarkia sp. [M]
Cancellaria sp. [M]
Neverita sp. [M]
Turritella sp. [M]

Vertebrates

OSTEICHTHYES
Bathylagidae [M]
Carangidae [M]
Clupeidae [M]
Unidentified marine mammal bones [M]

Paleobotany

Unidentified fossil wood [M]
Unidentified fossil leaf [M]
Algal imprints [M]

B: REPOSITORIES FOR ADDITIONAL SAMO FOSSIL SPECIMENS

University of California, Berkeley Museum Collections
Museum of Paleontology
University of California
1101 Valley Life Sciences Building
Berkeley, CA 94720-4780
Phone: 510-642-1821
Email: ucmpwebmaster@uclink.berkeley.edu
Webpage: www.ucmp.berkeley.edu

University of California, Riverside Museum Collections
Dr. Marilyn Kooser
Phone: 909-787-3440
Email: kooser@ucrac1.ucr.edu

Peabody Museum of Natural History at Yale University
Peabody Museum of Natural History
PO Box 208118
New Haven, CT 06520-8118
Phone: 203-432-5050

U. S. Geological Survey Vertebrate Paleontology Collections, Denver, Colorado
K.C. McKinney
Phone: 303-236-7561
Email: kcmckinney@usgs.gov

California Academy of Sciences Collections
California Academy of Sciences
55 Concourse Drive
Golden Gate Park
San Francisco, CA 94118-4599
Phone: 415-750-7145
Email: research@calacademy.org

San Diego Natural History Museum
Department of Paleontology
PO Box 121390
San Diego, CA 92112-1390
Phone: 619-255-3821
Email: paleo@sdnhm.org

Smithsonian Institution
National Museum of Natural History
Department of Paleobiology
PO Box 37012
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