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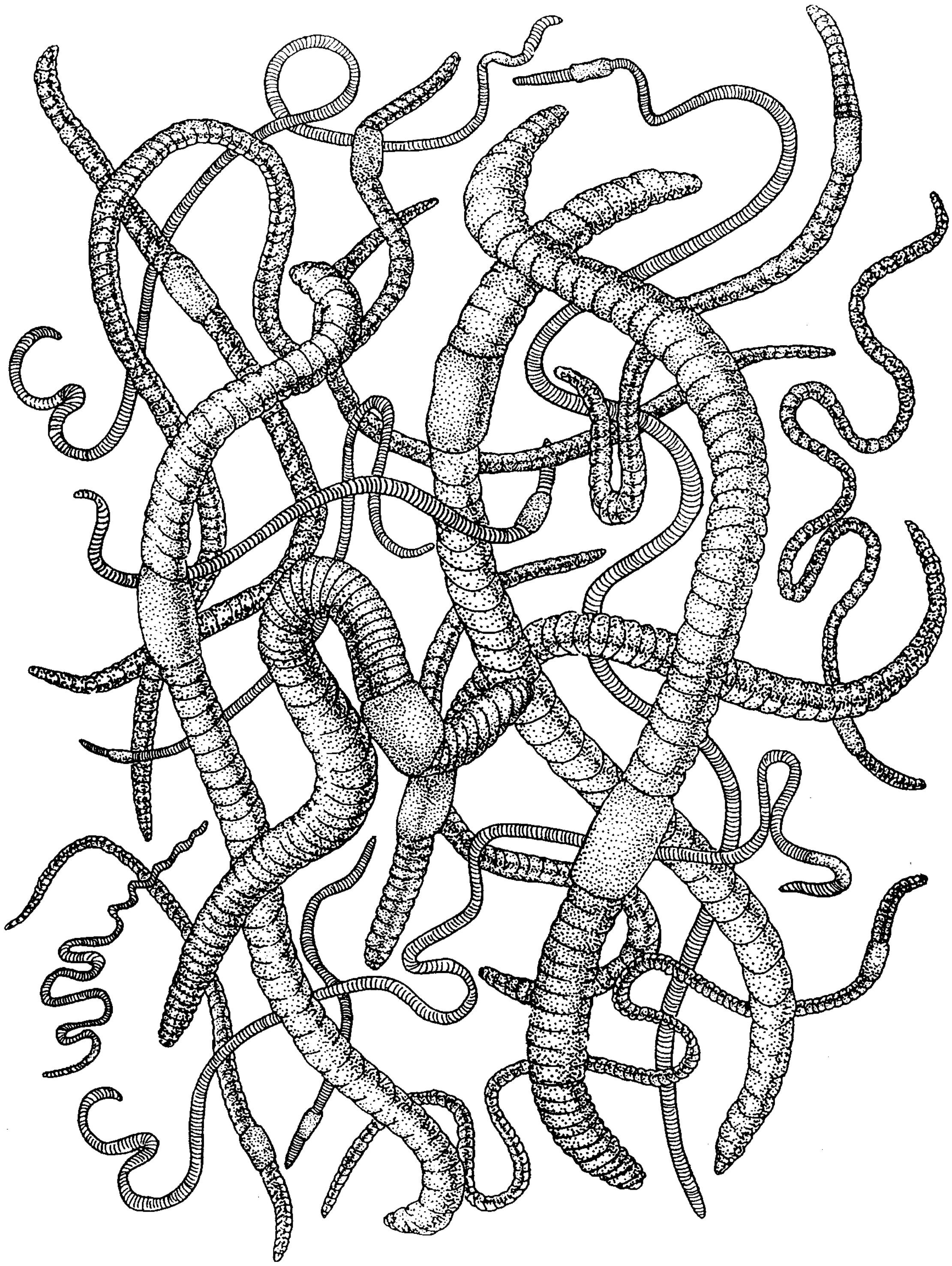
Native and Introduced Earthworms from Selected Chaparral, Woodland, and Riparian Zones in Southern California

Hulton B. Wood **Samuel W. James**



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Relatively little is known about the earthworm fauna of southern California. Some 20 different species of earthworms were collected and identified in a survey of various southern California wildland habitats. The ecology and biology of earthworms are outlined, and the results of the survey are documented. Introduced species belonging to the Lumbricidae family were encountered most often; however, native species, primarily of genera *Argilophilus* and *Diplocardia,* are widely distributed. Several of the natives collected are believed to be new species. Habitats for both the native and introduced species ranged from riparian zones to relatively dry chaparral sites. Preference of earthworms for certain types of plant communities began to emerge even in this somewhat limited survey: oak and grass being the most preferred, and conifers the least. Geographical separation of the two principal native genera occurs at about 34°N. Further research is needed relative to earthworm ecology, impacts on soils, ecosystem dynamics, and fire. An appendix includes all collection records by location, and vegetation and soil type.

Retrieval terms: earthworms, Mediterranean ecosystems, southern California, new species, Lumbricidae, Megascolecidae, Acanthodrilinae, Ocnerodrilinae, Sparganophilidae, soil, habitat, chaparral, grassland, woodland, riparian, aquatic

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Contents

In Brief ...

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During a recent investigation of soil properties in southern California chaparral, earthworms and evidence of significant earthworm impact on soil development (Graham and Wood 1991) were noted. Because earthworms were not known or expected to occur in these soils, the findings were of great interest and curiosity, leading us to the realization that earthworms may be an overlooked and important component of some ecosystems in southern California.

Earthworms alter soil properties in ways that are beneficial to plant growth by improving soil structure for better aeration, water intake, and water transmission. They also accelerate decomposition and improve nutrient availability to plants, promoting greater plant productivity.

Until now earthworms have been an unrecognized component of wildland ecosystems in southern California, even though they are well documented from many parts of the world. Both native and introduced earthworm species were collected and identified from a variety of wildland habitats from Santa Barbara County to San Diego County, in spring 1990 and 1991.

Earthworms were collected from many soil textural types ranging from heavy clays to sands, but they seemed to do best in loamy soil. Few earthworms live in soils at or below pH 4.

Collection sites varied from wet streambed sands and riparian zones to dry chaparral and woodland sites. The wetter sites invariably contained earthworms. On many of the drier sites no earthworms were found. Enough of the drier sites were sampled that an earthworm plant-food preference began to emerge: grass and oak habitats being the most preferred, ceanothus and other mixed chaparral species next, with chamise and pine being the least preferred. Some general habitat preferences observed suggest the hypothesis that native *Argilophilus* spp. prefer grassland and oak forest. Highest numbers of *Diplocardia* spp. were found in grasslands. Earthworms are usually not found under naturally developed conifer stands in southern California.

Earthworms are cylindrical and segmented, with a mouth at one end and an anus at the other. They are hermaphroditic, and their young are produced in cocoons. Maturation varies from months to years among species.

Earthworms are placed in three ecological categories depending on where they dwell and feed: epigeic--dwell and feed at the surface, anecic--dwell in burrows, often very deep in the soil, and feed at the surface, and endogeic--dwell and feed below the soil surface. Soil organic matter is vital to most earthworms primarily as a source of food. Like other detritivores, earthworms may derive more nutrition from microbes ingested than from the detritus itself.

Earthworm activity is governed primarily by temperature and moisture. Activity peaks at moderate temperatures. Earthworms require a moist body surface for gas exchange and hydrostatic pressure for burrowing. They are able to hibernate under conditions of extreme temperature and low soil water. The 4-5 years of subnormal precipitation preceding our survey may have influenced our collections.

Over 4000 earthworm species are known. Of the 20 species encountered in this survey, half of them were native species. Some of them are believed to be new species. The predominant native species belong to *Argilophilus* and *Diplocardia* in the Family Megascolecidae. Two other natives found were in genera *Ocnerodrilus* (Family Ocnerodrilinae) and *Sparganophilus* (Family Sparganophilidae) and are limited to water-saturated areas. Finding *Sparganophilus* was significant because its usual range is the Eastern United States. The nonnative species in taxa *Aporrectodea*, *Eiseniella*, *Eisenia*, and *Allolobophora*, however, were by far the most prevalent and widely distributed. They are in the Family Lumbricidae and are European in origin. *Microscolex* from South America were also found. We did not collect the best-known earthworm species in North America, the night crawler.

Humans are the major distributors of earthworms by transporting plants and soil. Further dispersal methods are many and varied. Floodwaters are known to redistribute viable cocoons and live earthworms. Birds and other animals have also been suggested as dispersal mechanisms.

The native genera *Diplocardia* and *Argilophilus* are of particular interest, not only because they comprise the bulk of the native species, but for their apparent separate geographical limits in southern California. The northern boundary of *Diplocardia* spp. appears to be about 34° N. The southern limit for *Argilophilus* spp. is also somewhere near 34° N. From this survey, the interactions between native and introduced species are not clear. Where native species were found, introduced species were almost always associated with them.

Given the potential importance of earthworms from an ecosystem functioning context, virtually nothing is known of their biology and ecology, nor of their role in ecosystem processes. Therefore, to obtain more information, earthworm research should be carried out in southern California in (1) their taxonomy, biology, ecology and population dynamics, (2) their influences on soils, (3) their interactions with soil and plants, and (4) their role in fire adapted ecosystems.

Introduction

> *We are unaware of the nocturnal, hidden, subterranean activity of the most important animal biomass that shares with us the earth's land surface. This paradoxical situation, this ecological divorce of humanity from the environment, must undoubtedly have some explanation....our knowledge of ecosystems is, fundamentally distorted by our above-ground, visual perception of nature and our ignorance of life below-ground--Bouche (Lee 1985, p. ix).*

During a recent investigation of soil properties in southern California chaparral, earthworms and evidence of significant earthworm impact on soil development (Graham and Wood 1991) were noted. Because earthworms were not known or expected to occur in these soils, the findings were of great interest and curiosity, leading us to the realization that earthworms may be an overlooked and important component of some ecosystems in southern California.

Earthworms are well documented from many parts of the world, particularly Europe and many of the British Commonwealth countries (Darwin 1881, Gates 1982, Lee 1985, Stephenson 1930). Extensive areas, notably portions of France, Italy, Spain, South Africa, Western Australia, Chile, and California have Mediterranean-type climates characterized by cool, wet periods followed by hot, dry seasons of 6 months or more. With the exception of a few locations in the Mediterranean (Bouche 1972, Diaz-Cosin and others 1980, Omodeo 1959, 1960, 1982), Africa (Ljungstrom 1972, Pickford 1937), and Australia (Abbott 1984, 1985; Barley 1959), information is lacking on earthworm populations in Mediterranean climates and is particularly sparse for southern California.

Nearly a hundred years ago Eisen (1900) described species from southern California and Baja California, Mexico. Collection records that do exist for southern California are relatively few (Eisen 1900, Gates 1967), and are primarily species descriptions and location records. The bulk of the earthworm literature for the Pacific Coast States (Fender 1985, Fender and McKey-Fender 1990, Gates 1967, Macnab and McKey-Fender 1947, McKey-Fender 1970) generally lacks information from southern California locations. Except for a few of the introduced earthworm species, virtually nothing is known of the biology and ecology of most earthworm species found in southern California, native or introduced.

Where present in sufficient numbers, earthworms can have major beneficial impacts on physical and chemical soil properties (Darwin 1881, Edwards and Lofty 1977, Lee 1985, Satchell 1967). In the decades just before and after World War II, southern California was perhaps a Western center for the commercial promotion of earthworm farming. The virtues of "domesticated" earthworms for increasing soil fertility, soil humus development, soil porosity, and soil drainage were widely acclaimed for farmers, orchardists, and backyard gardeners (Barrett 1947).

The potential loss of native earthworm species by habitat destruction through urbanization or from competition with introduced European or Asian species has been a concern for a long time (Eisen 1900, Gates 1977b, Ljungstrom 1972, Smith 1928, Stebbings 1962). It is now a moot point in southern California, after some two centuries of landscape and cultural impacts, that endemic species may have been replaced by introduced ones. The reason is no baseline or precolonization data exist for comparison. What is important now, however, is to determine what species are extant, regardless of origin, and their ecological importance to edaphic and plant functions.

We conducted-what is to the best of our knowledge--the first survey on earthworms in southern California. The geographical area that we are calling southern California is essentially the area west and south from the midribs of the Transverse and Peninsular Ranges *(fig. 1).* It comprises portions of seven counties and for the most part has a Mediterranean climate. The northernmost collection zone was in Santa Barbara County, and the southernmost was in San Diego County. Sampling was confined to nonurban mountain and park areas. The survey results set the stage for future work on assessing what ecological role native or introduced earthworms play in these ecosystems.

This paper does the following: (1) introduces a general outline of the biology, ecology, and taxonomy of earthworms to those readers unfamiliar with their fascinating and complex nature; (2) provides the first-ever data from selected wildland areas of southern California on species, locations, and habitat of native and introduced earthworms; (3) documents the dis covery of new earthworm species; (4) discusses the ecological implications of earthworms in many of our wildland habitats, and (5) identifies some of the research and management needs relative to this major but "unseen" portion of the ecosystem.

An Earthworm Briefing

Curiosa

The following selection of earthworm facts and oddities answers frequently asked questions about earthworms (Adis and Righi 1989, Bouche 1983, Edwards and Lofty 1977, James 1988, Lee 1985, Satchell 1967).

- It is not clear why many species of earthworms come to the surface after a rain storm. Earthworms can survive in water for many days.
- Species that are surface or near-surface feeders are active only at night; long exposures to ultraviolet light are lethal to most species.
- Several different species of earthworms often occur in the same habitat.

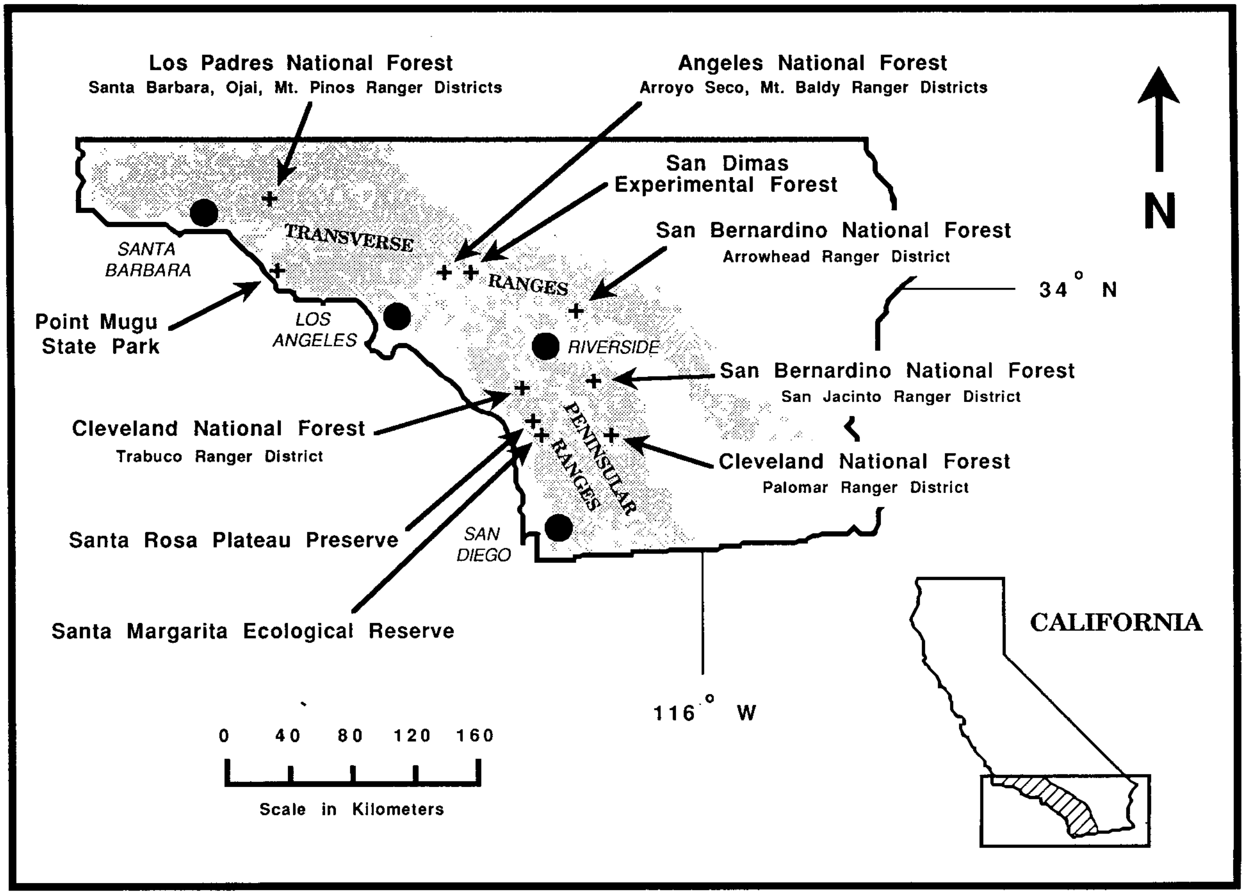

Figure 1-Earthworms were collected from a variety of vegetation and soil habitats in the Tranverse and Peninsular Ranges of southern California.

- Earthworms are not randomly distributed; obtaining population estimates is extremely difficult.
- In some areas it is not uncommon to have earthworm population densities in the range of 100 to 500 per square meter.
- There are usually considerably more juveniles in any given population than there are adults.
- Some species can regenerate severed tail sections.
- Some are luminescent. Some exhibit changes in body colors depending on diet.
- Some may even produce a plant growth hormone.
- Earthworms are voracious ingesters of soil and decomposed organic material. A rough estimate for some of the common European species is that they ingest soil and organic matter equivalent to about 30 percent of their 1- to 2-gram body weight daily.
- They are capable of burying plant seeds and bringing seeds to the surface.
- Some climb trees.
- Populations in some ecosystems may benefit from fire.

These tidbits of information imply a wealth of knowledge about earthworms; however, relatively little is known of the biology and ecology of most earthworm species.

Biology Basics

This section outlines some of the basics of earthworm biology, which may or may not serve as appropriate models for the earthworms in Mediterranean ecosystems in southern California. Though people have been observing earthworms for millenia, the first detailed written account of their biology and ecology was by Charles Darwin (1881). Earthworms belong to the Phylum Annelida, Class Oligochaeta *(fig. 2)*. The Oligochaeta include aquatic and terrestrial groups, the latter composed largely of the Opisthopora, which are commonly known as earthworms. Opisthopora are so called because the pores from which sperm exit are behind the segments containing the female gonads. About 4300 species of earthworms exist worldwide (Reynolds and Cook 1976, 1981, 1989). Many general zoology texts provide a good summary of earthworm anatomy, but Edwards and Lofty (1977) and Reynolds (1977) provide introductions directed specifically to the individual interested in earthworm studies.

In North America there are five families of earthworms: the Lumbricidae, Megascolecidae, Komarekionidae, Sparganophilidae, and Lutodrililidae (Gates 1982, James 1990). The last two are found exclusively in saturated or submerged soils under or next to lakes and rivers. The Komarekionidae have a limited distribution within the Appalachian Mountains.

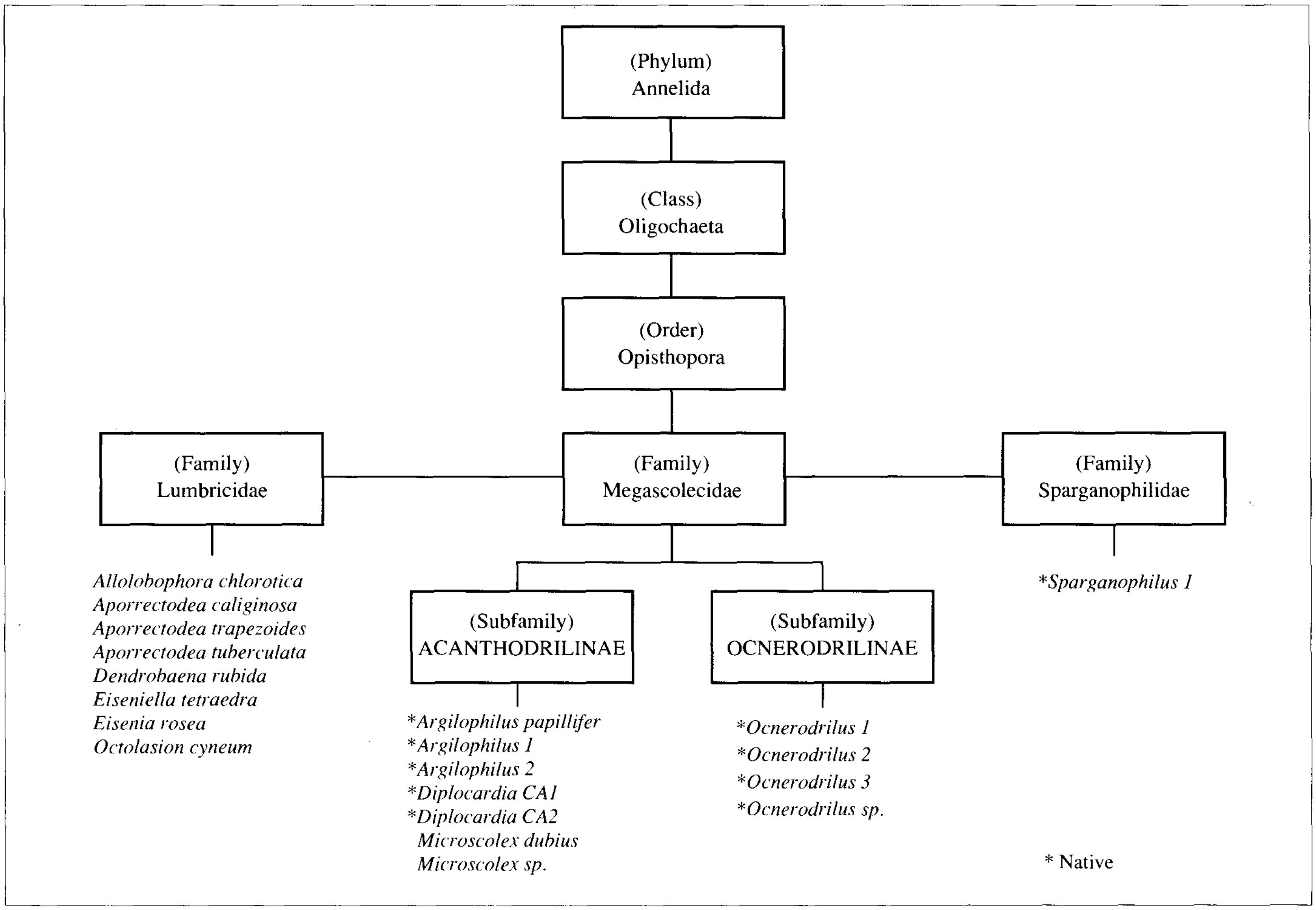

Figure 2-The earthworms collected in southern California represent three families in the phylum Annelida.

The most commonly encountered earthworms in the United States are Lumbricidae, usually species accidentally imported from Europe. However, the two genera, *Bimastos* and *Eisenoides*, are native to eastern North America. A good key to their identification is by Schwert (1990). The bulk of the earthworm ecology and biology literature is concerned with European Lumbricidae.

Megascolecid earthworms are represented by several genera naturally occurring in the United States, plus a few genera of Asian or South American origin (Fender and McKey-Fender 1990). The native genera include *Diplocardia, Arctiostrotus, Argilophilus, Chetcodrilus, Kincaidodrilus, Driloleirus, Macnabodrilus, Toutellus, Nephrallaxis,* and *Drilochaera.* In addition, there are some species of the megascolecid subfamily Ocnerodrilinae, but they are new taxa and not yet assigned to a genus.

The gross external morphology of all earthworms is essentially the same *(fig. 3).* Earthworms have a mouth at the head or anterior end and an anus at the tail or posterior end. They have no eyes. Their bodies are cylindrical and are composed of individual sections or segments, often numbering a hundred or more. Each segment contains setae (hairs) that can be extended or retracted. Mature earthworms have a clitellum, a ring-like or saddle-shaped collar that functions in reproduction, near the anterior end of the body. The location of the clitellum, relative to the number of segments it is from the anterior end, is an aid to species identification in the Lumbricidae and Megascolecidae *(fig. 4).* The visible external sex organs are all located in the anterior region; their prominence and positioning by segments are also important taxonomically.

Earthworms are hermaphroditic, though there are cases of parthenogenesis. Generally earthworms reproduce by exchanging sperm, which is stored in spermatophores or spermathecae. The sperm fertilize eggs which are deposited in an ovate sac containing eggs (one to many) and a food source for the developing embryo(s). The sac or cocoon is secreted by the clitellum *(fig. 3)* and deposited in a small cavity in the soil. Development time varies among species, and can be prolonged by drought or cold. A general figure for common species during the growing season is 3 to 4 weeks from deposition to hatching.

After hatching, the period of growth to maturation may be short, a matter of 5 or 6 months in some small species living on rich organic substrates, or much longer in the cases of large species living on relatively low-quality diets. The largest earth-

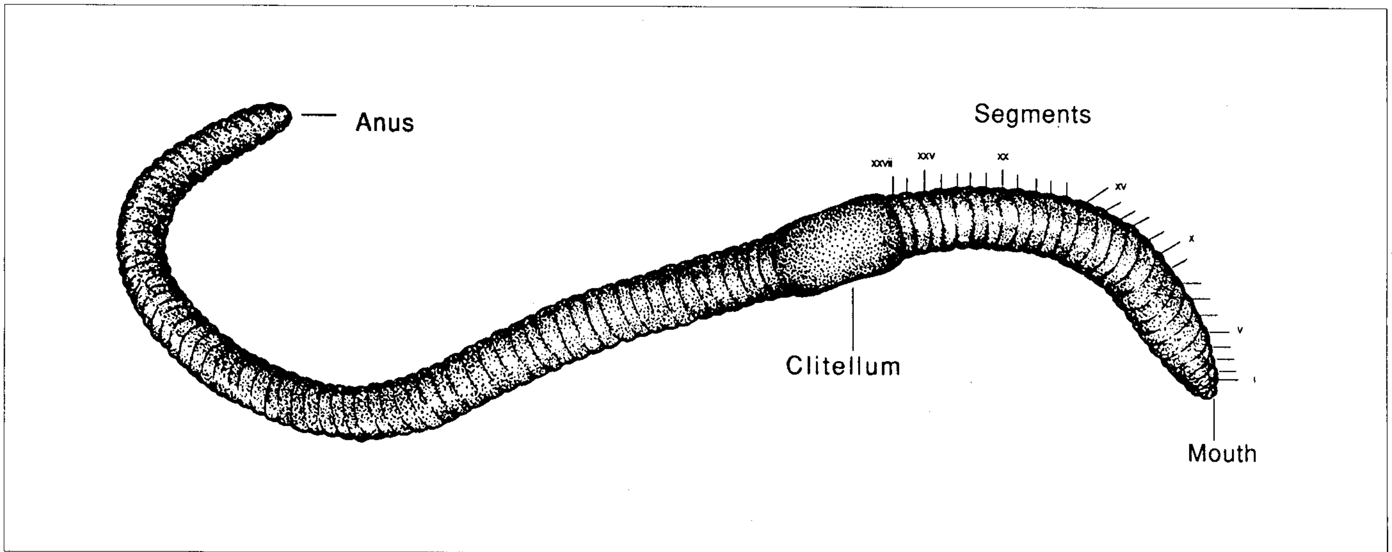

Figure 3--All earthworms have essentially the same external morphology.

worms are not from California, but are found in Brazil, South Africa, and Australia. They are over a meter long, with reports of some up to 2 meters, and weigh 500 grams (fresh weight). Such species may take a few years to reach maturity.

Seasonal Activity Patterns

Given habitable soils and an adequate food supply, earthworm activity is primarily governed by temperature and moisture. Low soil temperatures limit activity, though active earthworms have been observed just below snow cover in unfrozen soil. However, maximal activity usually takes place at moderate temperatures. For most European Lumbricidae, activity peaks between 10 and 20 °C (Daugbjerg 1988, Edwards and Lofty 1977, Laverack 1963). Some *Diplocardia* are known to tolerate close to 30 °C, and tropical species generally tolerate higher temperature optima than do temperate species (Madge 1969). When temperatures become too low for activity, earthworms become dormant. Similarly, when high temperatures are encountered, and depending on the species, a worm may enter a true diapause state lasting for a fixed period of time, or simply cease activity until temperatures return to lower levels (Edwards and Lofty 1977). In temperate zones with spring and summer rainfall, activity may close in midsummer due to high soil temperature, even with adequate soil moisture (e.g., James 1991).

Soil moisture is the other primary factor controlling activity. Earthworms are fundamentally aquatic in body plan, requiring a moist surface for gas exchange. Thus there must be free water present in soil for them to be active. Earthworms are 65-90 percent water by weight, and depend on hydrostatic pressure for their ability to burrow (Dales 1963, Lee 1985). A loss of 10 percent of body water can prevent movement (Satchell 1967). Water leaves earthworms through the cuticle, in castings, through the nephridia in urine, and through dorsal pores in the species having them. Daily water turnover can be 10-20 percent of the total body weight (Lee 1985).

When soil moisture begins to fall towards some critical value, earthworms burrow deeper into the soil to find moisture, or enter a dormancy called quiescence. This state is indistinguishable from the dormant states induced by high temperatures; the two often occur together. When earthworms cease activity in drought, they void their guts within a roughly spherical cavity and roll themselves in a ball. Thus encased with a plastering of their castings, they can remain inactive for long periods, losing up to 75 percent of their body water and slowly metabolizing their reserves (Edwards and Lofty 1977). This quiescence can be quickly broken with the introduction of water.

Ecological Strategies and Feeding Behavior

Being so dependent on soil moisture, earthworms are influenced by soil texture. They are found in all textural types, but they seem to do best in loamy soils, followed by clays and coarse sands (Guild 1948). Unless precipitation is steady, very coarse-textured soils do not retain enough water to support earthworm activity. Soil pH tolerance ranges vary among species, but in general few earthworms are able to live in soils at or below pH 4. The upper limit is weakly alkaline, in the neighborhood of pH 8 (Edwards and Lofty 1977).

Soil organic matter is vital to most earthworms, primarily as a source of food. The North American lumbricid genus *Bimastos* is an exception, since most of its species inhabit rotting logs rather than soil. Other groups of earthworms, as described below, are relatively independent of soil organic matter.

Most earthworm species can be placed into one of three basic types by ecological, niches: (1) epigeic--surface feeders and surface dwellers, (2) anecic--surface feeders that dwell in burrows sometimes deep within the soil, and (3) endogeic subsurface feeders and subsurface dwellers (Bouche 1977, 1983; Lavelle 1983; Lee 1959, 1985).

The first type, the epigeic earthworms, feed on surface litter or other forms of organic matter above the mineral soil, such as logs or accumulations in rock crevices or tree limb crotches. Typically they are darkly pigmented, relatively small, have high reproduction rates, and flee rapidly to avoid capture. Such species may retreat to the soil to avoid intolerably dry or hot conditions in the surface litter, but ordinarily would not be found in the soil except as transients.

The second type, the anecic earthworms, create deep vertical burrows or burrow systems from which they emerge to feed on surface organic matter, such as dead leaves, seeds, or small twigs. The most familiar example is the nightcrawler (*Lumbricus terrestris*). A few native North American species are known or suspected to be deep burrowers. Among these are the largest *Diplocardia, D. fusca,* and *D. biprostatica,* and some large species endemic to the Pacific Northwest. Anecics are usually large, long-lived, darkly pigmented on the anterior dorsal surface, and capable of rapid escape by

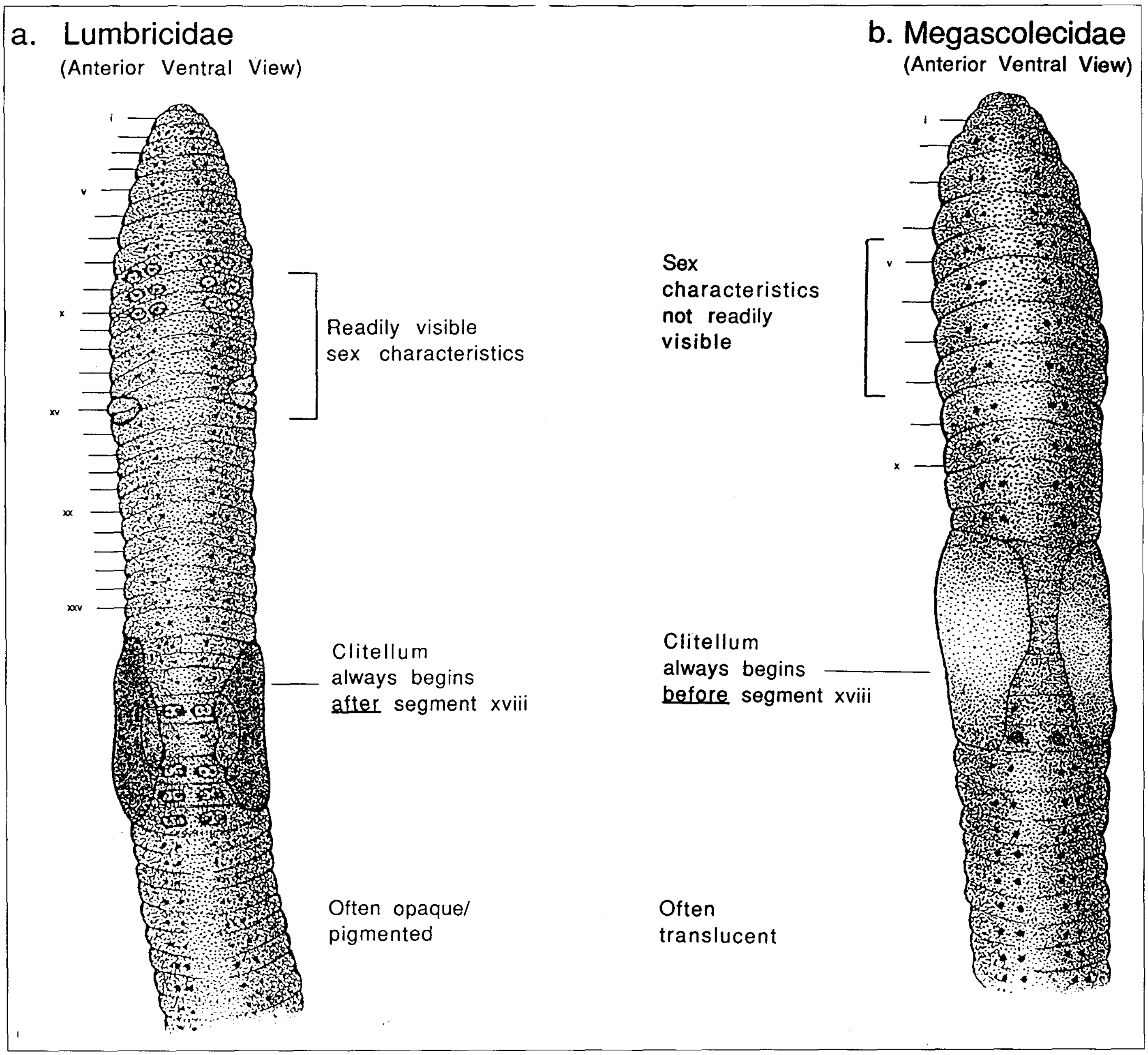

Figure 4-Lumbricidae (a) and Megascolecidae (b) from southern California can often be distinguished by their opacity or translucence, segment position of the clitellum, and by the position and prominence of sex characteristics.

quick contraction and moving down their burrows. This behavior makes them difficult to sample accurately. Special techniques such as formalin extraction may have to be used (Raw 1959). Dilute solutions of lime sulfur (calcium polysulfide) are effective for large anecic *Diplocardia* and are used by fishermen in south Texas. Soil vibration may also be effective on some species, but the accuracy of quantitative sampling by this method is poor (Lee 1985).

The last type, the endogeic earthworms, in general are lightly colored to unpigmented, slower moving, may exude fluids when irritated, and vary considerably in size. The endogeic type is divided into three subgroups: polyhumic, mesohumic, and oligohumic, referring to decreasing concentrations and lability of organic matter consumed by the earthworms (Lavelle 1983). Polyhumic species live in the soil proper, but nearer the surface than the other two subgroups, and consume partially decomposed organic matter in the soil. Oligohumic species live deeper in the soil and feed on relatively stable soil organic matter. Mesohumic species are intermediate in vertical distribution and organic matter consumed. Those feeding on further decomposed material, such as the mesohumic and oligohumic types, tend to be larger. The distinctions among the three groups of endogeic earthworms are fine, so one may wish to lump them together in the early phases of studying earthworms.

When soil and organic matter are ingested by an earthworm, the materials are subjected to mechanical and chemical action. The order of events varies among earthworm families, but consists of the same basic processes: grinding in a tough muscular gizzard; treatment with earthworm-generated enzymes and mucus (Lavelle and others 1983); attack by microbes in the ingested soil, or in the gut of the earthworm, or both; absorption of nutrients; and excretion of unassimilated material. In some species a glandular region produces calcium carbonate which is added to the gut contents. Like other detritivores, earthworms may derive more nutrition from microbes colonizing ingested detritus than from the detritus itself (Cummins 1974).

Influence on Soils

Earthworms alter soil both chemically and physically. By burrowing and casting, earthworms mix soil horizons (e.g., Buntley and Papendick 1960, Langmaid 1964) and change the physical structure of the soil. Their effects on soil are considered beneficial to plants (Edwards and Lofty 1977). Vertical mixing between soil horizons is accomplished by the different ecological types of earthworms. Epigeic species, for example, break down surface litter and accelerate incorporation of decomposed organic material into the upper few centimeters of soil. Anecic species bring subsoil material to the surface and line their deep burrows with highly organic cast material derived from surface plant remains.

Some structural changes to soil resulting from earthworm activity are increased porosity, decreased bulk density, changes in pore size distribution, and increased water stability of soil aggregates. Air and water move more freely in worm-worked soils, and root penetration may be facilitated (Lee 1985). Water entry into the soil is often greatly enhanced by earthworm activity (Edwards and others 1989, Ehlers 1975), thereby reducing surface water runoff and consequent soil transport. Earthworms help reduce crusting of surface soil, a problem in many cultivated soils (Kladivko and others 1986). Earthworms actually reduced soil erosion in cropland (Hopp 1946). Fresh surface casts are easily dispersed by raindrop impact, while aged casts are more stable (Marinissen and Dexter 1990, Shipitalo and Protz 1989).

Depending on the feeding and burrowing habits of the earthworm, casts may be deposited as a lining of the burrow, within burrows or krotovinas (tunnels made by other burrowing animals), in the soil, or on the surface. Casts are higher in available nutrients than the surrounding soil. This does not mean that earthworms supply more nutrients to the soil, merely that the form of nutrients is more readily accessible to plants (Lee 1985). Casts contain a myriad of different microbial populations (bacteria, fungi, protozoa), and biological and enzyme activity in fresh casts is high, with a rapid decline as the cast ages (Edwards and Fletcher 1988, Parle 1963a, b).

From a plant nutrition standpoint, interactions are not well understood among earthworms, plants, and mycorrhizal fungi-major symbionts for plant nutrient uptake. Earthworms may be major dispersal agents or detrimental consumers of mycorrhizal fungi (Rabatin and Stinner 1988, Reddell and Spain 1991). Another source of available nutrients, primarily nitrogen, is earthworm urine, excreted from the nephridia in each segment. Additional nitrogen is added to the soil when the earthworm dies; slightly over 70 percent of the dry weight of an earthworm is protein, and about three-quarters of that is usable nitrogen (Satchell 1967).

Survey of Southern California Habitats

Collection Areas

Ten broad geographical areas were selected to represent Mediterranean climatic zones in essentially wildland settings in southern California. The northernmost collection area was the Los Padres National Forest near Santa Barbara and the southernmost the Palomar District on the Cleveland National Forest in San Diego County *(fig. 1)*. We searched each of these areas and collected earthworms from a wide variety of vegetation and soil habitats ranging in elevation from 55 to 1876 meters. Vegetation types included many different chaparral associations, native and exotic grasslands, oak woodlands, and riparian zones containing various mixed hardwoods. A few high elevation mixed oak-conifer sites were also sampled.

Most of the earthworms were collected by digging into the soil with a shovel, hand sorting through the excavated material, and picking out specimens. The average maximum sampling depth was about 30 cm. On a few occasions we used a formalin solution extraction procedure (Raw 1959) with limited success. Other known earthworm collection techniques, such as electric shock, vibrating metal rods, and "thumping" procedures (Lee 1985) were not used. We did not attempt to quantify earthworm populations in any of the areas sampled. A major note of caution: "one-time" sampling such as was done for this project is no assurance that data collected is representative of a particular site or area. Our two major collecting periods were late March-early April 1990 and late April 1991. Ideally, one would visit a site at intervals during an entire season and sample more intensively at every site.

The live earthworm specimens were placed in plastic vials immediately upon collection. Detailed notes taken at each sampling spot included location, date, time, habitat (such as landscape position, plant species), and soil information. Once we completed collecting at a site, the live earthworm specimens were removed from the collection vials, and quick-killed and cleaned by placing them in a 50 percent solution of ethanol for a few minutes. The specimens were then placed in a 5 percent formalin solution for a minimum of 1 week. Specimens retained for long-term storage were eventually placed in a 70 percent ethanol solution.

Identification was a three-stage procedure. The first stage was gross field examination sometimes with the aid of a hand lens. Relying solely on external morphological characteristics, all of the specimens could be identified at the family level, about 95 percent to genera, and about 50 percent to species. Many of the specimens were juveniles or were fragmented, thereby limiting identification or making it impossible. In the second stage of identification, specimens were examined in the laboratory under a low power microscope, to cross check and verify the field classification, based again on external morphological characteristics. In the third stage specimens that could not be identified by external features alone were dissected and identified using various taxonomic keys based on internal structures (Gates 1977 a, b, James 1990, Michaelson 1900, Schwert 1990). In a few cases, when a new species was encountered, we described and recorded complete external and internal features. We searched known taxonomic records for past documentation of the same or similar species, to verify possible new species. The new species found in this survey will be described in separate publications. In this report, the new species are identified by genus name and a temporary label for the species, e.g., *Argilophilus* 2.

Results

Classification of Collected Earthworms

We collected and identified 20 diverse earthworm species *(table 1)*. Half of them are native species, including hitherto undescribed new species or genera. The species collected represent 11 genera, 3 families, and 2 subfamilies *(fig. 2)*. Most of the specimens collected were nonnative earthworms in the family Lumbricidae. They were, in fact, the most abundant and most widely distributed earthworms encountered.

The earthworms found most often in this survey were the introduced species, *Aporrectodea trapezoides* and *Eiseniella tetraedra*, followed closely by *Eisenia rosea* and *Allolobophora chlorotica (table 1)*. The best known earthworm species in North America, the night crawler, was not collected from any of our sampling areas. A high percentage of specimens were juveniles (without well-formed clitellae) and could be classified only as juvenile Lumbricidae.

The native earthworms belonged to two different families: Megascolecidae and Sparganophilidae *(fig. 2)*. Of special interest are species in two genera, *Diplocardia* and *Argilophilus*, belonging to the family Megascolecidae (subfamily Acanthodrilinae). Several of these species have not been described before. Based on our field observations, these species have soil ameliorating behavior comparable to some of the nonnative species. We know essentially nothing of their biology. They apparently do not require continually wet or moist soil conditions, and are primarily subsurface casters. The two other native species collected are small and thin, and are limited to water-saturated habitats. These two are represented by species yet unnamed. One is in the Ocnerodrilinae (a subfamily of the Megascolecidae), but not assignable to any known genus and the other in the genus *Sparganophilus* (family Sparganophilidae).

Origins and Distributions

The earthworm fauna of the areas sampled indicate that the region has elements of three separate sources. The nonnatives are the Lumbricidae introduced from Europe (Gates 1982) and *Microscolex* from southern South America (Michaelsen 1900). The Lumbricidae encountered are now widely distributed throughout the temperate zones of the world. The indigenous component consists of new species of four taxa: *Argilophilus*, *Diplocardia, Ocnerodrilus,* and *Sparganophilus.*

Most earthworm introductions are the result of transporting plants and soils from one part of the world to another (Lee 1985). After the initial introductions, further dispersal mechanisms are many and varied. Humans, of course, are the major distributors. In the United States, the shifting and settling of millions of people over the centuries likely has been responsible for the spread of nonnative earthworm species. Lakesides and stream banks are prime candidate areas for earthworm establishment because of discarded earthworm fish bait. Marijuana plantings in remote areas may be another recent introduction mechanism. Colonization, reproduction, and spreading then occur. Aside from humans, floodwaters are known to carry viable cocoons and live earthworms for redistribution elsewhere. Birds and other animals have also been suggested as dispersal mechanisms (Schwert 1980).

These dispersal mechanisms may seem unlikely for some of the sites and species in this survey. For example, Fern Canyon on the San Dimas Experimental Forest is remote and uninhabited, yet had three introduced species. One of them, *Eiseniella tetraedra*, is limicolous (mud-loving) to aquatic, and generally is not used as fish bait. It would not be transported with ordinary garden plants or by fishermen. How, then, did it reach

Table 1--*Native and introduced earthworm species collected in southern California, by general locations*

Earthworm species	**Los Padres National Forest** Santa Barbara, Ojai, Mt Pinos Ranger Districts	**Point Mugu State Park**	**Angeles National Forest** Arroyo Seco, Mt. Baldy Ranger Districts	**San Dimas Experimental** Forest	**San Bernardino National Forest** Arrowhead Ranger District	**San Bernardino National Forest** San Jacinto Ranger District	**Santa Rosa Plateau** Preserve	**Cleveland National Forest** Trabuco Ranger District	**Santa Margarita** Ecological Reserve	**Cleveland National Forest** Palomar Ranger District
Allolobophora chlorotica	•			•			•		••	
Aporrectodea caliginosa	•••	•		•••••	•••	•		•		•
Aporrectodea trapezoides	••••		•••	•••••••••	•		•	••	•	••
Aporrectodea tuberculara				•						
Aporrectodea sp.					•					
**Argilophilus papillifer*		•								
**Argilophilus 1*	•									
**Argilophilus 2*			••••							
**Argilophilus sp.*		•••		•	••			•		
Dendrobaena rubida			••			•				
**Diplocardia CA1*							•	•••		••
**Diplocardia CA2*							•			
Eisenia rosea	••	••••••	•				•	••		••
Eiseniella tetraedra	••		•	•		•	•			
Lumbricidae juveniles	•	•	•	••••••••			••		•	
Microscolex dubius		••••							•	
Microscolex sp.	•		••	••••••						
**Ocnerodrilus 1*									•	
**Ocnerodrilus 2*	•									
**Ocnerodrilus 3*									•	
**Ocnerodrilus sp.*	•			•••			•	•	•	
Octolasion cyaneum	•									
Octolasion sp.			•							
**Sparganophilus 1*									•	

*Native
•Different collection sites
1 "See FIGURE 1 for geographic locations of collection sites, and see APPENDIX for descriptions of collection sites."

this site? More detailed knowledge of site histories and earthworm dispersal mechanisms is needed to answer this question.

The genus *Microscolex* originated in the Southern Hemisphere (Michaelsen 1900). Two species, *Microscolex dubius* and *Microscolex phosphorous*, are now widely distributed due to human activity. Both are variable, making identification difficult.

Argilophilus is restricted to the Pacific Coast States of Washington, Oregon, and California (Gates 1977b, Fender and McKey-Fender 1990). Prior to the survey reported here, the southernmost record was from Fresno County, California (Eisen 1894). Three species were collected; two of them are believed to be new. The known species, *Argilophilus papillifer*, was collected from Point Mugu State Park in Ventura County. The others, as yet undescribed, were from locations even farther south, in both the Angeles and San Bernardino National Forests *(table 1, app.)*. They may be widely distributed, but further collecting will be required to determine how widely. Juveniles, probably also of an *Argilophilus* species, found on the San Dimas Experimental Forest may belong to one of the new species or even to a third. The absence of *Argilophilus* earthworms from apparently suitable habitats on the San Jacinto Ranger District, San Bernardino National Forest region may indicate the boundary of the genus is north of there.

The two new species of *Diplocardia* found are similar to *Diplocardia keyesi*, known only from Ensenada, Baja California (Eisen 1900). All other members of the genus are from the Central and Southern United States and Northeastern Mexico. The new species are an important find from a biogeographical perspective. It appears their northern limit is at about 34 degrees N., excluding the San Jacinto Peak area of the San Bernardino National Forest. The southern California species of *Diplocardia* were found in a system of mountains (Peninsula Range) extending from the Santa Ana Mountains south into Mexico. Though we have not examined all the potential areas for *Diplocardia*, they likely will be found in suitable habitats of most sections of the Cleveland National Forest.

Our finding of Ocnerodrilinae in several aquatic habitats is another tie to the earthworm fauna of Mexico, which includes many in this subfamily. Some described species in the subfamily, however, are quite variable (Eisen 1900, Gates 1982). We are not yet certain that the California species found are distinct taxa, but it appears likely.

Some *Sparganophilus* were found also. This finding is significant, because other than a few records from northern California, the genus is unknown from California. The bulk of the range of *Sparganophilus* is the eastern United States (Reynolds 1980).

We encountered what appears to be a biogeographical boundary separating two elements of the native earthworm fauna of southern California. To the north and west of San Gorgonio Pass, including the low coastal mountains of Point Mugu, the genus *Argilophilus* was present. No native earthworms were found in the San Jacinto Peak area *(table 1,* San Jacinto District), though some introduced Lumbricidae were collected. *Diplocardia* were found in the Santa Ana Mountains west of Lake Elsinore, in foothill grasslands near Temecula, and in the vicinity of Palomar Mountain, all south and west of the San Jacinto Peak area. *Argilophilus*, which is primarily a Pacific Northwest group, apparently reaches its southern limit at about 34° N. Presence of *Argilophilus* in the Santa Lucia and Coast Ranges toward Monterey is possible.

In contrast, *Sparganophilus* sp. and *Ocnerodrilus* spp. were encountered in sediments of streams north and south of 34° N.

Habitat Preferences

The wetter sites (riparian areas) are obviously preferred habitats for many of the species encountered during this survey. In these wet habitats a wide variety of food sources (organic matter) is available. With the exception of the almost aquatic genera *Ocnerodrilus* and *Sparganophilus*, which exist in saturated soils and mucks, no particular vegetation or soil type was noted to be associated with them. In the mesic or "arid" collection sites, or where earthworm activity was evident, a definite habitat or plant type community preference began to emerge. Soils under oaks *(Quercus* spp.) and grass (including *Avena, Bromus, Stipa)* had the greatest earthworm activity followed by ceanothus *(Ceanothus* spp.), chamise *(Adenostoma fasciculatum)*, and pine *(Pinus* spp.).

Our observations generally confirm the earthworm plant preferences observed in the soils of the large, unconfined lysimeters on the San Dimas Experimental Forest, which contains monocultures of scrub oak, ceanothus, chamise, and pine. The worm-worked A horizon under oak was at least three times as thick as any other A horizon, had higher clay contents and greater aggregate stability (Graham and Wood 1991).

Apart from the semi-aquatic species and the riparian forests, chaparral plant communities do support earthworm populations to some degree. They are less abundant in chaparral, however, and a great many of the chaparral sites appear not to support earthworm populations at all. Populations may have been reduced by the 4-5 years of subnormal precipitation that preceded our collections in 1990-91.

Most of the introduced species have distributions dependent on human activity. It is difficult to draw any conclusions about their plant food preferences, although an oak > grass > ceanothus > chamise > conifer preference for many of the earthworm species might be a good guess. This order assumes adequate soil water and does not distinguish between soil types. We did find several locations where pine trees had been introduced in chaparral environments as roadside amenity plantings or fuel breaks, where nonnative earthworm species were present. The earthworms were probably introduced to these sites during planting of the containerized pine tree stock. Our general observation is that earthworms, introduced or native, are usually not found in soils under naturally developed conifer stands in southern California.

The native *Argilophilus* species were found in grasslands, oak forests, and various chaparral types *(table 2)*. A single specimen was collected in a sandy soil on the flood plain of the West Fork of the San Gabriel River, under mixed hardwoods. On the San Bernardino National Forest, *Argilophilus* sp. was

Table 2--*Habitats of the earthworm species collected in southern California*

Earthworm species	Woodland	Grass	Grass/ Woodland	Chaparral	Riparian	Aquatic
Allolobophora chlorotica				•	•	•
Aporrectodea caliginosa	•	•	•	•	•	•
Aporrectodea trapezoides	•	•	•	•	•	•
Aporrectodea tuberculata	•					
Aporrectodea sp.				•		
**Argilophilus papillifer*		•				
**Argilophilus 1*	•					
**Argilophilus 2*	•				•	
**Argilophilus sp.*		•	•	•		
Dendrobaena rubida	•					•
**Diplocardia CA1*		•	•			
**Diplocardia CA2*				•		
Eisenia rosea	•	•	•	•	•	•
Eiseniella tetraedra					•	•
Lumbricidae juveniles	•	•	•	•	•	•
Microscolex dubius	•	•	•	•		•
Microscolex sp.		•		•	•	•
**Ocnerodrilus 1*						•
**Ocnerodrilus 2*						•
**Ocnerodrilus 3*						•
**Ocnerodrilus sp.*		•		•		•
Octolasion cyaneum						•
Octolasion sp.		•				
**Sparganophilus 1*						•

*Native

found at elevations above 1500 m in oak-conifer-grasslands, but confined primarily to the grassed areas within these zones. We tentatively offer as an hypothesis that *Argilophilus* is primarily associated with grasslands and oaks in southern California. Eisen (1894) observed *Argilophilus* to be confined to "heavy adobe or clayey soil." We also collected them in this type of soil (grass-covered Vertisols from Point Mugu State Park), but primarily we found them in lighter soil types.

Diplocardia spp., the other native species, were collected from several locations on the Cleveland National Forest's Trubuco and Palomar Ranger Districts. Although we collected them from a number of different habitat types (mixed chaparral, oak, and grassed areas), the highest population numbers were in the grasslands. Where we found them in the oak or chaparral habitats they were invariably associated with introduced species, with the nonnatives outnumbering them by a considerable margin. On some of the cattle-grazed grassland sites, cattle droppings (a desirable food source for many *Lumbricid* species) appeared not to be a prime food source for the *Diplocardia.* Collection success was no greater under droppings than elsewhere.

The habitats where *Diplocardia* were found on the Santa Rosa Plateau Preserve illustrate some of the complexities in attempting to define habitat preferences for these native species. *Diplocardia* CA1 was found on Mesa de Colorado near the largest of the vernal pools. The site was wet, soils were deeper than 30 cm, and vegetation included grasses and a mix of wetland species on the fringes of the vernal pool. *Diplocardia* CA2 was collected in slightly moist, deep soils in mixed chaparral (scrub oak, black sage, chamise) on a slope leading to Mesa de Burro. Some earthworm activity was evident on Mesa de Burro at the shrub-grass interface, but not in the herbaceous vegetation, which was within 50-100 m of the vernal pools where the soil depth is generally 20 cm or less.

Several possible explanations emerge. The *Diplocardia* species may have restricted and specialized distributions or soil depth limitations. Conditions at the time of collecting may not have been conducive to finding the species present in the grass-forb community on Mesa de Burro. Neither species of *Diplocardia* was found in other chaparral sites, grasslands, or riparian areas on the Preserve. However, Lumbricidae and Ocnerodrilidae were found in the grassland and riparian habitats of the Preserve. *Diplocardia* CAI was collected from numerous grassland sites on the Trabuco and Cleveland Districts of the Cleveland National Forest.

We repeatedly observed, particularly under oaks, that where earthworms, their burrows, and castings were abundant, depth of leaf litter was reduced. Also, the leaf litter showed little evidence of decomposition throughout its depth profile (classified as an Oi horizon in its entirety). Where earthworms were not evident, the leaf litter was often deep, having Oi, Oe, and Oa horizons, indicating increased decomposition with depth. And depending on the site, the litter below the immediate surface on the earthworm-free sites was frequently intertwined with abundant fungal mycelia. We never found earthworms and a thick litter layer, except where steep slopes deposited extra litter at their bases. We never found earthworms and the abundant mycelia just mentioned in the same spot.

Earthworm activity, by reducing litter volume, probably does not reduce surface fuel loads enough to be a significant factor in reducing fire initiation and propagation. On the other hand, this accelerated decomposition process may provide a greater soil nutrient capital, promoting greater plant productivity.

Summary and Concluding Remarks

We are encouraged by our discoveries in this somewhat rudimentary excursion into the earthworm world of some southern California wildland habitats. A wide variety of species were collected from many different habitats. Nonnative species far outnumbered the natives. Several new species of native earthworms were collected, and work on their taxonomies is being assembled.

Some harsh chaparral sites contained earthworm populations, many of them native species. The wetter sites, typically accepted as the best earthworm habitats, were found to have an abundance of species, in most cases, primarily introduced ones. Well-defined habitat (food-plant) preferences for the more mesic or dryland areas are not nearly as clear-cut. Our observations lead us to this generalization: the most preferred plant habitats on the drier sites are the oaks and grasses, followed by ceanothus and numerous other chaparral species, some of the least preferred being chamise and buckwheat; conifers seem to be the least preferred.

At this stage nothing definitive can be said regarding soil types or soil preferences on the drier sites we sampled. The majority of soils were deeper than 35 cm, and textures ranged from heavy clays to sands. Soil orders included Mollisols, Entisols, Alfisols, Inceptisols, and Vertisols. Most, but not all, had mollic or umbric epipedons (diagnostic surface horizons) that were darker in color than the subsurface horizons. The predominate soil feature indicative of earthworm activity (not soil preference) is in the kind and degree of soil structure, particularly in the surface horizons. Most earthworm-worked soils we investigated had some granular or crumb structure to them; loose single spheroids to aggregated spheriods, ranging from less than 1 mm to greater than 5 mm. We believe earthworm castings are the principal components contributing to this distinctive type of structure. It should be possible to identify, within certain limits, the earthworm genus or even the species, based on characteristics of the observed cast material and soil structure (Rusek 1985).

Soil surveys for southern California contain little mention of earthworm-influenced soils (Anderson 1966, Bowman 1973, Edwards and others 1970, Knecht 1971, O'Hare and Hallock 1987, Retelas 1980, Ryan 1991). Many of the soils we encountered, some covering fairly extensive areas, were heavily influenced by earthworms and should be considered worm-worked by any standards. These soils probably meet the Soil Taxonomy (USDA 1975) criteria of "verm"; and somewhere in their taxonomic classification this fact should be noted. Why a major diagnostic soil attribute (thick surface horizons, with greater than 50 percent of the soil volume composed of worm-worked casts and burrows) has not been recognized until now in southern California is somewhat of a puzzle to us.

Research and Management Needs

Before this survey was begun we had little idea of what earthworm populations and species existed in southern California. We now know that some rather diverse, if not unusual, earthworm habitats are populated by both native and introduced earthworm species. From an ecological and biological diversity perspective we find this fact exciting but tremendously perplexing and complex, for it raises numerous questions of interest to research and management that will not necessarily be easy to answer. Some of the answers may come if research on earthworms is conducted in the following four areas:

- Taxonomy, biology, ecology, and population dynamics
- Impacts on soil physical, chemical, and hydrological properties
- Interactions with soil and plants
- Role in fire-adapted ecosystems

Earthworm taxonomy, biology, ecology, and population dynamics--One of the biggest problems we encountered during the general course of this project was obtaining live, adult specimens from the drier, chaparral sites that we knew contained earthworms based on the presence of cast material. Seasonal patterns of activity, growth, and reproduction for both selected native and introduced species need to be clearly understood. The winter and early spring rainy period clearly is most conducive to earthworm activity, but it is not known whether soil temperatures at mid-to-low elevations (1500-300 m) ever become low enough to suppress earthworm activity. Soil temperatures below 6 °C terminate activity in many common Lumbricidae, including *Aporrectodea caliginosa* and *A. trapezoides.* The upper limit for activity is about 25 °C. Absolutely nothing is known of the temperature tolerances of any *Argilophilus,* including the species found in this survey.

Earthworm related impacts on soil physical, chemical, and hydrologic properties--Earthworms undoubtedly enhance both the chemical and physical condition of soils, often with consequent increases in plant productivity, improved water intake rates into the soil, enhanced water and nutrient transmission to the lower depths, and increased aggregate stability. The question now is this: are earthworms a major soil ameliorating factor in selected wildland sites in southern California? To answer this question studies should be initiated comparing chemical and physical differences between worm-worked and worm-free soils, in both field and laboratory settings, involving different soil types and plant species. Both native and introduced earthworm species should be studied.

Earthworm-soil-plant interactions--Particular emphasis should be placed on earthworm-generated soil nutrient and soil biological effects relative to site productivity and plant growth processes. It would be useful to know the sensitivity of chaparral ecosystems to fertilization, the nutrient cycling patterns, and plant production in worm-free and worm-inhabited plots. One hypothesis is that under major litter-producing plant species (such as oaks), earthworms increase the rate of litter decomposition and reduce the importance of fungi in litter decomposition. Another is that earthworms enhance fungal importance by dispersing propagules and by speeding up fungal turnover, thereby making the fungi more active in nutrient cycling. We need to know what the interactions are among earthworms, mycorrhizal fungi, and plant nutrient uptake. In the somewhat controversial arena of global climate change, studies should be aimed at earthworm ecology in specific Mediterranean ecotones relative to plant and soil associations (including carbon dynamics).

Earthworms and fire--For the land manager in southern California, both wildfire and prescribed fire and their management are critical issues. Earthworms and fire have obviously coexisted in many of these fire-adapted chaparral ecosystems for quite some time. Just what role, if any, does the earthworm play in the interaction of fire, soil, and plant production and species composition or diversity? Earthworms may have a role in seed burial or retrieval after fire, or in improving water and nutrient transmission into soils that have been burned over, or even in breaking soil water repellency, which commonly occurs after fire.

Appendix--Earthworm Collection Records

This appendix lists the geographic locations we surveyed in order from north to south *(fig. 1)*. Earthworm species are listed alphabetically by geographic location, then collection sites are described.

In site descriptions, the formal soil taxonomic classifications (soil) are based primarily on published and nonpublished soil surveys (Anderson 1966, Bowman 1973, Edwards and others 1970, Knecht 1971, O'Hare and Hallock 1987, Retelas 1980, Ryan 1991). Often the soil type described in these surveys did not correspond to the soil type at the sites; in these situations we reclassified the soils. Elevation (elev.), latitude (lat.), and longitude (long.) were estimated from 7.5-minute U.S. Geological Survey quadrangle maps (quad.). Unless rainfall records were available for specific sites, average annual precipitation (precip.) was estimated from isohyets (U.S. Geological Survey 1969).

Los Padres National Forest

Santa Barbara, Ojai, and Mt. Pinos Ranger Districts

Species	Site
Allolobophora chlorotica	1
Aporrectodea caliginosa	1, 2, 3
Aporrectodea trapezoides	1, 2, 3, 4
Argilophilus 1 (new species)	5
Eisenia rosea	4, 6
Eiseniella tetraedra	1, 7
Lumbricidae (juveniles)	4
Microscolex sp	2
Ocnerodrilus 2 (new genus/species)	2
Ocnerodrilus sp	7

Site 1--About 500 m down old Hwy. 150, off Hwy. 154, from Cold Springs Resort. Streambed gravels, wet sands and muck; adjacent streambanks moist sandy loamy. Overstory *Quercus agrifolia* and *Platanus racemosa*. Litter depth 4-8 cm. Soil alluvial sands; elev. 473 m; aspect NE.; slope NA; precip. 640 mm; lat. 34°31'21" N.; long. 119°50'18" W.; quad. San Marcos Pass.

Site 2--Santa Ynez Recreation Area, Forest Service Rd. 5N 18, end of paved road past Live Oak Campground where Santa Ynez River crosses road. Streambed, gravelly muck. Scattered *Salix lasiolepis* and unknown marsh grasses and sedges. Soil alluvial sands; elev. 342 m; aspect NA; slope NA; precip. 690 mm; lat. 34°32'05" N.; long. 119°42'47" W.; quad. Little Pine Mountain.

Site 3--Wheeler Gorge Campground, north fork Matilija River, riparian zone. Typical worm-worked A horizon, no fungal mycelia in oak litter, mollic epipedon, loam, slightly moist, casting evident throughout A horizon and on surface. Primarily *a Quercus agrifolia* overstory, scattered *Platanus racemosa.* Soil probably Mollisols; elev. 616 m; aspect NA; slope NA; precip. 760 mm; lat. 34°31'09" N.; long. 119°16'26" W.; quad. Wheeler Springs.

Site 4--Santa Ynez Recreation Area, first major side drainage west of Santa Ynez campground on Forest Service Rd. 5N18. Mucky, gravelly sands in creek bottom. Soil alluvial sands; elev. 323 m; aspect N.; slope NA; precip. 685 mm; lat. 34°32'14" N.; long. 119°44'47" W.; quad. Little Pine Mountain.

Site 5--Hwy. 33, near marker 41.50, just south of Forest Service Rd. 6N06, in *Quercus agrifolia* grove next to highway. Moist, fine sandy loam; litter 6-14 cm. Single specimen also collected from adjacent field of *Artemisia tridentata,* fragmented shallow litter, ochric epipedon. Soil coarse-loamy, mixed, mesic Pachic Haploxerolls; elev. 1502 m; aspect N.; slope 7 pct; precip. 508 mm; lat. 34°38'54" N.; long. 119°22'40" W.; quad. Rancho Nuevo Creek.

Site 6--Sespe River, Hwy. 33. Specimens from an otherwise "sterile" riverbed in moist sands under 2-3 cm *Salix* sp. litter. Soil alluvial sands; elev. 1037 m; aspect NA; slope NA; precip. 635 mm; lat. 34°33'47" N.; long. 119°15'48" W.; quad. Wheeler Springs.

Site 7--Wheeler Gorge Campground, north fork Matilija River. Riverbed saturated sands and muck; overstory *Alnus* sp. and *Populus* sp. Soil alluvial sands; elev. 616 m; aspect NA; slope NA; precip. 760 mm; lat. 34°31'09" N.; long. 119°16'26" W.; quad. Wheeler Springs.

Point Mugu State Park

Species	Site
Aporrectodea caliginosa	8
Argilophilus papillifer	9
Argilophilus sp	10
Argilophilus sp. (juvenile)	11, 12
Eisenia rosea	8, 9, 11, 13, 14,15
Lumbricidae (juveniles)	16
Microscolex dubius	8, 9, 12, 14

Site 8--Wood Canyon/Campground. Overstory *Quercus agrifolia,* mixed grasses and *Toxicodendron diversilobum* understory. Dry to moist, surface loam, rocky and cobbly, worm-worked mollic epipedons under oak litter, otherwise ochric, depths quite variable. Soil fine-loamy, mixed, thermic Calcic Haploxerolls; elev. 55 m; aspect NE.; slope 1 pct; precip. 330 mm; lat. 34°08'57" N.; long. 119°57'41" W.; quad. Point Mugu.

Site 9--La Jolla Valley. Native grassland, primarily *Stipa pulchra,* some unidentified exotic grasses. Surface dry, moist to slightly moist below surface, light gray, heavy clay, sticky, some surface cracking. Soil fine, montmorillonitic, thermic Chromic Pelloxererts; elev. 244 m; aspect SW.; slope <2 pct; precip. 330 mm; lat. 34°06'20" N.; long. 119°03'18" W.; quad. Point Mugu.

Site 10--Chaparral slope adjacent and west of La Jolla Valley (site 9). Mixed chaparral vegetation of *Salvia mellifera, Salvia* sp., *Rhus* sp. plus unidentified others. Dry to slightly moist below surface, mainly ochric but some inclusions of mollic epipedons, loam to clay loam surface, sticky. Soil fine, montmorillonitic, thermic Typic Argixerolls; elev. 259 m; aspect E.; slope 8 pct; precip. 330 mm; lat. 34°06'04" N.; long. 119°03'25" W.; quad. Point Mugu.

Site 11--Ridge just east of La Jolla Valley (site 9). Mixed chaparral and grassland; *Stipa pulchra* and other unknown grasses, *Rhus* sp., *Salvia* sp., and other unidentified shrub species. Soil moist to dry, some cobbles, ochric epipedon, vertisol-like. Soil fine, montmorillonitic, thermic Abruptic Palexerolls; elev. 250 m; aspect NW.; slope 3 pct; precip. 330 mm; lat. 34° 06'21" N.; long. 119°02'36" W.; quad. Point Mugu.

Site 12--Last grassland-chaparral interface on road heading east from La Jolla Valley (site 9). Mixed grasses including *Stipa pulchra* and others; *Rhus* sp., *Salvia* sp. plus other shrubs. Soil moisture spotty, dry to slightly moist; dark gray to brown heavy clay, vertisol-like. Soil fine, montmorillonitic, thermic Abruptic Palexerolls; elev. 237 m; aspect NW.; slope 5 pct; precip. 330 mm; lat. 34°06'32" N.; long. 119°01'55" W.; quad. Point Mugu.

Site 13--Drainage cutting southwest through La Jolla Valley grassland (site 9), riparian zone. Under *Quercus agrifolia;* 10 cm litter, no fungal mycelia. Moist to very moist, mollic epipedon, vertisol-like. Soil fine, montmorillonitic, thermic Chromic Pelloxererts; elev. 236 m; aspect W.; slope 5 pct; precip. 330 mm; lat. 34°06'13" N.; long. 119°02'36" W.; quad. Point Mugu.

Site 14--Sycamore Valley, about 200 meters west of barn just off main road. Mixed grasses of unidentified species, scattered large *Platanus racemosa.* Deep (>30 cm) sandy loam, moist to dry, few rocks. Soil fine-loamy, mixed, thermic Fluventic Haploxerolls; elev. 256 m; aspect NW.; slope 1 pct; precip. 558 mm; lat. 34°08'57" N.; long. 119°57'41" W.; quad. Newbury Park.

Site 15--Chaparral slope adjacent and west of La Jolla Valley grassland site (site 9). Mixed chaparral vegetation of *Salvia mellifera, Salvia* sp., *Rhus* sp., plus unidentified others. Dry to slightly moist below surface, mainly ochric but some inclusions of mollic epipedons, sticky. Soil fine, montmorillonitic, thermic Typic Argixerolls; elev. 259 m; aspect E.; slope 8 pct; precip. 330 mm; lat. 34°06'04" N.; long. 119°03'25" W.; quad. Point Mugu.

Site 16--Eastern side of La Jolla Valley Loop Trail, *Quercus agrifolia* grove above spring; understory *Toxicodendron diversilobum.* Very slightly moist loam to clay loam, 3-7 cm litter depth, shale fragments throughout. Soil fine, montmorillonitic, thermic, Chromic Pelloxerts; elev. 170 m; aspect NW.; slope <5 pct; precip. 330 mm; lat. 34°05'55" N.; long. 119°02'20" W.; quad. Point Mugu.

Angeles National Forest

Arroyo Seco and Mt. Baldy Ranger Districts

Species	Site
Aporrectodea trapezoides	17, 18, 19
Argilophilus 2 (new species)	20, 21, 22, 23
Dendrobaena rubida	18, 24
Eisenia rosea	24
Eiseniella tetraedra	19
Lumbricidae (juveniles)	17
Microscolex sp	17, 22
Octolasion sp	17

Site 17--Glendora Mountain Rd. Close to 9.77-mile post on firebreak off Forest Service Rd. 1N26. Unidentified grasses. Moist, deep (8-22 cm) mollic epipedon. Soil fine, mixed, mesic, Pachic Argixerolls; elev. 750 m; aspect NW.; slope 5 pct; precip. 640 mm; lat. 34°10'49" N.; long. 117°50'52" W.; quad. Glendora.

Site 18--Glendora Mountain Road, Fallen Leaf Spring. Overstory *Quercus agrifolia.* Creekbed saturated sand and gravel. Soil alluvial sands and gravels; elev. 1330 m; aspect N.; slope NA; precip. 762 mm; lat. 34°13'02" N.; long. 117°41'50" W.; quad. Mt. Baldy.

Site 19--West Fork San Gabriel River, Forest Service Rd. 2N24, just below Camp Kole, sec. 18, R. 11 W., T. 2 N. Overstory *Quercus agrifolia*, *Platanus racemosa*, *Pseudotsuga macrocarpa.* Riverbed, saturated sands. Soil alluvial sands; elev. 1067 m; aspect N.; slope NA; precip. 762 mm; lat. 34°15'16" N.; long. 118°04'13" W.; quad. Chilao Flat.

Site 20--West Fork San Gabriel River, about 1/2 mile northeast of Camp Hi-Hill, around spring on side slope off Forest Service Rd. 2N24. *Quercus agrifolia* overstory. Wet to saturated sands with some organics. Soil alluvial sands and gravels; elev. 1196 m; aspect S.; slope 20 pct; precip. 762 mm; lat. 34°15'27" N.; long. 118°05'00" W.; quad. Chilao Flat.

Site 21--West Fork San Gabriel River, Forest Service Rd. 2N24, just below Camp Kole, sec. 18, R. 11 W., T. 2 N. Riparian zone streambank and streambed, overstory *Quercus agrifolia, Platanus racemosa, Pseudotsuga macrocarpa.* Riverbed saturated sands and riverbank moist sandy loamy, mollic epipedons. Soil alluvial sands and Mollisols; elev. 1067 m; aspect N.; slope NA; precip. 762 mm; lat. 34°15'16" N.; long. 118°04'13" W.; quad. Chilao Flat.

Site 22--West Fork San Gabriel River, Forest Service Rd. 2N24, just past first concrete low water road crossing east of Valley Forge Campground. Riparian zone, primary overstory of *Quercus chrysolepis.* Moist sandy loam, surface litter continuous, moderately deep. Soil alluvial sand and Mollisols; elev. 991 m; aspect NE.; slope NA; precip. 672 mm; lat. 34°14'55" N.; long. 118°03'47" W.; quad. Mt. Wilson.

Site 23--Southeast of Newcomb Peak, on Forest Service Rd. 2N24, sec. 26, R. 11 W.,T. 2 N. Stand of *Quercus chrysolepis* and dense understory of *Toxicodendron diversilobum,* scattered *Pseudotsuga macrocarpa* saplings. Mollic epipedon to 22 cm, slightly moist, loam, litter depth 12 cm. Soil loamy-skeletal, mixed, mesic, Typic Haploxerolls; elev. 1196 m; aspect NE.; slope 8 pct; precip. 762 mm; lat. 34°13'50" N.; long. 118°00'33" W.; quad. Mt. Wilson.

Site 24--Chilao Flats, just north of ranger station, Forest Service Rd., 3N18. Vegetation type not recorded. Dry gravelly loam, litter depth 3-5 cm, mollic epipedon. Soil probably a coarse-loamy, mixed, mesic Typic Xerochrepts; elev. 1598 m; aspect S.; slope 5 pct; precip. 762 mm; lat. 34°20'05" N.; long. 118°01'26" W.; quad. Chilao Flat.

San Dimas Experimental Forest

Species	Site
Allolobophora chlorotica	25
Aporrectodea caliginosa	26, 27, 28, 29, 30
Aporrectodea trapezoides	28, 29, 31, 32, 33, 34, 35, 36, 37
Aporrectodea tuberculata	33
Argilophilus sp. (juvenile)	27
Eiseniella tetraedra	34
Lumbricidae (juveniles)	29, 30, 32, 33, 34, 35, 36, 37
Microscolex sp	27, 31, 34, 38, 39, 40
Ocnerodrilus sp	34, 36, 37
Octolasion cyaneum	40

Site 25--Tanbark Flats, unconfined *Quercus dumosa* lysimeter. Soil fill material/coarse-loamy, mixed, mesic, Typic Xerorthents; elev. 860 m; aspect S.; slope <5 pct; precip. 690 mm; lat. 34°12'25" N.; long. 117°44'18" W.; quad. Glendora.

Site 26--Modal soil site "B," through locked gate, first finger ridge on left going down to Bell Canyon Dam. Mixed chaparral primarily *Quercus dumosa* and unknown grasses. Moist loam to sandy clay loam, mainly ochric but broken and scattered mollic/umbric epipedons. Soil loamy, mixed, thermic Typic Xerorthents; elev. 793 m; aspect N.; slope 20 pct; precip. 660 mm; lat. 34°11'45" N.; long. 117°46'46" W.; quad. Glendora.

Site 27--Tanbark Flats, chaparral slope NE of lysimeter installation, primarily *Quercus dumosa, Adenostoma fasciculatum, Ceanothus crassifolius.* Litter depth 3-6 cm, moist to slightly moist, some mollic but primarily ochric epipedons. Soil loamy, mixed, mesic, shallow Typic Xerorthents; elev. 872 m; aspect SW.; slope 8 pct; precip. 685 mm; lat. 34°12'36" N.; long. 117°44'15" W.; quad. Glendora.

Site 28--Tanbark Flats, *Quercus dumosa* confined lysimeter 20. Soil fill material/coarse-loamy, mixed, mesic Typic Xerorthents; elev. 860 m; aspect S.; slope <5 pct; precip. 690 mm; lat. 34°12'27" N.; long. 117°44'16" W.; quad. Glendora.

Site 29--Tanbark Flats, *Quercus dumosa* confined lysimeter 19. Soil fill material/coarse-loamy, mixed, mesic Typic Xerorthents; elev. 860 m; aspect S.; slope <5 pct; precip. 690 mm; lat. 34°12'25" N.; long. 117°44'18" W.; quad. Glendora.

Site 30--Tanbark Flats, creekbed just northeast of lysimeter installation. *Quercus agrifolia* overstory. Wet decomposed granite with organics. Soil alluvial sands and gravels; elev. 854 m; aspect NW.; slope 2 pct; precip. 685 mm; lat. 34°12'31" N.; long. 117°44' 18" W.; quad. Glendora.

Site 31--Spot B. Riparian zone, *Quercus agrifolia, Platanus racemosa, Umbellularia californica* overstory. Stream sides and stream bottom, wet to saturated sands and muck. Soil alluvial sands and gravels; elev. 778 m; aspect NA; slope NA; precip. 762 mm; lat. 34°11'47" N.; long. 117°44'16" W.; quad. Mt. Baldy.

Site 32--Tanbark Flats, adjacent to unconfined *Quercus dumosa* lysimeter. Collections made in both soil and litter. Soil fill material/coarse-loamy, mixed, mesic Typic Xerorthents; elev. 860 m; aspect S.; slope <5 pct; precip. 690 mm; lat. 34°12'25" N.; long. 117°44'18" W.; quad. Glendora.

Site 33--Tanbark Flats, adjacent to pyramid soil storage building. Under *Quercus agrifolia;* side slope, moist sandy loam, litter depth 4-9 cm. Soil coarse-loamy, mixed, mesic Typic Xerothents; elev. 848 m; aspect NE.; slope 15 pct; precip. 690 mm; lat. 34°l2'27" N.; long. 117°44'16" W.; quad. Glendora.

Site 34--Big Dalton Canyon Rd., approximately 500 m southwest of Volfe Canyon and gauging station in streambed. Vegetation not recorded. Wet coarse sand. Soil alluvial sand; elev. 317 m; aspect NW.; slope 2 pct; precip. 635 mm; lat. 34°10'48" N.; long. 117°47'52" W.; quad. Glendora.

Site 35--Tanbark Flats, side slopes off creekbed trail just northeast of lysimeter installation. *Quercus dumosa* cover. Sandy loam with cobbles, 2-4 cm A horizon. Soil coarse-loamy, mixed, mesic Typic Xerorthents; elev. 863 m; aspect S.; slope 25 pct; precip. 685 mm; lat. 34°12'33" N.; long. 117°44'16" W.; quad. Glendora.

Site 36--Tanbark Flats, *Quercus dumosa* confined lysimeter 21. Soil fill material/coarse-loamy, mixed, mesic Typic Xerorthents; elev. 860 m; aspect S.; slope <5 pct; precip. 690 mm; lat. 34°12'25" N.; long. 117°44'18" W.; quad. Glendora.

Site 37--Tanbark Flats, *Bromus mollis* and *Eriogonum fasciculatum* unconfined lysimeter. Soil fill material/coarse-loamy, mixed, mesic Typic Xerorthents; elev. 860 m; aspect S.; slope <5 pct; precip. 690 mm; lat. 34°12'25" N.; long. 117'44'18" W.; quad. Glendora.

Site 38--Hummingbird Creek, just north of Spot B Road. Vegetation not recorded. Streambed saturated sands and gravel, some muck. Soil alluvial sands and gravels; elev. 808 m; aspect S.; slope NA; precip. 762 mm; lat. 34°12'24" N.; long. 117°45'15" W.; quad. Glendora.

Site 39--Waterfall creekbed, second small drainage north from Site 31 on Spot B Road. Overstory vegetation not recorded. Creekbed saturated decomposed granite with some organics. Soil alluvial sands and gravels; elev. 778 m; aspect SW.; slope NA; precip. 762 mm; lat. 34°12'11" N.; long. 117°44'37" W.; quad. Mt. Baldy.

Site 40--Big Dalton Canyon Rd., first major cross drainage coming from Glendora in northwest corner of sec. 22. Overstory *Quercus agrifolia* and *Umbellularia californica.* In creekbed, very wet coarse sandy loam. Soil alluvial sands and gravels; elev. 427 m; aspect NW.; slope 2 pct; precip. 635 mm; lat. 34°09'49" N.; long. 117°47'56" W.; quad. Glendora.

San Bernardino National Forest

Arrowhead Ranger District

Species	Site
Aporrectodea caliginosa	41, 42, 43
Aporrectodea trapezoides	44
Aporrectodea sp	45
Argilophilus sp.	46, 47

Site 41--Hwy. 18 gently sloping grass woodland southwest of Heaps Peak. Unknown grasses, *Polypodium californicum, Quercus kelloggii, Pinus coulteri.* Moist deep (>30 cm) sandy loam, mollic epipedon primarily all cast material. Soil fine-loamy, mixed, mesic Mollic Haploxeralfs; elev. 1876 m; aspect SW.; slope 5 pct; precip. 889 mm; lat. 34°13'58" N.; long. 117°08'08" W.; quad. Harrison Mt.

Site 42--Horseshoe bend in Hwy. 330 at Long Point before entering Fredalba. North side of highway in *Pinus* sp. plantings. Deep 5-30 cm mollic epipedon, moist, dark, essentially all cast material. Soil fine-loamy, mixed, mesic Mollic Haploxeralfs; elev. 1571 m; aspect N.; slope 15 pct; precip. 762 mm; lat. 34°12'30" N.; long. 117°08'53" W.; quad. Harrison Mt.

Site 43--Mojave River at entrance to Lake Silverwood off Hwy. 138. Overstory riparian vegetation *Alnus* sp., *Quercus* sp., *Platanus racemosa.* Riverbottom saturated sands with some organics. Soil alluvial sands and gravels; elev. 1092 m; aspect W.; slope NA; precip. 635 mm; lat. 34°16'19" N.; long. 117°17'33" W.; quad. Silverwood Lake.

Site 44--City Creek Truck Trail, first creek crossing at southern end of Mud Flat, starting from Hwy. 330. Creekbed, vegetation not recorded. Saturated coarse sands with some surface organics. Soil alluvial sands; elev. 964 m; aspect NA; slope NA; precip. 889 mm; lat. 34°12'39" N.; long. 117°12'14" W.; quad. Harrison Mt.

Site 45--Turnout Hwy. 330 near call box 330-346, ridge off main highway on old paved road. Chaparral cover of *Arctostaphylos* sp., *Salvia mellifera,* unknown grasses. Under manzanita litter, very slightly moist, coarse sandy loam, ochric epipedon. Soil loamy, mixed, nonacid, thermic shallow Typic Xerorthents; elev. 897 m; aspect NE.; slope 10 pct; precip. 508 mm; lat. 34°10'58" N.; long. 117°10'10" W.; quad. Harrison Mt.

Site 46--Hwy. 138 enroute to Silverwood Lake from Crestline, near highway marker 33.93. Mixed conifer-oak-woodland of *Quercus kelloggii, Pinus ponderosa,* and unidentified grasses. Mollic epipedon, moist, cold, dark brown, sandy to fine sandy loam. Soil fine-loamy, mixed, mesic, Mollic Haploxeralfs; elev. 1388 m; aspect NW.; slope 28 pct; precip. 762 mm; lat. 34°15'30" N.; long. 117°17'10" W.; quad. Silverwood Lake.

Site 47--Horsehoe bend in Hwy. 330 at Long Point before entering Fredalba, southside of highway. Grass woodland of unidentified grasses, *Pinus coulteri, Polypodium californicum, Quercus kelloggii.* Moist, mollic epipedons, deep, coarse sandy loam; scattered patches of snow. Soil fine-loamy, mixed, mesic Mollic Haploxeralfs; elev. 1571 m; aspect N.; slope 20 pct; precip. 762 mm; lat. 34°12'30" N.; long. 117°08'53" W.; quad. Harrison Mt.

San Bernardino National Forest

San Jacinto Ranger District

Species	Site
Aporrectodea caliginosa	48
Dendrobaena rubida	48
Eiseniella tetraedra	48

Site 48--James San Jacinto Mountains Reserve (University of California Natural Reserve System). Indian Creek within reserve boundaries; creek area between museum and campground. Overstory *Quercus chrysolepsis, Pinus ponderosa, Calocedrus decurrens.* Creekbed bottom and sides, saturated sand and muck. Soil alluvial sands and gravels; elev. 1641 m; aspect SW.; slope 3 pct; precip. 635 mm; lat. 33°48'42" N.; long. 116°46'22" W.; quad. Lake Fulmor.

Santa Rosa Plateau Preserve

Species	Site
Allolobophora chlorotica	49
Aporrectodea trapezoides	49
Diplocardia CA1	50
Diplocardia CA2	51
Eisenia rosea	*52*
Eiseniella tetraedra	49
Lumbricidae (juvenile)	49, 52
Ocnerodrilus sp	49

Site 49--Tenaja between Clinton Keith Rd. and Sycamore Trail. Riparian overstory of *Salix* sp., *Quercus agrifolia, Platanus racemosa.* Creekbed and tenaja, saturated sands and mucks, large granitic boulders. Soil alluvial sands; elev. 534 m; aspect SW.; slope <3 pct; precip. 406 mm; lat. 33°31'54" N.; long. 117°16'12" W.; quad. Wildomar.

Site 50--Mesa de Colorado, southwest outer fringe of vernal pool/plateau. Mixed unidentified grasses, *Lupinus* sp., *Juncus* sp., *Ranunculus californicus,* plus others. Red-brown silty clay loam, moist to wet, slightly sticky; single granule cast material 1-8 cm deep. Soil loam, fine, montmorillonitic, thermic, Typic Rhodoxeralfs; elev. 595 m; aspect SW.; slope 2 pct; precip. 406 mm; lat. 33°30'28" N.; long. 117°17'30" W.; quad. Wildomar.

Site 51--Southwest chaparral rim of Mesa de Burro and southwest chaparral side slope. Mixed chaparral of *Salvia mellifera, Quercus dumosa, Adenostoma fasciculatum, Quercus engelmannii.* Litter depths 2-5 cm, cast material 5-10 cm in umbric/mollic A horizon; slightly moist clay loam on plateau to fairly heavy clay to loam near bottom. Soil top--stony clay loam, clayey, montmorillonitic, thermic, Lithic Haploxeralfs; bottom--loam, fine, montmorillonitic, thermic, Typic Rhodoxeralfs; elev. 594 m; aspect SW.; slope 5-25 pct; precip. 410 mm; lat. 33°31'35" N.; long. 117°14'28" W.; quad. Murrieta.

Site 52--Ranch Rd. heading northeast from Preserve main gate. Collections made on an approximately 200-meter line transect between zones of introduced grasses *(Bromus mollis, Avena barbata)* and native grass *(Stipa pulchra)*. Slightly moist, clay loam, ochric epipedon, surface castings very evident. Soil fine-loamy, mixed, thermic, Typic Haploxeralfs; elev. 549 m; aspect S.; slope 2 pct; precip. 406 mm; lat. 33°31'49" N.; long. 117°16'00" W.; quad. Wildomar.

Cleveland National Forest

Trabuco Ranger District

Species	Site
Aporrectodea caliginosa	53
Aporrectodea trapezoides	53,54
Argilophilus sp	55
Diplocardia CA1	53, 54, 55
Eisenia rosea	53, 54
Microscolex dubius	55
Ocnerodrilus sp	56

Site 53--Falcon Campground area, Forest Service Rd. 6S05. Grass woodland; grasses unidentified, *Quercus agrifolia.* Slightly moist to dry, clay loams to gravelly and sandy clay loams, generally ochric surfaces, some compacted areas. Soil coarse-loamy, mixed, thermic Typic Xerochrepts; elev. 1007 m; aspect W.; slope 5 pct; precip. 508 mm; lat. 33°39'30" N.; long. 117°26'44" W.; quad. Alberhill.

Site 54--In general proximity of Tenaja Campground and Forest Service Rds. 7S01 and 7SO4. Approximately 500 ha of grass-woodland-chaparral, seasonally grazed; 90 percent of area in unidentified grasses and forbs, scattered *Quercus agrifolia, Quercus dumosa, Adenostoma fasciculatum.* Deep (>25 cm), moist sandy loam, generally ochric epipedons but some umbric/mollic epipedons in a few locations. Soil fine-loamy, mixed, thermic Typic Haploxeralfs; elev. 595 m; aspect W.; slope 2 pct; precip. 406 mm; lat. 33°31'03" N.; long. 117°22'22" W.; quad. Wildomar.

Site 55--Long Canyon, at intersection of Hwy. 74 and Forest Service Rd. 6S05. Grass-oak woodland, species not identified. Very deep (>75 cm), fine sandy loam, dry under grassland, slightly moist under oak litter; traces of surface casting in grassland. Soil loamy, mixed, thermic Pachic Haploxerolls; elev. 726 m; aspect SE.; slope 2 pct; precip. 457 mm; lat. 33°38'15" N.; long. 117°25'25" W.; quad. Alberhill.

Site 56--San Juan Creek, Lower San Juan Picnic Area, Hwy. 74. Riparian overstory vegetation *Quercus* sp. and *Alnus* sp. Creekbed saturated sands and muck. Soil alluvial sands and muck; elev. 381 m; aspect SW.; slope 1 pct; precip. 381 mm; lat. 33°35'54" N.; long. 117°27'39" W.; quad. Sitton Peak.

Santa Margarita Ecological Reserve

Species	Site
Allolobophora chlorotica	57, 58
Aporrectodea trapezoides	59
Lumbricidae (juvenile)	57
Ocnerodrilus 1	57
Ocnerodrilus 3	60
Ocnerodrilus sp	61
Sparganophilus 1 (new species)	61

Site 57--Temecula Canyon, Santa Margarita River crossing, southwest along river from Reserve road. Overstory riparian vegetation not recorded. Riverbottom saturated medium to fine sands, some banding of muck. Soil alluvial sands and muck; elev. 236 m; aspect NE.; slope <5 pct; precip. 279 mm; lat. 33°26'52" N.; long. 117°08'22" W.; quad. Temecula.

Site 58--Temecula Canyon, Santa Margarita River crossing, southwest along river from Reserve road, northwest side of river in riparian area. Vegetation primarily *Salix lasiolepis.* Moist medium sand under 1-7 cm of undecomposed willow leaf litter. Soil alluvial sands; elev. 236 m; aspect SE.; slope <5 pct; precip. 279 mm; lat. 33°26'52" N.; long. 117°08'22" W.; quad. Temecula.

Site 59--Approximately 500 m northeast along road from southwest Reserve gate in northeast corner of sec. 4, T. 9 S., R. 3 W. *Quercus agrifolia* woodland, *Toxicodendron diversilobum* understory. Slightly moist loam to fine sandy loam, litter depth 3-13 cm, mollic epipedon. Soil loamy, mixed, non-acid, thermic, Typic Xerorthents; elev. 159 m; aspect N.; slope 5 pct; precip. 279 mm; lat. 33°25'48" N.; long. 117°11'00" W.; quad. Temecula.

Site 60--Just outside main entrance to Santa Margarita Ecological Reserve where "spring" creek crosses paved road. Overstory riparian vegetation primarily *Quercus* sp., collections in creekbed. Saturated sand and muck. Soil alluvial sands and muck; elev. 351 m; aspect NE.; slope <5 pct; precip. 279 mm; lat. 33°27'56" N.; long. 117°10'12" W.; quad. Temecula.

Site 61--Temecula Canyon, Santa Margarita River crossing, southwest along river from Reserve road. Collections from exposed rock outcrops midstream; vegetation includes tule *(Scirpus olney),* cat-tail *(Typha domingensis),* bur-reed *(Sparganium eurycarpum),* yerba mansa *(Anemopsis californica).* Saturated fibrous mats and mucks with traces of sand, 1-8 cm deep, hydrogen sulfide odor, on granite boulder substrates. Soil muck--Histosols; elev. 236 m; aspect NA; slope NA; precip. 279 mm; lat. 33°26'52" N.; long. 117°08'22" W.; quad. Temecula.

Cleveland National Forest

Palomar Ranger District

Species	Site
Aporrectodea caliginosa	62
Aporrectodea trapezoides	63, 64
Diplocardia CA1	63, 65
Eisenia rosea	63, 64

Site 62--Creekbed adjacent to Mount Palomar Hwy. west of Jeff Valley, in southeast comer of sec. 14, T. 10 S., R. 1 E. Mixed conifer/hardwood overstory of *Pinus ponderosa, Abies concolor, Quercus* sp. and a *Toxicodendron diversilobum* understory. Saturated decomposed granite and muck. Soil alluvial sands and gravels; elev. 1562 m; aspect SW.; slope 15 pct; precip. 584 mm; lat. 33°18'08" N.; long. 116°51'45" W.; quad. Palomar Observatory.

Site 63--Love Valley, southeast border large grazed grassland with watering pond. Mixed grasses and forbes of unknown species. Moist, mollic or umbric surface to 20 cm, sandy loam to sandy clay loam, fine granular surface structure. Soil loamy, mixed, mesic Ultic Haploxerolls; elev. 1024 m; aspect NW.; slope 5 pct; precip. 558 mm; lat. 33°15'10" N.; long. 116°46'17" W., quad. Palomar Observatory.

Site 64--Love Valley, southeast edge of watering pond. Cattle grazed rangeland, mixed grasses and forbs of unknown species. Moist, clay loam to sandy clay loam, sticky, ochric epipedon. Soil loamy alluvium; elev. 1024 m; aspect NW.; slope 5 pct; precip. 558 mm; lat. 33°15'10" N.; long. 116°46'24" W.; quad. Palomar Observatory.

Site 65--Just below Mount Palomar Observatory a few meters off main highway adjacent to Upper French Valley gate entrance. A grassland of unidentified species and dead bracken fern *(Polypodium californicum),* a few scattered *Pinus ponderosa* and *Calocedrus decurrens.* Moist, surface ochric/umbric to 20 cm, sandy loam, unusually warm. Soil coarse-loamy, mixed, mesic, Ultic Haploxerolls; elev. 1623 m; aspect W.; slope 5 pct; precip. 609 mm; lat. 33°21'10" N.; long. 116°52'14" W.; quad. Palomar Observatory.

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