Environmental Monitoring and Bioassessment of Coastal Watersheds in Ventura and Los Angeles Counties

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Executive Summary

During Fall 2001, UCLA performed a series of field investigations to examine the relationship between different land uses and the ecological health of stream communities, with the purpose of providing data relevant to the generation of nutrient or other TMDLs to the LARWQCB. We sampled many of the physical (water chemistry and flow, channel morphology, substrate, light) and biological (riparian vegetation characteristics, algae, diatoms and macrophytes, benthic macroinvertebrates, fish) features contributing to the overall health of stream ecosystems. We sampled three southern California coastal watersheds (Malibu Creek, Calleguas Creek, and Santa Clara River), selecting a number of sites within each watershed representing the range of land uses commonly found in the region. Sampling occurred once at each site. While our project targeted individual sites based upon their land use characteristics, our objective was to understand the functioning of individual sites within the context of their relationship to all sites surveyed. The strength of this study lies in its large spatial scope; it was not designed to provide detailed information about individual sites.

One goal of our study was to understand the factors (especially nutrients) influencing (1) the abundance of macroalgae, and (2) the community structure of benthic macroinvertebrates. Predictably, the relationships between the various physical factors we measured and stream community characteristics are complex. No single factor predicts the occurrence of nutrient impairment or algal growth in the rivers studied, although several variables show strong correlations. Light is clearly an important factor, with shading associated with lower algal cover (but not lower diatom cover). The relationships between nutrients and algal or diatom cover differed in sunny versus shady sites. In shaded sites, algal cover was not significantly related to nutrient concentrations (i.e., light appeared to limited algal growth, so algae did not respond to higher nutrient concentrations), while diatom cover was positively associated with total phosphorus and negatively associated with total nitrogen. In contrast, in unshaded sites algal cover was associated with nutrient concentrations (positively with nitrogen, negatively with phosphorus), while diatoms were negatively associated with nitrogen only. Thus, in shaded areas more phosphorus seems to lead to higher diatom cover, while in sunny areas more nitrogen seems to lead to higher algal cover. These relationships match the abundance patterns of diatoms and algae, with diatoms more abundant in shade and algae more abundant in sun. Other variables associated with the abundance of algae or diatoms include nitrogen, temperature, pH, and conductivity.

The degree of correlation for each of these factors varied from site to site, so that the appropriate remedy for nutrient or algal impairment will be site-specific, perhaps requiring the preservation or provision of shade in one location and the replacement of concrete channels in another.

In addition to algae, we assessed the relationship between nutrients (and other factors, including algae) and benthic macroinvertebrates. High water temperatures were consistently associated with low biotic integrity, as was a high proportion of fine-grained substrates. The covers of algae and diatoms (medium to thick) were generally not detrimental to the benthic macroinvertebrate community. There is an indication that total nitrogen and total phosphorus concentration could be leading to lower biotic integrity, since both were negatively associated with total taxa richness and total phosphorus was negatively associated with Ephemeroptera-Plecoptera-Tricoptera (EPT) taxa richness. Caution must be exercised in interpreting these results, however, because only riffles (not pools) were sampled in order to be consistent with the Department of Fish and Game stream bioassessment protocol. Thus, the results of the benthic invertebrate sampling represents the best possible case with respect to algal impacts, since macroalgal cover can be much higher in pools or glides than riffles, and including pools with higher algal cover might indicate a negative effect of algal cover on invertebrates.

Although the invertebrate patterns in shaded versus unshaded sites were generally consistent with those derived by looking at all sites combined, several interesting patterns emerged. In shaded sites, total nitrogen and total phosphorus were negatively associated with a number of indicators of biotic integrity, whereas this association was weaker in unshaded sites. In unshaded sites, light reduction was positively associated with six indicators of biotic integrity and negatively associated with the one indicator of degradation. Thus, among the sites with little shade, the more shading present, the better the condition of the invertebrate community. Conductivity was positively associated with biotic integrity in unshaded sites, but tended to be negatively associated with integrity at shaded sites.

In addition to analyses focused on understanding the factors influencing different aspects of stream health, we looked for associations with different land uses. Some clear patterns emerge. For nutrient concentrations, total nitrogen and NO_2+NO_3 were significantly different among different land uses. For total nitrogen, the difference was driven by the very high value below POTWs. For NO_2+NO_3, the difference was driven by high values at agricultural sites and below POTWs. For the vegetation characteristics, algal biomass, algal cover, diatom cover, and macrophyte cover were all significantly different among different land uses. For algal biomass, the difference was driven by high biomass values below POTWs. For algal cover, the difference was driven by higher cover at commercial sites compared to reference, rural residential, and single family residential sites. For diatom and macrophyte cover, the difference was driven by high values above POTWs. All of the invertebrate indicators (except percent Baetidae) were significantly different among different land uses. These were frequently driven by low values in agriculture, commercial and single family residences. In general, low-density rural residential and reference sites had nearly equally high indicators of invertebrate biotic integrity.

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1. Introduction

As a result of legislation stemming from the Federal Clean Water Act (CWA) of 1972, the California State Water Quality Control Board has been charged with the responsibility of determining acceptable standards for the quality of the state's water resources (RWQCB-LA 1994). These standards consist of numeric and narrative objectives necessary to support designated beneficial uses of water resources, and are mandated for all water bodies within the state under the California Water Code. Among these obligations is the need to establish total maximum daily loads (TMDLs) of various pollutants impacting California watersheds. A TMDL specifies the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and allocates pollutant loadings to point and non-point sources. In compliance with a CWA mandate, specific TMDLs are to be established for southern California watersheds that have been identified as impaired, and these impaired watersheds have been given a priority ranking. The Malibu, Calleguas and Santa Clara watersheds are all impaired watersheds that have been given a high priority ranking. TMDLs need to be established for nutrients in these three watersheds.

Like most areas in southern California, the coastal watersheds of Malibu Creek, Calleguas Creek, and the Santa Clara River have been subjected to drastic landscape modification due to urban development and agricultural practices. Stream networks, floodplains, and hill slopes have been extensively reshaped, redirected, and otherwise modified, causing heavy erosion, sedimentation and increased flooding potential. To combat the effects of flooding, streams have been straightened and channelized, often with rip-rap banks or concrete box channels completely eliminating evidence of the original stream course and habitat. The effects of this increasing urbanization and agriculture often include the addition of unnatural levels of nutrients, fecal bacteria, organic material, trace metals, and pesticides, as runoff water enters the streams. The impact of this habitat alteration and the adverse contributions of agricultural and urban expansion have seriously compromised the hydrology, water quality, riparian habitat and biological community integrity of these coastal streams.

The primary goal of this research was to provide data needed for the establishment of nutrient TMDLs for the Malibu Creek, Calleguas Creek and Santa Clara River watersheds. Besides providing information supporting the establishment of nutrient TMDLs for these three impaired coastal watersheds, the data collected through this bioassessment project may provide insight into how compliance with these TMDLs might be achieved. By elucidating the interrelationships between water quality and habitat condition and the resulting effects that these interactions have on the biological communities of coastal watersheds, this research will further our understanding of the ecology of southern California watersheds.

In this research we employed a methodology that combined and modified standard methods from two widely used programs: US EPA's Environmental Monitoring and Assessment Program [EMAP] (Lazorchak and Klemm 1997) and California Department of

Fish and Game's Rapid Bioassessment Program (Harrington and Born 2001). Three specific objectives of this project were:

1. Provide the LARWQCB with data needed to determine where water quality objectives are not being met, and for the establishment of (especially nutrient) TMDLs.

2. Investigate the relationships between water quality (especially nutrients), habitat quality, and the biological community.

3. Compare the relationships between water quality, habitat quality, and biological communities among different watersheds, and among different land uses.

2. Monitoring Sites

2.1 Site Proportioning Among Watersheds

We sampled 11 sites in the Malibu watershed, 16 sites in the Santa Clara watershed, and 10 sites in the Calleguas watershed (Table 1). While the bulk of these sites had the full complement of survey work done, several (especially in Calleguas) could not be sampled completely because (1) some sites dried up before full sampling could be performed or (2) some sites had only been partially completed before the arrival of fall rains.

2.2 Site Selection

Sites were selected non-randomly using a targeted reach design (Table 2). Within each watershed we tried to find sites that represented, or occurred within, discrete land use types such as open space (reference), rural residential, single-family residential, commercial, and agricultural. Sample sites were generally selected to represent targeted land uses in different regions of each watershed, but in some instances sites were selected with above/below comparisons in mind to determine the contributions of certain inputs such as water treatment plants or agriculture.

In all cases, site selection followed from a series of reconnaissance surveys during which certain selection criteria were assessed. Sites were chosen based upon the following considerations: location in one of the three relevant watersheds, location within the watershed (i.e., stream order), seasonal flow characteristics, land use, substrate type, and degree of habitat alteration. In addition, the accessibility, relative homogeneity, and adequacy of riffle habitat of the site were considered. In Malibu, these reconnaissance surveys were attended by representatives from the Southern California Coastal Water Research Project (SCCWRP), University of California, Santa Barbara (UCSB), Heal the Bay (HtB), and UCLA[1]. An attempt was made to select sites that were already being monitored by HtB in their ongoing stream monitoring program, but that also satisfied the selection criteria of both the UCSB and UCLA research teams. After our reconnaissance, SCCWRP and UCSB selected some sites that were not HtB locations; to maintain our coordination with SCCWRP/UCSB, we also sampled those sites. In the Santa Clara watershed, site reconnaissance and selection involved a coordinated effort between UCLA and LARWQCB staff. With few exceptions, we sampled SCR sites that were directly requested by LARWQCB staff. In the Calleguas watershed, sites were selected within the perennially flowing Conejo Creek and Arroyo Santa Rosa tributaries, and were chosen solely by UCLA researchers.

2.3 Site Descriptions

2.3.1 Malibu Creek Sites

Chesebro – This site was chosen as an alternate to the UCSB reference site at Palo Comado, which had dried up before we were able to begin sampling. The site was an intermittent stream located in the Santa Monica Mountains National Recreation Area. This site was only sampled for water chemistry and benthic macroinvertebrates, due to the lack of continuous flow. Dense overgrowth of willow and other vegetation surrounded the immediate channel, with grassy areas beyond the banks. Human influences near the stream consist primarily of trails for hiking, mountain biking and horseback riding, but very little activity occurs directly in the stream. This is Heal the Bay's site number 6.

Lindero at Falling Star – This site was chosen to represent a semi-natural stream within a single family residential land use. The site was located on Lindero Creek near the intersection of Kanan and Falling Star roads. The reach we sampled was just upstream of Lakeview Canyon Rd. The source of the stream water is a combination of ground water and urban runoff from nearby homes. In addition to the adjacent single family residences, there is recreational open space further upstream of the site. The site is a popular trail for walking dogs, with evidence of some human activity directly in the stream. Oak trees were common along the stream, as were willow and non-native trees.

[1] SCCWRP conducted a project in the Malibu Creek watershed funded by the LA RWQCB with objectives and timing that overlapped this project. In an effort to maximize the combined benefits of our research, we decided to collaborate with SCCWRP in Malibu Creek. Through this collaboration, sites were to be chosen mutually and sampled concurrently. UCLA was to collect data on the benthic macroinvertebrate community, light, and canopy data, which would be made available to SCCWRP. SCCWRP, through a subcontract to UCSB, was to perform nutrient limitation experiments plus collect water quality (especially nutrient), algae cover, and flow data, which would be made available to UCLA. Because the nutrient limitation experiments failed, that information is not included in this report, although we do rely on the nutrient data collected and analyzed by UCSB.

Medea Creek Park – This site also represents a semi-natural stream within a single family residential land use. The site is located at Conifer St. in Agoura Hills. The stream water is a combination of groundwater and urban runoff from nearby homes. Recreational open space occurs further upstream of the nearby residential communities. The site has a path running along the stream and is a popular trail for walking dogs and bicycling, with evidence of some human activity directly in the stream. The streambed has been stabilized with concrete in many areas, and our reach traversed a 40m long tunnel at the Conifer St. over crossing. Dense macrophytes occurred in the channel upstream of the tunnel, and a gentle cascade dropped off into a deep plunge pool beyond the sampled reach.

Chumash Park – This site was located downstream of a large commercial center in Agoura Hills, accessed through Chumash Park. The stream consisted of a concrete channel with steeply sloping banks, and was just downstream of a tunnel at the Kanan Rd over crossing. Some sediment had accumulated at the margins of the wetted areas and some low macrophytes and macroalgae occurred there as well. There was evidence of vegetation clearing in the stream using heavy equipment, but this was just downstream of the site, where the concrete ends. This site is downstream of Medea Creek Park, and the water in the stream includes additional runoff from the commercial center.

Lindero Country Club – This site was located within the Lindero Country Club's golf course in Agoura Hills. The stream traverses the golf course upstream and consisted of a narrow (~1m) concrete ditch immediately bordered by mowed grass. The edges of the ditch were lined in places by dense macrophytes. Just downstream of the reach, the channel drops off into a deep pool with tules and large non-native fish. We assume that most of the source water of the stream is from runoff of the golf course and nearby homes.

Triunfo – This site was chosen to represent a natural stream within horse ranch properties. The site is located in an unincorporated area of Los Angeles southeast of the city of Westlake Village. We collected benthic macroinvertebrate (BMI) samples at the site, but the water had dried up before we were able to return to complete the remainder of our sampling protocol. The stream contains many low water crossings, as well as high horse activity directly in the stream. Much of the site consisted of deeper glides, with few riffle habitats present. Most of the source water of the stream is from Westlake, an urban lake with many single family residences on its banks. This is near Heal the Bay's site number 17.

Upper Cold Creek – This reference site was located in a relatively unaltered portion of the Santa Monica Mountains, ~200m upstream of the Stunt Rd over crossing. This site is owned by a conservancy and is one of the few places in the Malibu Creek watershed where human influences are minimal. The site is a natural stream with a steep gradient and undisturbed native trees and other vegetation. Some hiking and other recreation occurs on the surrounding land, but these impacts are minimal. This is Heal the Bay's site number 3.

Middle Cold Creek – This site was located downstream of the Upper Cold Creek reference site, surrounded by low density rural residential homes and ranches. A hiking and horseback riding trail is adjacent to the stream with a public access point on Cold Canyon Rd. This trail traverses the stream just downstream of our reach. The native vegetation is relatively unaltered at the site, but is limited by the extensive bedrock that is exposed in the channel and on the left bank where a vertical wall of rock rises from the stream. Much of the stream substrate is dominated by bedrock with little sedimentation or other substrate types. The stream channel is within a narrow canyon and torrential flow can occur there. However, during base flow conditions, the stream is quite narrow (<2m). This is Heal the Bay's site number 11.

Lower Cold Creek – This site was located along Piuma Rd near the bottom of Cold Creek, just upstream from its confluence with Malibu Creek. The gradient at this site was lower than the two upstream sites, and the vegetation is less natural with a mix of native and non-native trees and shrubs. Bedrock is present in and alongside the stream, but to a lesser extent than the Middle Cold Creek site. Accumulations of sand were common and some cobble and gravel occurred in the lower portions of the reach. A hiking and horseback riding trail traversed the stream in the middle of our reach. There was some evidence of human activity within the stream, and the banks were stabilized with riprap just upstream of the site. This is Heal the Bay's site number 2.

Malibu Creek Above Tapia – This site was a reasonably natural stream section located within Malibu Creek State Park several kilometers upstream of the Tapia POTW plant. Our reach was positioned just downstream of a series of deep pools that are frequented by swimmers; recreational use of the stream is substantial at this site. The streamside vegetation is mostly unaltered, with sycamore and other native trees common. Cobble and boulders were common where gradients were steeper, while sand and other fine sediments were present in pools. This is Heal the Bay's site number 12.

Malibu Creek Below Tapia – This site was located on Malibu Creek, just downstream of the Tapia POTW outflow and upstream of a heavily stabilized section where a gauging station occurs. At the upper portion of the reach, a wide shallow pool was caused by a small rock dam constructed across the channel. Below this pool the stream was split into two channels separated by a high and heavily vegetated bar. The sampled reach consisted of the right channel and a portion of the shallow pool. While some cobble and boulders occurred in this reach, much of the benthos consisted of sand and finer sediments. The streamside vegetation consisted of small willow trees and saplings mixed together with *Arundo donax* and other native and non-native trees and shrubs. This is Heal the Bay's site number 15.

2.3.2 Santa Clara River Sites

Soledad Canyon – This reference site was a reasonably natural stream reach located within a small section of Forest Service land. The site was located along Soledad Canyon Road adjacent to a public day use area. Human activities in the stream reach are common. Rural residential and camping facilities occurred upstream of the site; however, flow was intermittent and the water did not appear to come directly from these land uses. The stream existed as a narrow base flow channel within a larger dry floodplain containing often dense saplings and other young native vegetation. Aquatic vascular macrophytes were common in the base flow channel.

Bouquet Below Dam – This reference site was a narrow and densely overgrown stream reach located just below the outflow from the Bouquet Canyon Reservoir, and just above a small community of rural residences that occurs in the area. A continuous flow of water is released from the reservoir from a pipe and weir structure just below the dam. The water comes from the State's system of aqueducts. Because the release of water is continuous, and flooding events are rare or absent, the stream channel is well defined without a floodplain, and sediment accumulation is very low. Throughout most of the reach, the water flowed across a mass of root structures that covered the bottom of the channel. The stream was overgrown with dense vegetation (mainly willow), making it difficult to traverse the reach.

Bouquet Rural – This rural residential site was a narrow stream channel immediately down stream of the last section of homes that occur in the area. Forest Service lands start at this site and continue downstream for several miles. Bouquet Canyon Road runs along the stream in this narrow canyon and a dirt parking area exists at the site. Human activities in the stream reach are common. Large native trees line the stream as do brush and other overgrowth. Some sediment accumulation occurs in the channel, mainly around pools formed by rock dams. Stickleback fish were encountered at this site. It is not clear whether these were the unarmored or partially armored populations, but anecdotal evidence suggests the latter.

Bouquet Horse – This site was flowing during our initial reconnaissance surveys, but was mostly dry by the time our sampling began. The only data we collected from this site was a small sample for ammonia (NH_3) analysis. The site was located in the middle of horse properties that occur just downstream of the Forest Service lands. Only limited horse activity occurred upstream of the sampling location as the water dried up quickly. These data are not included in our main report, but are included with our data files.

Haskell Canyon – This single family residence site was located immediately upstream of the confluence with Bouquet Canyon Creek. The entire reach consisted of a relatively wide (~20m) curving concrete box channel. No vegetation or sediment occurred in the channel and the water was shallow and spread out with no sub-channel. Flow was very low. Houses were abundant beyond gravel flood control roads, which lined both sides of the channel.

Seco Canyon – This single family residence site was located along the Seco Canyon wash, immediately upstream of a bridge at Garzota Rd. The site was a straight concrete channel with steeply sloping sides. No vegetation and minimal sediment occurred in the channel and the water was shallow and spread out with no sub-channel. Flow was moderate. Houses were abundant along both sides of the reach. A paved street occurred within 3 meters of the left bank and a gravel flood control road lined the right bank. There was evidence that a tractor had recently been in the channel, probably clearing away accumulated sediment or debris.

Bouquet Commercial – This commercial site was a wide (40m) concrete box channel located on Bouquet Creek, immediately upstream of the bridge at Newhall Ranch Rd. The confluence with the Seco Canyon wash was about 75m upstream of the reach and all of the water in the channel was coming from that wash. Water flowed through the reach in a narrow (~2m) sub-channel running down the middle of the main channel. No vegetation or sediment occurred in the channel. A large commercial complex occurred along the entire length of the left side of the channel. Multi-family residences were also common in the area. Just downstream of the bridge, the concrete stopped and a densely overgrown sandy flood plain began.

Peck Road, Santa Paula – This commercial/industrial site was a concrete box channel (~5m wide) located in Santa Paula, just downstream of the bridge at Harvard Blvd. The flow was very low and seemed to be coming from agricultural packaging plants and other urban runoff. Some sediment had accumulated at the margins of the wetted areas and low macrophytes and often dense mats of macroalgae occurred there as well. Trash was common at the site and our meter tape discolored following contact with the water.

Old Road Bridge – This "above POTW" site was within the main Santa Clara River (SCR) channel about 40m downstream of The Old Road bridge, and just upstream of the outflow from the Valencia waste water treatment plant. The stream existed as a narrow base flow channel within a larger dry floodplain containing often dense saplings and other young native vegetation. The wetted areas were heavily overgrown by watercress and other vascular macrophytes. The water flowing through the site was a combination of urban run off and POTW flow from the Saugus waste water treatment plant further upstream. Numerous fish (mostly arroyo chub) were seen along the reach, but we did not fish the site because threatened or endangered species had been reported in the area.

Magic Mountain – This "below POTW" site was within the main SCR channel just downstream of the outflow from the Valencia waste water treatment plant. The discharge coming from this outflow was very high and overwhelmed the base flow water coming from upstream in the main channel. The wetted area was relatively wide, and there was a wide band of low growing vascular macrophytes occurring along most of the stream margins. Most of the main channel was dry, however, with occasionally dense saplings and other vegetation growing on the exposed substrates. Dense stands of *Arundo donax* occurred along most of the right bank. Numerous fish (mostly arroyo chub) were seen along the reach, but we did not fish the site because threatened or endangered species had been reported in the area.

Blue Cut – This row crop site was located within the Newhall Ranch lands on the main SCR channel, west of the Ventura County line, and just upstream of an old USGS gauging station. The site consisted of a wetted channel about 4 to 5 meters wide within a wide sand/cobble flood plain. The margins of the flood plain were lined with tall willow and cottonwood trees, while sparse saplings and other vegetation occurred on the exposed channel substrates. Flow was relatively high at the site and consisted of the residual urban run off and POTW outflow water coming from upstream. In addition, rising ground water is reported to occur in the general vicinity of Blue Cut (E. Erickson, *personal communication*). This section of the river was relatively natural with only limited direct human alteration of the immediate channel. Row crop agriculture occurred along the surrounding plains and hillsides upstream of the site. Livestock appear to be common in the stream channel as evidenced by cow feces and footprints within the wet and dry portions of the reach. Numerous fish (mainly arroyo chub) were seen in backwater habitats by the gauging station, but we did not fish the site because threatened or endangered species had been reported in the area.

Camulos Ranch – This orchard site was located in the main SCR channel just downstream of the Blue Cut area. While sedimentation is significant at upstream sites as well, the main SCR widens out and becomes an extensive sandy flood plain just south of the bend at Blue Cut. Flow was substantial, but quickly disappeared into the sediments and was completely gone just downstream of this site. This entire reach was composed of sandy substrate, the top surface of which was visibly drifting downstream during out visit to the site. The wetted area was relatively wide compared to other sites, but the remainder of the immense flood plain was dry. The base flow stream occurred at the extreme left margin of the flood plain and this bank was lined with willow trees and other vegetation. The right bank of the base flow stream was lined by an extremely dense, tall stand of *Arundo donax*, plus some willow and other vegetation.

Main SCR at Santa Paula – This site was located on the main SCR channel in Santa Paula just upstream of the town's POTW outflow channel. This site was at base flow conditions during our initial reconnaissance surveys, but had very high flow at the time of our sampling due to release of water from Lake Piru to recharge ground water in the Oxnard plain (http://www.unitedwater.org/uwcd/). We did not sample this site, but we did collect water quality samples. These data are not included in our main report, but will be included with our data files.

Wheeler Canyon – This site was adjacent to Wheeler Canyon Road, just downstream of a livestock pasture through which the stream traverses. This stream is the upstream extension of the Todd Barranca, though the water in only intermittent in the area. We did not sample this site, but we did collect water quality samples. These data are not included in our main report, but are included with our data files.

Upper Todd Barranca – This orchard site was located on the Todd Barranca drainage channel within the Limonera Ranch properties, about 100m downstream of Foothill Road. While the flow further upstream of this site is intermittent, an overflow pipe continually discharges irrigation source water into the channel just upstream of our reach. The channel is rather deep and is lined by native and non-native trees. Tall Eucalyptus trees line the entire left bank of the reach. The channel is about 25m wide, but the base flow stream was only 0.5 to 2m wide. Dense macrophytes line the wetted areas in most places, and sparse saplings and other vegetation occur in the dry areas. Citrus and Avocado orchards are present on either site of the channel.

Lower Todd Barranca – This orchard site was located at the downstream end of the Todd Barranca above its confluence with the main SCR channel. The site was located just upstream of a low water crossing in the vicinity of the Ventura County Jail. The site was very similar to the upstream site with the following exceptions: No native trees were present, and the line of tall Eucalyptus trees lining the left bank was accompanied by another line on the right bank that was set back from the bank about 15m. The channel had slightly higher flow and the wetted areas took up a greater proportion of the channel. More sediments and less vegetation occurred in the channel. Orchards were present on the right side only, beyond the row of Eucalyptus trees.

2.3.3 Calleguas Creek Sites

Arroyo Conejo at Deepwood – This site consisted of a somewhat natural stream channel running through single family residential neighborhoods. A narrow buffer of oak and other native and non-native vegetation surrounded the immediate stream. The channel was relatively narrow (1-4m) with steep sided banks stabilized by root structures. Some artificial bank stabilization occurred with gabions present in one portion of the reach. Riffle habitats were limited, giving way to long pool/glide habitats with substantial sediment accumulation. Some gravel and cobble was present in the riffles, but most of the substrate consisted of sand and fine substrate. Flow was mostly perennial with natural springs and urban runoff further upstream. This site was included in SCCWRP's surveys of the Malibu Creek watershed.

Oaks Mall – This was a somewhat natural site surrounded by extremely heavy urbanization. It is located in Thousand Oaks, between the Oaks Mall parking lot and the Ventura freeway. The stream flows naturally through a steep bedrock channel with some old concrete bank stabilization, but the stream is culverted just upstream and downstream of the reach. Most of the water is urban runoff from the extensive urban areas that surround the area.

Reino Rd. – This single family residence site was located along the Arroyo Conejo wash along Reino Rd, immediately upstream of a bridge at Mayfield St. The site was a straight concrete channel with steeply sloping sides. No vegetation and minimal sediment occurred in the channel and the water was shallow and spread out with no sub-channel. Flow was moderate. Houses were present along both sides of the reach. A paved street (Reino Rd) occurred within 3 meters of the right bank.

Ventu Park Rd. – This commercial site was a moderately wide (10m) concrete box channel located on Arroyo Conejo in a heavily urbanized area of Thousand Oaks. The reach was just upstream of Ventu Park Rd, between a motel complex and the Ventura freeway. The channel became a culvert just downstream of the reach. Some sediment accumulations occurred at the margins of the wetted areas and low macrophytes and macroalgae occurred in these areas. A gravel flood control road lined the right bank. Streamside vegetation was limited to a few non-native shrubs.

Young Rd. – This single family residential site was located on Conejo Creek, and consisted of a wide dirt flood control channel with gently sloping banks and a narrow (~1m) concrete sub-channel running down the center. Some horse property occurred further upstream. Flow was very low and limited to the concrete sub-channel. The entire flood control channel was devoid of vegetation, as were the gravel flood control roads that lined both banks. Non-native trees and other vegetation occurred beyond these areas in the backyards of nearby homes.

Upper Wildwood – This site was located on Conejo Creek within the limits of Wildwood Park, downstream of the site at Young Rd. This site was difficult to describe in terms of land use, because it was located in an open space area, but was just downstream of rural residential and single family residences. It was chosen because we wanted to determine the effect of the park on the health of the stream, but the first rains came before we could sample a paired site further downstream in the park. We have designated the site as rural residential, but this is only partially so. Despite the upstream influences, this site was reasonably natural with native trees and other vegetation surrounding the stream channel. Some non-native trees and shrubs were also present. The channel was steep on both sides but was stabilized by root structures. Riffle habitats were limited, giving way to long pool/glide habitats with substantial sediment accumulation. Some bedrock and root mass was present in the riffles, but most of the benthos consisted of sand and fine substrate. While most of the water came from upstream runoff, there was considerable ground water input that began in the vicinity of our reach and contributed to the water quality downstream.

Arroyo Santa Rosa at Moorpark – This site was located on Arroyo Santa Rosa at the downstream end of an area dominated by row crops. We did not sample this site, but we did collect water quality samples. These data are not included in our main report, but are included with our data files.

Arroyo Santa Rosa at Las Posas - This site was located on Arroyo Santa Rosa at the downstream end of an area dominated by rural residential horse properties. We did not sample this site, but we did collect water quality samples. These data are not included in our main report, but are included with our data files.

Leisure Village – This row crop site was located on Conejo Creek in the vicinity of the Leisure Village community. The stream channel was wide (~40-50m), though the wetted areas were much narrower and often braided. Flow was moderate to high in narrow sections and lower in pool glides that occurred in the upstream portion of the reach. The sampled reach was positioned just downstream of a bend with an extremely high incision zone on the right bank. Below this incision zone, the right bank was stabilized with cemented riprap. The left bank was lined by a buffer of willow trees, saplings and *Arundo donax*. Beyond the left bank was extensive row crop agriculture. Row crops were also present on the right bank beyond the incision zone. Additional upstream influences include a considerable amount of orchard land, and the Hill Canyon POTW, plus urbanization. The substrate was a mixture of cobble and gravel within riffle habitats, and sand and fines, mostly in pool and glide habitats. Some instream vegetation was present including tules and other vascular macrophytes.

Bottom Conejo Creek – This row crop site was located adjacent to the Camarillo POTW plant ~2km upstream of the confluence with Calleguas Creek. Our reach was located well upstream of the POTW outflow, but several agricultural drainage pipes were located on the banks. The right bank consisted of a high levee with limited riprap while the left bank was a lower dirt burm. Dirt agricultural roads were common in the area. Very little vegetation existed on the right bank, while brush, saplings, *Arundo donax* and other non-native vegetation were present on and beyond the left bank. The stream channel was sand dominated with little additional substrate present. Few macrophytes occurred within the stream, or along the banks.

3. Methods

3.1 Background of Methods

This project involved field studies of stream resources along three coastal watersheds in Ventura and Los Angeles Counties, with a focus on the effects of natural and human influences on stream macrobiota. An assessment of the biological community and its habitat is critical to understanding the health or biological integrity of a watershed. Biological integrity is widely defined as an ecosystem supporting and maintaining community structure and composition comparable to that of natural habitats (Karr 1991). Federal, state and local agencies have recognized the importance of determining the biological integrity of watersheds, by funding the establishment and implementation of stream monitoring and assessment protocols. As stated earlier, we employed a methodology that combined and modified standard methods from two of these widely used programs: US EPA's Environmental Monitoring and Assessment Program, hereafter EMAP (Lazorchak and Klemm 1997) and California Department of Fish and Game's California Stream Bioassessment Procedure, hereafter CSBP (Harrington and Born 2001). EMAP is a comprehensive stream monitoring program that assesses multiple aspects of habitat condition, from water quality to stream channel morphology, bank and vegetation characteristics and includes bioassessment protocols. CSBP is a more focused program that surveys the benthic macro-invertebrate (BMI) community of a stream, along with a few additional in situ metrics, and uses the condition of this community as indicator of overall stream health. This approach has been adopted by many of the state agencies and research organizations within California that are responsible for monitoring the health of stream resources throughout the state. In an effort to collect data that were consistent with these other state agencies, and because the LARWQCB has other research units that utilize this approach, we decided to adopt the CSBP methodology for our benthic invertebrate sampling even though this would represent a departure from the EMAP methods outlined in our proposal. We employed CSBP-based methods to collect our benthic invertebrate samples, and then superimposed an EMAP-type reach based sampling design on top of the CSBP sampling locations, to provide us with the comprehensive stream-wide survey information our objectives mandated. A brief description of the each of these methods and the modifications we made to them follow.

With the exception of the BMI sample collections, the research described in this report is, in large part, a continuation and extension of a Regional Environmental Monitoring Assessment Program (R-EMAP) project in the Calleguas Creek watershed (see Lin 2002). The R-EMAP project is part of a larger national effort by the U.S. EPA to assess the condition of the nation's ecological resources. The objectives of EMAP are:

1. To estimate the current status, extent, and trends in indicators of the condition of the nation's ecological resources on a regional basis with known confidence.

2. To monitor the indicators of pollution exposure and habitat condition and seek associations between human-induced stresses and ecological condition.

This project focuses on the second of these two objectives by relating water quality and habitat condition to the integrity of the biological community within streams. For the purposes of this study, water quality relates to the level of general nutrients and solids, bulk anions, metals, dissolved oxygen, temperature, alkalinity, pH, conductivity, and turbidity. Also important to water quality are the levels of pesticides and fecal coliform bacteria in the water, but these two metrics are expensive to assess and were outside the scope of this project. Habitat condition relates to the general physical condition of the stream and includes the degree of human manipulation of the stream habitat, from pristine to complete alteration. Also included in this category is the level of bulk flow of water within stream channels as well as site-specific flow. Biological community relates to the diversity and abundance of terrestrial and aquatic organisms found within and in proximity to the stream channels. Included here are bioassessments of fish, benthic macroinvertebrate, and aquatic macrophyte assemblages as well as descriptions of riparian vegetation surrounding the streams.

After using EMAP in previous studies, we felt that several aspects of the methodology, having been designed to include large river systems with perennial flow, were inappropriate or unnecessary for sampling the ephemeral and highly altered stream reaches within southern California watersheds. For this project we refined EMAP methods to make them more suitable for our local stream types. One significant change we made was to shorten the length of the reach by one half. All the parameters used to determine the stream length were therefore halved including the wetted width multiplier (from 40 to 20), the maximum reach length (from 300m to 150m) and the minimum reach length (from 150m to 75m). In addition, the number of transects into which the reach was subdivided was reduced from 11 to 6. We understood that the previous number of transects (replicates) was determined empirically and was considered the minimum necessary to account for the variability of streams (Kaufmann, personal communication). However, given our targeted reach design where relative homogeneity of the reach was an important aspect of site selection, we felt that this reduction in the number of replicates would result in comparable levels of sample induced variation, while greatly reducing the effort.

With the exceptions outlined below, much of the actual data we collected either followed the EMAP approach, or were analogous to those data obtained using EMAP. Water quality sampling, discharge and densitometer measurements, vertebrate collection methods, and rapid habitat assessments followed EMAP directly except that we never used the glide/pool rapid assessment form since we specifically targeted riffle habitats. Three notable items that we eliminated were thalweg profiles, woody debris surveys, and torrent scour assessments. Many of the remaining data collection methods were based on EMAP, but were modified in subtle to substantial ways. Notable examples are: (1) stream bank measurements were not taken except that a single averaged bankfull width was estimated for the site; (2) some of the human influence data which were previously collected at each transect do not vary at that scale, so these were only collected on the general site (X-site) form; (3) percent cover interval classes were changed to include a “less than 5%” category and quartile intervals (i.e. 25-50%), and these were standardized across the entire suite of data forms; (4) the substrate cross-sectional information was increased substantially (usually 20 data points) to include percent cover estimates for vascular macrophytes, macroalgae, and diatoms; (5) algae biomass data were added; (6) incident light data were added; (7) riparian vegetation data were modified dramatically; (8) several other parameters were added to the various data categories. The EMAP protocol for periphyton collection was judged to be inadequate for this project. Instead we collected percent cover on diatom communities at each transect using a new method described below.

Benthic invertebrate communities are significantly influenced by environmental factors such as water quality and physical characteristics of the stream. The presence or absence of certain invertebrate groups provides an indication of environmental stress. In the EMAP protocol, benthic macroinvertebrates are collected from nine of the eleven transects, and these transects are pooled into one composite sample for processing. In a recent adaptation of the EMAP protocol, our group at UCLA analyzed each of these nine transect samples independently (Lin 2002). This method was much more rigorous and yielded much higher spatial resolution in the data, but at a substantial increased cost of processing. As stated previously, we abandoned the EMAP methods for the collection of benthic macroinvertebrates in favor of the CSBP approach. Whereas EMAP BMI samples are collected at the nine interior transects regardless of channel flow status, CSBP samples are collected exclusively within riffle habitats, with the assumption that the most healthy and diverse BMI communities present will be sampled. BMI samples within non-riffle habitats such as glides or pools were only sampled if riffle habitats were absent. CSBP methods were strictly adhered to except that we added a suite of supplementary data collected at the exact locations that the BMI samples were collected, and we almost always collected our BMI samples within three contiguous riffles. The latter exception represents a departure from the CSBP approach in that their methods call for the random selection of three out of five contiguous riffles. This modification was necessary because (1) at many southern California stream reaches, it is difficult to find five contiguous riffles in a discrete reach, and (2) we tried to maximize the possibility that those riffles would be encompassed by the superimposed transect design (discussion follows). This method provided an unbiased means of establishing an "X-site" from which a transect design could be laid out.

3.2 Initial Site Protocols

3.2.1 Site Arrival, Layout and Logistics

Upon arrival at a site, the stream reach would be surveyed to determine the presence and locations of riffle habitats as per CSBP methods. Three contiguous riffles were selected for the sampling of benthic invertebrates. Once these riffles were identified, a transect tape was laid out from the lower limit of the downstream riffle to the upper limit of the upstream riffle and the midpoint of this distance was marked as the "X-site". The X-site was independent of the six transects (unlike EMAP) and was the collection point for all water chemistry samples as well as flow measurements. At the X-site, three wetted widths were taken and the average width was multiplied by 20 to determine the reach length. If the calculated reach length was less than 75m or greater than 150m, then one of these limit reach lengths was employed. The transect tape was adjusted so that the midpoint of the calculated reach length lay at the X-site. Then the length was divided by 5 to determine the interval between the six cross-sectional transects. These six transects were then marked with labeled pin-flags or flagging tape. The locations of the riffles were also flagged at this time. Photographs of the stream reach were taken at the X-site, as per EMAP, and at each of the three riffles where benthic invertebrates were collected. Photos of the X-site and the riffle habitats were taken from a position that would yield the most representative photograph possible. Light measurements (discussed below) were usually taken at a convenient stopping point in the middle of the day by a single person or a team of two. The benthic invertebrates and water quality samples were taken first, followed by transect measurements (being sure to remain downstream of the BMI sampling). Electrofishing was conducted after the transect sampling was finished. Water samples were usually taken at the X-site either prior to any disturbance or on a follow-up visit, but were occasionally taken upstream of stream activities just before leaving the site. Site forms such as the X-site form and rapid bioassessment sheet were usually filled out upon the completion of sampling.

3.2.2 Site Data Sheet

After completing all data collection at the site, observed site characteristics were recorded on the X-site data sheet (see Addendum). This data sheet includes aspects of several EMAP forms that have been modified and condensed into single concise form. Textual descriptions of the site were minimized. A general land use category was selected prior to sampling for each site and was recorded. Watershed activities and disturbances were recorded based on knowledge of activities surrounding and upstream of the sampling site. The choices for watershed activity data were "O" (absent), "L" (low), "M" (moderate), and "H" (heavy). Reach characteristics were recorded based on experiences at the sampling site. The choices for reach characteristic data were "0" (absent), "1" (<5%), "2" (5-25%), "3" (25-50%), "4" (50-75%), and "5" (>75%). Waterbody character data were recorded based experiences on the day of sampling. Sections were included for the tracking of overview photographs and for the in situ water chemistry data (discussed below).

3.2.3 Rapid Habitat and Stream Assessment Form

The EMAP Rapid Habitat Assessment form for riffles/runs was used with minor modifications. The categories of bank stability, vegetative protection, and riparian vegetative zone width were split into right and left bank. Values of 0 to 10 were used for each bank to maintain a total value of 0 to 20 for each category.

3.3 Water Chemistry

3.3.1 Water grab samples

The methods employed here were identical to EMAP (Lazorchak and Klemm 1997) except that the water samples were generally taken on a follow-up visit to the site. This was necessary to comply with Standard Methods (APHA 2000) due to the constraints of the analytical laboratory we used, which required a minimum of ten samples per delivery and an early afternoon drop time. To comply with this requirement, we scheduled separate water sampling days and visited multiple sites consecutively to take the water samples. One gallon capacity cubitainers were used for the primary water samples, and 125mL Nalgene containers were collected separately for TKN/TP analyses. Target water quality parameters are presented in Table 3. (Note that some of the parameters reported in Table 3, such as trace elements, are not analyzed in this report, but are included in the Addendum and the data files.) Water samples were stored in a cooler with ice during transport. The gallon samples were driven to the Castaic Lake Water Agency (CLWA) analytical laboratory in Santa Clarita, CA and the 125mL samples were frozen and shipped to the DANR analytical lab in Davis, CA for TKN and TP analyses. In situ water chemistry measurements were always taken concurrently with the water sample collection, usually providing us with a second set of these measurements for each site. Water sampling days were scheduled as close to the regular sampling days as possible.

An exception to these procedures occurred at all of the Malibu sites and at one of the Calleguas sites (Arroyo Conejo SFR at Deepwood Dr.). At all of these sites, water samples were taken by the UCSB research team during their 3 days of field sampling, as part of our collaboration, and these were analyzed for only nutrients (not the rest of the parameters presented in Table 3). At these sites, two samples were collected (one for inorganic nutrients and one for total nutrients). Samples for inorganics were filtered on site using 0.45 micron polycarbonate membrane filters; samples for total nutrients were not filtered. Water samples were collected at the various Malibu Creek sites over a 3-day period and stored on ice in a cooler for the duration of that time and during transport back to Santa Barbara. The samples were delivered to an analytical lab immediately upon arrival at the UCSB campus, resulting in variable holding times of 3-60 hours (K. Kamer, SCCWRP, *personal communication*). This storage period exceeds the period specified in Standard Methods (which states that ammonia, nitrate, etc., must be sampled immediately unless the sample is reduced by the addition of pH<2, after which it can be stored for no longer than 48 hours; APHA 2000). As a result, the concentrations of different forms of nutrients may have changed before the samples were analyzed, and hence may not be comparable to our data for the other sites. However, total N and total P should be unaffected, and hence we based our multiple regression analyses on these values.

3.3.2 In situ measurements

In situ measurements of water temperature, pH, conductivity, and dissolved oxygen were taken in adherence to EMAP guidelines. While ammonia analysis was performed on the grab samples mentioned above, we often took separate field measurements of ammonia using an ion selective ammonia probe attached to an Orion pH meter. This method yields an accurate measurement of ammonia that can be obtained onsite, thus minimizing the possibility of sample decay during transport to an analytical lab. In this method, small samples of stream water were collected just before leaving the site in clean (and rinsed 3 times in stream water) 125mL Nalgene bottles. Processing and analysis of the samples were performed at the field vehicle, usually within 20 minutes of collection. Sites with ammonia analyses performed within this time frame included Camulos Ranch, Blue Cut, SCR below POTW, SCR above POTW, Peck Rd., Soledad Canyon, and Bottom Cold Creek. Occasionally these samples were stored on ice in a cooler until two or three samples were collected from nearby sites and in such cases, the analyses were performed within a maximum of 2.5 hours. In each case where two measurements of ammonia were obtained (field measurements and laboratory analysis), we report the average of the two values. In each case where only a single measurement was obtained (field measurements or laboratory analysis), we report that value.

3.4 Discharge

Stream flow discharge methods followed the EMAP protocol. Flow measurements were generally taken at or near the X-site, but were occasionally taken in another location if the channel characteristics at the X-site were unsuitable for discharge measurements. In Malibu Creek, the discharge measurements were to be collected by the UCSB group, but a malfunctioning meter hindered their ability to do so. Data for some of the sites was obtained from Heal the Bay, but these data were not taken concurrent with the rest of our measurements (but were within about 2 weeks of sampling).

3.5 Riffle Data

The following methods describe the collection of the BMI samples, and any supporting data, taken within the three riffle segments as per the CSBP protocols.

3.5.1 Benthic Macroinvertebrate (BMI) Sampling

Sampling of benthic macroinvertebrates precisely follows the procedures outlined in the California Department of Fish and Game CSBP handbook (Harrington and Born 2001) with the following exceptions: (1) As mentioned above, rather than randomly select three out of five contiguous riffles, we identified and sampled three contiguous riffles in order to maximize the inclusion of those riffles in the superimposed transect design. (2) The benthic invertebrate samples were subjected to streamside cleaning prior to preservation. Contents of the kick net were initially placed in a large plastic bucket for rinsing and removal of large debris and sediment. A second bucket was used to gather clean rinse water or to use as a secondary containment vessel. Cobble, Twigs, leaves, and other debris that could be cleaned and separated without the potential loss of benthic invertebrates were removed from the buckets. The bucket water was agitated and swirled and algae and small, entangled bits of debris were poured off into a 500 micron mesh sieve. Using additions of clean water, any remaining sediment and gravel was re-suspended by strong manual agitation and the water was then quickly poured off into the sieve. This sediment rinsing was done a minimum of three times. After all easy to remove pieces of clean debris were removed from the sieve, the remaining sample was placed in a jar and preserved in 70% ethanol. (3) Rose Bengal stain was added to the sample at the time of preservation. (4) Preserved samples remained within our research unit and were processed in-house.

Once at the lab, samples were prescreened to determine the rough concentration of benthic invertebrates, and if needed, were subsampled to yield final counts within the target range of 200-300 individuals. Subsampling involved the use of a 0.5L Folsom plankton splitter to obtain 50:50 fractions that could be split further if necessary. Prior to splitting, the Rose Bengal ethanol solution was poured off into a waste container using nylon hose material (i.e. knee-high nylons) to contain the sample. Samples were split in water and then returned to ethanol for storage and processing. Large twigs, leaves, or any other debris that would impair the even halving of the sample was cleaned and removed, and the sample was thoroughly agitated just prior to insertion in the splitting vessel. Algae clumps were separated with tweezers to facilitate splitting, and algae that ended up draped across the splitting median were severed and washed into the fractionation vessels. Sorting and identification of benthic invertebrates was done by our experienced researchers using a wide-view dissecting microscope. Individuals were identified to the lowest taxonomic level practicable. In many cases this was to the genus level, in others a broader taxonomic category was used. If the total count of invertebrates fell short of the 200 limit, then the remaining fraction was processed as well. All identified invertebrates were placed in ethanol-containing snap vials and will be stored indefinitely as vouchers.

3.5.2 Supplementary Data

Supplementary data were taken along with each of the benthic invertebrate samples. The location within the site, riffle length, gradient, and densitometer readings were taken for each riffle. We indicated whether these were transect samples (across the wetted width), or spot samples (in succession along narrower stream segments). The location within the riffle, riffle width, depth, and the embeddedness and consolidation of the sediment were taken for each sample within each riffle. Water velocity, densiometer and light measurements were taken, and the methods for these are specified below. The three most common substrate types composing the benthos of the sampling locations were recorded, along with an estimate of the percent composition of each. Sometimes only a single substrate type was present (i.e. sand), but if multiple substrates were recorded, their percentages were made to total 100%. Macroalgae and diatom cover were recorded for each sample using the standard abundance classes ("0" (absent), "1" (<5%), "2" (5-25%), "3" (25-50%), "4" (50-75%), and "5" (>75%)) for areal cover. The most representative diatom classification ("F", Fine (<1mm), "M", Medium (1-4mm), and "T", Thick (>4mm)), was indicated. The consolidation of the substrate within each sample was recorded using "O" (not consolidated), "L" (low consolidation – loosely cemented), "M" (medium consolidation – moderately cemented), and "H" (high consolidation – highly cemented).

3.5.2.1 Water Velocity

In addition to the discharge measurements, we also recorded flow at each of the nine benthic invertebrate kick net locations. These measurements were taken with the flow sensor centered within the 1 x 2 ft plot and positioned just above the benthos. A single measurement was recorded in each of these locations.

3.5.2.2 Densiometer

Densiometer readings (described later) were taken at each of the riffles. If "transect" sampling was used (wherein all three samples per riffle were taken across the wetted width of the stream), densiometer readings were taken across this section. When "spot" sampling was used (wherein the three samples were taken along the stream in an upstream/downstream orientation), densitometer readings were taken at a section midway between the downstream and upstream samples.

3.5.2.3 Light

Light readings (described later) were taken at each kick net location, by positioning the light bar in a central location directly above the 1ft x 2ft plot.

3.6 Transect Data

The following methods describe the collection of all data taken at each of the six stream positions ("transects") into which the reach was divided.

3.6.1 Substrate Cross-Sections

Because this project emphasized nutrient relationships, we sought to include more rigorous estimates of algae and vascular macrophyte cover than is sometimes included in monitoring programs. We collected point cover data at 20 points across the stream at each of the transects. (In the EMAP approach, depth, substrate, and embeddedness data were taken at five positions across the wetted width at each transect.) In stream sections where the wetted width was less than 1m, we sampled 10 points. After measuring the wetted width from left to right bank and staking the transect tape in place using chaining pins, we divided the wetted width by 21 to calculate the sampling interval (or by 11 in streams <1m), then collected data at each of the points along the tape. For each point we recorded all of the standard EMAP metrics, plus diatom, macroalgae, or vascular macrophyte cover. Depth was measured at every other point unless a substantial change occurred, or if depth went to zero. To avoid sampling bias, we recorded the category immediately underneath the point defined by the interval marking and the edge of the meter tape. For plant cover, only the first contact point was recorded; we did not record layers. The plant cover categories we used are given in Table 4. Diatoms were categorized according to the thickness of the periphyton (DF <1mm thick, 1mm<DM<4mm, DT>4mm thick). Our classification of diatoms includes the periphyton community less macroalgae, which is consistent with the classification used by the UCSB group. We made no attempt to positively identify the components of this community, so the general diatom category may include other taxa (such as cyanobacteria). After sampling, the number of points within each category were summed and multiplied by 5 (or by 10 if <1m) to obtain the percent cover estimate.

3.6.2 Algae Biomass

Upon completion of the algae and substrate cross-section, and prior to removing the transect tape, macroalgae samples were collected for the determination of biomass. Three of the substrate cross section intervals were selected randomly. At each location, a bottomless 5 gallon plastic bucket (1 gal. bucket, if wetted width < 1m), was centered directly upstream of the appropriate mark on the transect tape and pressed down into the sediment, or held firm against the substrate. If any of these points fell on dry substrate (e.g. on a bar or large boulder) or were so close that samples would overlap, a new random point was generated. Once the bucket was in place, all macroalgae were removed by hand and placed in a second bucket for rinsing. After multiple rinses with clean stream water to remove sediment, large debris such as leaves, twigs, and vascular plants were discarded. While it was impossible to remove every trace of foreign matter, a consistent level of effort was employed to minimize any non-algal contribution to biomass. Clean algae samples were labeled appropriately and placed in nylon stockings. With the ends tied to prevent tissue loss, the samples were stored in another bucket with clean water until they were ready to be processed. Once all samples were collected, the stockings were removed from the water, squeezed tightly, and spun vigorously for one minute in a salad spinner to remove water to a standard level. The algae samples were then removed from the stockings, cleaned of any substantial debris, and weighed to the nearest 0.1g on a field balance. Occasionally when the collection bucket was in place, only a trace amount macroalgae was observed. In these instances, we simply recorded either <0.1g or <0.01g and these were later approximated as 0.1g or 0.01g in the data files, respectively.

3.6.3 Densiometer

Densiometer measurements were taken according to the EMAP protocol. Using a standard spherical densitometer modified to show only 17 point intercepts, canopy cover estimates were taken at both stream banks facing inward, and in the center of the stream facing each of the four standard directions.

3.6.4 Light

Densiometer measurements provide an estimate of the amount of shading present at a site, but have limitations such as a failure to estimate the shading due to lower shrubs or grasses. We used a light meter with the sensor placed at the water's surface to provide a direct measure of shading actually experienced by the aquatic organisms. A Licor light meter with a one meter long line quantum sensor was used and incident light measurements were recorded in micro-moles. The sensor integrates light readings over a one meter long area which is advantageous given the spatial variability of stream bank vegetation. Light readings were also taken in full sun in proximity to the stream reach, in an open spot with minimal influence of shading elements. The light sensor was held level and parallel to the course of the stream. Variation in sun angle and cloud cover can significantly affect light readings. To minimize variation due to sun angle, we always took the light readings midday within one hour of high noon, and took all light readings consecutively in as short a time as possible.

While it would have been best to take light readings on clear sunny days, this was not always possible. On clear days, we usually took full sun readings once at the start of light sampling and once at the termination, and recorded the average of the two. On cloudy days we took paired full sun and sample readings at each reach location (transects and riffles). On days with rapid changes in light due to fast moving clouds, we usually postponed this portion of the sampling until a subsequent visit. Light readings were taken at each of the six transects and at each of the three benthic invertebrate riffles. Three light readings were taken at each transect (following the pattern of densiometer readings), one in the center of the stream and one at each bank. Bank readings were taken just streamward of the wetted width margin. All readings were taken with the one meter sensor held level as close to the stream surface as possible without getting it wet (generally about 10cm up), and parallel to the course of the stream. Researchers would always position themselves to minimize their influence on the light readings.

3.6.5 Riparian Vegetation

Visual estimation of riparian vegetation closely followed EMAP protocols for vegetative layering, but with certain modifications. Like EMAP, vegetation data were collected within 10m x 10m sections of stream bank along both sides of the each transect. However EMAP calls for those sections to begin at the bankfull margins, which for many southern California streams can be tens of meters away and functionally unconnected during base flow conditions. Since we wanted to determine the contribution of the stream side vegetation relative to base flow conditions, we began all of our riparian estimates at the wetted width margin. The canopy structure used was the same as EMAP: canopy cover (>5m), understory (0.5>5m), ground cover (<0.5m) and bare ground. However, we simply recorded totals for each of those layers without regard to the size of the component vegetation. In addition, a special category was created for *Arundo donax*, a highly invasive species of particular interest to California streams. Areal cover for grouped categories of total native and total non-native tree species were recorded, and most common individual tree species present were recorded (Table 5).

Due to the large variation in understory species only those which were of particular interest (e.g. non-native invasive species or sensitive native species) were recorded. The entry choices for areal cover were also changed. The areal cover categories we used for vegetation cover were different from EMAP, but the same as for “Reach Characteristics” on the X-site data sheet. These were “0” (absent), “1” (<5%), “2” (5-25%), “3” (25-50%), “4” (50-75%), and “5” (>75%). These new choices for areal cover were made in collaboration with Heal the Bay (of Santa Monica), and represent a combination of the categories used in their long term stream monitoring program and those used in EMAP. We also included a visual estimate of unstable banks in this section. These were estimated within 5m upstream and downstream of each transect, using our standard areal cover categories to record a linear value for unstable banks.

3.6.6 Fish Habitat

Estimation of fish habit was conducted similar to EMAP methods for fish cover, but with certain modifications including our standard areal cover choices. We used more clearly defined plant and algae categories including diatoms (medium and thick only), macroalgae, and vascular macrophytes. We also added a separate category called "total instream cover" to provide a general metric for all elements of fish cover taken together. This metric should not necessarily be considered a sum of all of the individual elements. For example, the presence of macrophytes or artificial structures may not necessarily provide cover for fish. The presence of bubble curtains was also included because these features can sometimes provide cover for fish.

3.6.7 Human Influence

The human influence portion is a simplified version of the corresponding section in EMAP. From our experience with EMAP, we felt that this section had limited utility with respect to the scale at which these elements influence streams. We felt that human activities such as agricultural practices could exert influences to the reach overall, but not at the scale of the transect. We therefore removed these elements from the transect data sheet and considered them solely within the "reach characteristics" section of the X-site data sheet. We only retained those human influences that could exert an influence at the scale of the transect. Human influences recorded were: rip-rap, concrete, paved roads, dry pipes/inlets, wet pipes/inlets, landfill, and park/lawn. These were sampled within 5m upstream and downstream of the transect on each side of the stream. The categories used were the same as EMAP: O (absent), P (>10m from bank), C (<10m from bank), and B (on stream bank). Certain choices were removed when appropriate (i.e., rip-rap only relevant on the stream bank).

3.7 Aquatic Vertebrate Sampling

3.7.1 Fish Sampling

Fish sampling was conducted according to EMAP protocols. Generally, the entire length of one bank was fished, with a standard backpack electrofisher and dip nets. The fished side was determined randomly. Sites with no identifiable fish habitat (e.g., very shallow cement channels) and sites with endangered species (e.g., three-spined stickleback) were not fished, and were so recorded. All organisms collected were held for a short period of time in plastic buckets with water regularly changed, were identified, counted and measured at the side of the stream, and then released. If very high numbers of a species were collected at a site, only the first 50 individuals were measured, with the rest tallied.

3.7.2 Wildlife Survey

We collected wildlife data using the following abundance categories: "0" no individuals or evidence observed, "S" one single observation was made, "F" few (2-10) individuals seen, "C" individuals were common (11-100) at the site, and "M" many (>100) individuals were present. We recorded these data for large mammals (larger than rabbit or squirrel), small mammals (rabbit or squirrel), or smaller aquatic birds (ducks, egrets, etc.), song birds (sparrows, etc.), turtles, other reptiles, frogs, tadpoles, other amphibians, flying insects, and swimming insects. For certain groups, such as large mammals, individuals are either cryptic or have behavioral patterns that reduce the chance of them being directly observed by researchers. We therefore used evidence of their presence rather than our direct observations to estimate their inhabitance of the sites. Tracks in the mud (mammals and birds), burrows (small mammals and reptiles), and audible sounds (songbirds) were used in this manner. We also included estimates for fish and crayfish that can be used when electrofishing was not possible. Obviously, some fish are more cryptic than others, but experienced field researchers will generally observe most of the common fish present throughout the course of sampling a stream. We included categories for the common species seen in our local streams (arroyo chub, fathead minnow, mosquito fish, sun fish, bullheads, and crayfish) and also included a category for unidentified small fish, and several places to write in novel or additional species. Estimates of this form have been used in many other types of monitoring programs and ours could be expanded to be more appropriate for other areas. These data are available in the associated Addendum, but are not otherwise included in this report.

4. Results and Discussion

Because of the complexity of the data collected in this project, we first describe the organization scheme used to present the data. One of our goals was to compare our results across the three watersheds we investigated. Therefore, we display each parameter as a set of three graphs per figure, one for each watershed. In each of these graphs, sites and their corresponding land uses are given on the X axis. Within the X axis, sites are arranged according to the progression of land uses commonly encountered as stream order increases. The order is arbitrary and other ordering schemes could have been used. In all cases the scale of the independent (Y axis) variable was standardized on associated or adjacent graphs to facilitate direct comparison of the data. Three types of data were collected at each site. Some data, such as water quality, discharge, and human use, were taken at a single location, usually at the X-site, and the influence of these metrics is assumed to be consistent throughout the entire reach. These data usually consisted of single measurements or readings and since no averages were calculated, there are no standard error bars. Another suite of data was taken at each of the six transects per site. The data presented are averages of these six transects with error bars. The third type of data was taken at each of the three riffles where benthic macroinvertebrate samples were collected. These data are averaged across the three riffles, and error bars are included. In some of the figures error bars appear to be absent, but this is due to identical readings. Superimposed within this organizational scheme, the data for each parameter were grouped according to land use. Initially, for each parameter, we present the data for all sites and watersheds without modification. Next, we combined and/or averaged sites of similar land use within watersheds, and presented these condensed data across watersheds as before. The purpose of doing this was to determine if land use effects vary between watersheds. Lastly, we combined sites from all three watersheds according to land use and displayed the results in single graphs for each parameter. Statistical analyses of the data were also performed within this organizational scheme and these results are presented separately, after displaying the graphs. We have taken an inclusive approach to investigating and reporting on many aspects of the data. Our descriptions of these results are more limited, however, and focus only on those aspects of the results where interesting or significant patterns can be seen.

4.1 Graphical Depiction by Site, Within, and Among Watersheds

4.1.1 Results from reach-scale sampling

As expected at the time of year in which sampling occurred, discharge was low at most of the sites surveyed (Figure 1). The sites with higher discharge were located below POTW outflows. In the CC watershed these were the two sites on Arroyo Conejo below the Hill Canyon treatment plant. On the SCR watershed, these were the three sites on the main river channel below the Valencia waste water treatment plant, plus the site above the outflow which was in turn, downstream of the Saugus POTW outflow. Emerging groundwater also contributed to the discharge in this area (E. Erickson, *personal communication*); discharge continued to increase until the Camulos Ranch site, after which, the water quickly disappeared into fluvial sediments. Our discharge data from the MC watershed are limited (due to our reliance on other research groups for these data), but qualitatively, we estimate that discharge at the above POTW site in Malibu Creek State Park would have been slightly less than $0.2m^3/s$ and between 0.2 and $0.4m^3/s$ at the below POTW site. These data are available for the site below the Tapia POTW outflow, since our site was just upstream of the gauging station, but we do not provide it here. The discharge at the remainder of the sites was primarily due to urban runoff except for the following: Soledad Canyon was due to emerging ground water or sub-surface flow, Bouquet Ref and rural residential were due to continuous release from the Bouquet Reservoir, upper and lower Todd Barranca were due to clean irrigation pressure overflow water from the Limonera plant (C. Taylor, *personal communication*), and lower Todd Barranca had additional tile drain input. When sites of similar land uses were combined (Figure 2 and Figure 3), these general results are corroborated, with a significant difference in discharge found among land uses (ANOVA, $p=0.025$). In pair-wise comparisons, the only significant difference was between agricultural, and single family residence land uses ($p=0.049$; Tukey HSD Multiple Comparisons test was used for all pair-wise comparisons), though qualitatively, flow at agricultural sites was not very different from POTW associated sites. This result is probably not representative of all local agricultural sites. While agricultural practices (especially row crops) are common along the higher order coastal plains and valley floors that are below most POTW outflows, significant agricultural land (especially orchards) is present along lower order hillside sites with lower flow.

Water temperature varied among sites (Figure 4), but the following patterns can be observed: in general, urban runoff sites had higher temperatures than corresponding non-urban sites, Bouquet Reservoir water is cooler than any other ambient water sampled in these watersheds, POTW water may result in spikes in water temperature. Two of the urban sites in SCR had temperatures that exceeded the limit of 26.7°C (80°F) which was identified as extreme in the Basin Plan (RWQCB-LA 1994). In the vicinity of Magic Mountain, rising groundwater resulted in lower temperature at the above POTW site. Then the POTW outflow created a spike in water temperature which was subsequently cooled by rising groundwater through the Blue Cut area and Camulos Ranch. This spike (25.5°C- highest measurement) was close to, but did not exceed, the limit of 26.7°C outlined in the Basin plan. When land uses were combined (Figure 5 and Figure 6) no obvious trends were apparent, and differences were not significant. The water temperature at the Triunfo horse property site in MC was particularly high on the day of sampling (Figure 6).

pH was relatively consistent across sites within the MC and CC watersheds, but more variable in the SCR watershed (Figure 7). pH was consistently higher in CC (just above 8) and lower in MC (just below 8). In the SCR watershed, pH was extremely high (between 9 and 11) at all of the sites with urban runoff, far exceeding the limit of 8.5 identified as extreme in the Basin Plan (RWQCB-LA 1994). A few other sites were close to this limit, including the Chumash Park commercial site in MC and several urban sites in CC. Bouquet reservoir water had lower pH. POTW outflows lowered the pH of the stream water. These patterns are more clearly seen when land use is combined within watersheds (Figure 8), but obscured when combined across watersheds due to the high urban readings at SCR (Figure 9). Overall, pH varied significantly with land use ($p=0.05$), but no pairwise differences were significant.

Dissolved oxygen values were quite variable, and only limited inference can be made (Figure 10). Urban runoff sites usually had higher DO values than reference waters (Figure 11 and Figure 12). POTWs did not seem to influence DO readings. None of these sites exhibited DO values below the lower limit of 5mg/L (Basin Plan), but these data were collected during the day and thus do not reflect the daily minimum (which typically occurs at dawn).

Conductivity values were quite variable, and only limited inference can be made (Figure 13, Figure 14 and Figure 15). Clean reference water (upper Cold Creek and Bouquet below dam) had low conductivity (0.67 and 0.35 mS/cm, respectively), urban sites usually had higher conductivity (0.87-3.45 mS/cm) and agricultural sites had no clear pattern. POTW's seem to increase stream water conductivity to a certain extent, but this was not significant. Overall the SCR sites had lower conductivity than the other two watersheds.

Nitrogen (Total Kjeldahl Nitrogen) values at most sites were dwarfed by an extremely high reading (over 1300µM) seen at the Magic Mountain below POTW site (Figure 16). The Blue Cut site downstream also had a high nitrogen value (>200µM) relative to the other sites. Because of this outlier, the remaining sites were plotted (Figure 17) at a more appropriate scale. While nitrogen values were variable, agricultural sites exhibited substantially higher values. It is unclear whether the high nitrogen value seen at Blue Cut was due to the residual nitrogen from the Valencia POTW spike, the surrounding agriculture, or both. As with all of the nutrient data, the analyses for the MC (and for the Deepwood SFR site in CC) and the other sites in CC and SCR were done by different labs. The differences in holding times between these groups of analyses would not be expected to have impacted the results for total nitrogen. Figure 18 and Figure 19 show the results when combined for land use, but most of these data are obscured by the same off-scale reading mentioned before. Combined across all watersheds, these differences were significant (p=0.013) with significant pair-wise differences between above and below POTW sites (p=0.024), and between below POTW sites and both reference (p=0.024), and rural residential (p=0.008) sites.

Total phosphorous also had sites with off-scale values (Figure 20). Both of the two row crop sites in the lower portion of Arroyo Conejo had extremely high phosphorous readings (around 50µM) relative to the other sites. Again, data for the remaining sites were replotted with the appropriate scale (Figure 21). Even at this scale, a clear pattern in phosphorous is difficult to discern, and human influences are probably site specific. For example, it may be that Seco Canyon runoff had a unique phosphorous input not representative of all urban channels. Water at the Bouquet Commercial (also higher phosphorous) site originated in Seco Canyon, as the main Bouquet channel was dry upstream of the confluence. The MC phosphorous data (supplied by the UCSB group) had higher resolution than the SCR data at low values, hence the uniform readings for SCR. The differences in holding times between these groups of analyses would not be expected to have impacted the results for total phosphorus. The Deepwood SFR (also supplied by UCSB) site was not graphed separately here but the total phosphorous value for this site was around 2µM. Figure 22 and Figure 23 show the results when combined for land use, but most of these data are obscured by the same off-scale reading mentioned before, and the differences were not significant.

Nitrogen to Phosphorous (N:P) ratios were also influenced by the off-scale nitrogen reading (>400) found at the Magic Mountain below POTW site (Figure 24). Because of this outlier, the remaining sites were graphed again (Figure 25) at a more appropriate scale. The N:P ratio at the Blue Cut site was still very high (>80) compared to the other sites. The commercial/industrial sites and the lower Todd Barranca site also had higher values. In MC, middle Cold Creek rural residential and the Lindero golf sites stand out as having higher N:P values. In CC, the Deepwood SFR site had a high N:P ratio as well. The same results combined for land use are given in Figure 26 and Figure 27, but most of these data are obscured by the same off-scale reading mentioned before, and the differences were not significant.

Combined nitrite and nitrate values were low throughout MC compared to the other two watersheds (Figure 28). The degree to which the variable holding times impacted the Malibu Creek (plus the Deepwood SFR site in CC) inorganic nitrogen results is unknown. However, comparison with nitrate+nitrite data collected by Heal the Bay on October 6, 2001 at the three sites that overlap (Cheseboro, Upper Cold Creek and Lower Cold Creek) indicate general agreement with the data presented here. The UCSB data were analyzed as combined nitrite+nitrate, rather than for the individual species. We have combined these two species for the rest of our sites in order to make the data comparable to the MC sites. The individual nitrite and nitrate data for the SCR and CC sites are included in the data. Of the SCR sites, the agricultural and below POTW sites had the highest combined nitrite+nitrate values, with a striking difference between the upper and lower Todd Barranca sites, and the above versus below POTW sites. The lower Todd Barranca site was the only site for which the Nitrogen level exceeded the limit of 10mg/L outlined in the Basin Plan (RWQCB-LA 1994), though the sites below the Valencia POTW were close to this limit. Upper Todd Barranca primarily consisted of overflow source water, so the dramatic increase in nitrogen at the downstream site was likely due to the influence of the orchard activities that line the Barranca. All of the urban and reference sites had very low values (reported as <1mg/L by the analytical laboratory). The row crop sites in the CC watershed had high values but were still below the limit of 10mg/L. Given the disparity between the MC sites and the other two watersheds, a new set of graphs was produced excluding the higher values in CC and SCR (Figure 29). With this increased resolution, it is evident that a significant increase in combined nitrite+nitrate occurred at the below POTW site in MC. No nitrite or nitrate was found at the horse site, while the golf course site had slightly higher values. The Deepwood SFR site had a relatively high level of inorganic nitrogen, but the reason for this is not clear. When land uses were combined (Figure 30 and Figure 31), similar results were found, and across watersheds, the differences were significant ($p=0.001$). In this ANOVA, above POTW sites differed from agriculture sites ($p=0.039$), which were in turn significantly different from commercial ($p=0.024$), reference ($p=0.004$), rural residential ($p=0.005$), and single family residential ($p=0.012$) sites.

Most of the sites had relatively low ammonia values, except for two sites in the SCR (Figure 32). The site below the Valencia POTW outflow had a very high ammonia level, (~20mg/L), and taking into account the pH and temperature of the water, this is the only site that exceeded the one hour average limit (~14mg/L) outlined in the Basin Plan (RWQCB-LA 1994). Blue Cut, further downstream, also had a relatively high NH_3 as well (~3mg/L), but this was lower than the Basin Plan limit (~6.8). All other sites had NH_3 values less than 1mg/L. The degree to which the variable holding times impacted the Malibu Creek (plus the Deepwood SFR site in CC) ammonia results is unknown. In addition, the MC data were reported as ammonium (NH_4) rather than ammonia, but the analyses were comparable. When land uses were combined (Figure 33 and Figure 34) similar results were found, but most of these data are obscured by the same off-scale reading mentioned before, and the differences were not significant.

Phosphate levels were disproportionately high at the CC row crop sites compared to all other sites (Figure 35). Given that these two sites had such high phosphate values (4.6 and 5.8 mg/L, respectively), the remaining sites were graphed again in Figure 36 at a more appropriate scale. In general, most of the sites in SCR had higher PO_4 levels relative to MC, but the degree to which the variable holding times impacted the Malibu Creek (plus the Deepwood SFR site in CC) ammonia results is unknown. Within these remaining sites, few patterns are obvious, except that the Todd Barranca sites appeared to be disproportionately lower than the rest of the SCR sites. When land uses were combined (Figure 37 and Figure 38) similar results were found, but across watersheds, no differences were significant.

Turbidity values varied throughout the sites, and only minimal inference can be made (Figure 39). In MC, the data are sparse because turbidity was not included in the set of analyses done on the UCSB water samples. The MC data we have were obtained from Heal the Bay and were taken within several weeks of our benthic invertebrate sampling. All of these four MC sites had relatively low turbidity values. In CC, the lower Conejo Creek row crop site had the highest turbidity of all our sites (~8 NTU), exceeding the drinking water standard of 5 NTU discussed in the Basin Plan (RWQCB-LA 1994). In SCR, the highest turbidity (5.3 NTU) was found at the Bouquet reference site below the Bouquet reservoir. This confirms our observation that the water emerging from the outlet appeared milky. This milky water became more clear further downstream of our site, and was not apparent at our rural residential site. This was the only full sampling site in SCR that exceeded drinking water standards. The urban and commercial/industrial sites all had elevated turbidity. The water at these sites was usually yellowish brown in color. The POTW sites had relatively low turbidity, but at Blue Cut and Camulos Ranch, the turbidity was elevated. The lower Todd Barranca site had higher turbidity relative to the upstream site. When land uses were combined (Figure 40 and Figure 41) similar results were found, but across watersheds, no differences were significant.

The results for the total number of fish collected at each of the sites are shown in Figure 42. This figure also breaks the data down into native and non-native species. Figure 43 shows the number of native fish collected by species. The most common native fish throughout these three watersheds was the arroyo chub. One Santa Ana sucker was observed at the Camulos Ranch site. There are numerous sites here with no data, and these apparent "data gaps" require clarification. Within MC, the Chesebro reference site and the Chumash commercial site were not fished because of the obvious lack of habitat. The other sites had possible fish habitat and were fished, but no fish were observed or collected. Of the CC sites, Reino, Young, and Ventu Park had an obvious lack of habitat and were not fished, and Deepwood was fished but none were observed or collected. Of the SCR sites, Haskell, Seco, Bouquet commercial, and Peck had an obvious lack of habitat, and Bouquet reference and upper Todd Barranca were fished, but none were observed or collected. Soledad Canyon, above POTW, below POTW, and Blue Cut were not fished because of the known presence of threatened or endangered species. Fish were observed at all of these sites, however. Stickleback were common at Soledad Canyon, and arroyo chub were abundant at the other three sites. When land uses were combined within watersheds (Figure 44, Figure 45, Figure 46, Figure 47, and Figure 48), almost every land use type was found to have either native or non-native fish. A notable exception was that no fish were found in any of the reference sites. Fish were usually absent from the lower order streams and substantially altered concrete channels.

While crayfish were common at many of the MC and CC sites, they were almost absent from the SCR sites (Figure 49). Only a couple of crayfish were collected or observed at the Camulos Ranch site. In MC, crayfish were most abundant at the Lindero SFR site, but were also common at several of the other urban sites as well as below the POTW outflow. In CC, crayfish were abundant at the Wildwood, Deepwood urban sites and at the row crop site in lower Arroyo Conejo. When land uses were combined within watersheds (Figure 50 and Figure 51), almost every land use type was found to have crayfish.

While not graphed separately here, an ANOVA was performed on the reach length with land use combined across watersheds. Reach length differed significantly overall (p=0.002), with agricultural sites differing significantly from commercial (p=0.007), reference (p=0.007), rural residential (p=0.003), and single family residence (p=0.036) sites.

4.1.2 Results from transect sampling

The cross-sectional transect data (substrate, algae, etc.) are reported as percent cover. All of the riparian percent cover results, plus unstable banks and fish cover, were obtained by averaging the cover classes described earlier (e.g. 25-50%), using the midpoints of the interval ranges.

The substrate composition of all sites is displayed in Figure 52. This figure provides much information on the geomorphology of these sites. Sites dominated by concrete are easily seen in comparison to those dominated by bedrock, sand and those of more diverse substrate composition. In MC, three of the four urban sites (Lindero golf, Medea SFR, and Chumash commercial) were concrete dominated with limited loose sediment accumulation. The other urban site, Lindero SFR, though heavily altered, had diverse substrate types from concrete to boulders. All of the Cold Creek sites had bedrock, but the middle rural residential site was dominated by bedrock with only limited boulders, cobble and loose substrate accumulation, the reference site had diverse substrate with a roughly even mix of boulders, cobble, and other substrate types, and the lower Cold Creek rural residential site was also diverse, but had a slightly higher proportion of cobble and coarse gravel. The MC State Park site (designated as above POTW) was a reasonably natural site dominated by boulder and cobble substrate. A limited amount of sediment accumulation occurred in pools. The below POTW site had a lower gradient, and while boulders and cobble were present, the site was dominated by sand.

In CC, three of the five urban sites (Reino SFR, Young SFR, and Ventu Park commercial) were concrete dominated with little or no loose sediment accumulation. The Oaks Mall commercial site was also heavily altered, but was bedrock dominated with moderate substrate diversity. Some old and patchy concrete sections were present, as were boulders and some sediment accumulations in pools. The Deepwood SFR site was considerably less altered and had diverse substrates. Though most sediment types were present in moderate proportions, the site was dominated by fines and other loose sediment. Of the two agricultural sites, the Leisure Village site had more diverse sediments and was dominated by cobble and coarse gravel, while the lower Conejo site was dominated by sand.

In SCR, all four of the urban sites were concrete dominated with essentially no sediment accumulation. Soledad Canyon reference site had a roughly even mix of gravels and finer sediments with some cobble and hardpan. The reference site below the Bouquet reservoir was also dominated by gravels and finer sediments but had a significant proportion of root mass composing the substrate as well. The rural residential site downstream had an even mix of substrate types with boulders and other coarse substrates composing over 75% of the substrate. Some sediment accumulation occurred in pool habitats. All of the lower elevation sites on the main SCR floodplain were dominated by sand and other fine sediments. Gravels were also common in these sites, especially below the POTW and at Blue Cut. Blue Cut had a limited amount of cobble present in higher flow areas. The Todd Barranca sites were dominated by gravel, sand and fine sediments. Hardpan was also present at these sites, especially at upper Todd Barranca where it composed over 40% of the substrate. When combined for land use (Figure 53 and Figure 54), it is clear that urban sites are usually concrete dominated, agricultural and POTW associated sites are dominated by sand and other fine sediments, and reference and rural residential sites are represented by an even mix of different substrate types.

Because we expected a negative influence of less stable accumulated sediments, we considered these substrates separately. Sands and fines were combined and graphed across all sites in Figure 55, and combined for land use in Figure 56 and Figure 57. Fine gravel was then added, and this combination is displayed in Figure 58 and Figure 59 (though we didn't include a graph for land use combined across watersheds). These data were primarily separated for statistical analyses; we have included the graphs here for completeness, but the general trends have already been discussed in the preceding sections. When all watersheds were combined, there was a significant difference in this combined metric (sand +fines+gravel) among the different land uses (p<0.001). Above POTW was significantly different from commercial (p=0.001) and single family residence (p=0.006), and agriculture differed significantly from commercial, rural residential, and single family residence (p<0.001 for all) and nearly so for reference (p=0.068). Additionally, below POTW was significantly different from commercial (p<0.001), rural residential (p=0.003), and single family residence (p<0.001), commercial from reference (p<0.001), and reference from single family residence (p=0.002).

While not graphed separately here, ANOVAs were performed on the following substrate components with land use combined across watersheds: Cobble differed significantly overall (p<0.001), with significant pair-wise differences between above POTW and commercial (p=0.011), commercial and rural residence (p<0.001), and a nearly significant difference between agriculture and rural residence (p=0.051). Boulder differed significantly overall (p<0.001), with significant pair-wise differences between above POTW and all other land uses (p = 0.001). Bedrock differed significantly overall (p<0.001), with significant pair-wise differences between rural residence and all other land uses (p<0.001 for all). Hardpan differed significantly overall (p<0.011), with significant pair-wise differences between agriculture and commercial (p=0.024), and single family residence (p=0.028), plus agriculture was nearly significantly different from rural residence (p=0.067). Concrete differed significantly overall (p<0.001), with significant pair-wise differences between commercial and above POTW, below POTW, agricultural, reference and rural residence sites (p<0.001 for all), and significant pair-wise differences between single family residence and above POTW, below POTW, agricultural and reference sites (p<0.001 for all).

Substrate embeddedness for all sites is given in Figure 60. It should be mentioned here that we followed the standard convention of considering concrete bedrock and hardpan zero percent embedded, and sand and silt (fines) as 100% embedded. As a result, Figure 60 shows concrete dominated sites to have low embeddedness and sand dominated sites having high embeddedness. The fact that many of our sites exhibited these extremes is apparent in this figure. Those sites with variable composition or with coarser substrates (e.g., MC State Park-above POTW, and Bouquet rural residential) all had embeddedness values over 60%. In general, most of the sites in these three coastal watersheds that have coarse sediments suffer from high embeddedness. When combined for land use (Figure 61 and Figure 62), urban sites show low embeddedness, rural or reference sites show moderate embeddedness, and agricultural and POTW associated sites show high embeddedness. Embeddedness greater than 60% differed significantly overall (p<0.001), with significant pair-wise differences between above POTW and commercial ($p<0.001$), rural residential ($p=0.017$) and single family residence ($p<0.001$), and between agricultural and commercial, reference, rural residential and single family residential sites ($p<0.001$ for all). Additionally, below POTW differed significantly from reference ($p=0.024$), and commercial, rural residential, and single family residence ($p<0.001$ for all). Finally, reference sites differed significantly from commercial ($p<0.001$) and single family residence ($p=0.007$).

Streamside canopy measurements for all sites are displayed in Figure 63, and combined for land use in Figure 64 and Figure 65. These data represent the cover of native trees, non-native trees, and/or *Arundo*. While the here are variable, canopy cover at golf and urban sites (SFR, Commercial, and Industrial) was usually low to absent. Reference sites and rural residential sites usually had higher canopy cover, and agricultural sites were variable. Among agricultural sites, row crops often had low canopy cover, and orchards had very high cover.

The percent cover estimates for streamside understory vegetation for all sites are shown in Figure 66, and combined for land use in Figure 67 and Figure 68. As per EMAP, these data represent the cover of shrubs, as well as the lower (0.5m to 5m above the ground) portions of larger canopy forming trees and *Arundo*. As with the canopy data, understory cover was quite variable, but was generally lower at golf and urban sites, and higher at reference and rural residential sites. Agricultural sites were variable, but often had moderate understory cover.

Ground cover estimates for all sites are shown in Figure 69 and combined for land use in Figure 70 and Figure 71. As per EMAP, these data represent the cover of grasses, and the lower (<0.5m above the ground) portions of shrubs and trees. As would be expected, the golf course site in MC had dense ground cover. As with the understory data, ground cover was higher at reference and rural residential, as well as those urban sites that more natural vegetation characteristics. Other urban sites that were devoid of riparian buffers had low or absent ground cover. Agricultural sites were variable, but often had moderate ground cover.

Bare ground (usually dirt or duff, without grasses, herbs, or basal portions of other plants) was high at most of these arid southern California sites (Figure 72, Figure 73, and Figure 74). Bare ground was lower at reference sites and at the golf course site. Bare ground was the highest at the urban sites that were heavily channelized and where buffer zones were absent.

The percent cover estimates for native trees for all sites are shown in Figure 75, and combined for land use in Figure 76 and Figure 77. These data transcend the layering structure of the EMAP approach, and represent the total cover of both large and small trees; they do not include saplings. In general, reference sites and rural residential sites had high cover of native trees while urban sites had lower cover. Some urban sites (Lindero SFR, Deepwood SFR, Oaks commercial) had vegetated buffer zones and had higher tree cover. Agricultural sites had greater variability in native tree cover. The data for Blue Cut indicate that native tree cover was low. Though both bankfull margins were lined by native trees, our cover estimates were within 10 meters of the wetted width (see site description), so these trees were usually not considered. The data for Camulos show around 50% cover of native trees. In fact, one bank of the stream was densely vegetated with native trees, the other bank was almost 100% *Arundo* (see below).

The composition of native tree taxa at all sites is given in Figure 78. Willows were the most common native trees in all three watersheds, followed by oak. Cottonwoods and Sycamores were more common at the MC and SCR sites than in CC. Willows and cottonwoods were common along the banks of Blue Cut, but these were beyond the survey plots. Several sites stand out as having greater diversity and abundance of native tree taxa than others (MC State Park – above POTW, Cold Creek sites, Bouquet rural residential). When combined for land use (Figure 79 and Figure 80), the reference and rural residential sites stand out as having high diversity and abundance of native tree taxa, as well as the above POTW category which is mostly due to the MC State Park site.

Non-native trees were not common at most of our sites (Figure 81), but were more common at urban sites. The Todd Barranca orchard sites stand out as having significant cover of non-native trees. This is due to the tall Eucalyptus trees that lined the left bank at both sites. Eucalyptus trees are commonly placed near orchards as wind breaks. When combined for land use (Figure 82 and Figure 83) the same results are corroborated; non-native trees were more common at the urban sites.

Figure 84 shows the sites in which the giant reed *Arundo donax* was found. While these sites may not be representative of the entire watershed, fewer sites in MC had *Arundo* than in CC and SCR had the highest number. The cover of *Arundo* was moderate at the Oaks Mall commercial site and at Leisure village in CC. Cover of *Arundo* was substantial below the POTW outflow and especially at the Camulos Ranch site in SCR. *Arundo* is extremely abundant within and adjacent to the flood plain in the lower portion of the SCR. When combined for land use (Figure 85 and Figure 86), it appears that agricultural sites and below POTW sites had high *Arundo* cover in general, though reference and rural residential sites had *Arundo* as well.

As one estimate of canopy shading, densiometer readings for all sites are displayed in Figure 87, and combined for land use in Figure 88 and Figure 89. These data compare fairly well to the canopy estimates given previously in Figure 63. With certain exceptions, densiometer readings at golf and urban sites (SFR, Commercial, and Industrial) were usually very low. Reference sites and rural residential sites usually had higher readings, and agricultural sites were variable. Among agricultural sites, row crops often had low readings, while those at orchards were quite high. Notable here was the site at Medea Park. While tree cover was almost absent at this site, a road over-crossing contributed to significant shading for over a third of the reach.

As an additional estimate of shading, incident light measurements for all sites are given in Figure 90, and combined for land use in Figure 91 and Figure 92. These light measurements were taken right above the stream water level during mid-day and reflect the shading due to the canopy and low growing vegetation. They are roughly the inverse of the densitometer (Figure 87) and canopy (Figure 63) estimates discussed previously. When all watersheds were combined, there was a significant difference among the different land uses ($p<0.001$). Urban and row crop sites tended to have the highest light levels (approx. 1000 µE);

reference and rural residential sites had lower light levels (approx. 200 µE). The same urban sites mentioned earlier with vegetated buffer zones also had lower levels of incident light. Above POTW differed significantly from reference ($p=0.011$) and rural residential ($p=0.084$), agriculture from reference ($p=0.011$), commercial from reference ($p=0.002$) and rural residential ($p=0.026$), and reference from single family residence ($p<0.001$).

Corrected against full sun readings taken nearby, the percent reduction of light due to shading for all sites is displayed in Figure 93. These data are directly comparable to the densiometer data (Figure 87) with certain exceptions. Most sites have low overhanging vegetation that is reflected in additional shading captured by our light meter. Certain sites such as the SCR below POTW site and Camulos Ranch had dense vascular macrophyte communities that contributed to increased levels of light reduction compared to the analogous densiometer measurements. When combined for land use within (Figure 94) and among watersheds (Figure 95), with exceptions, percent light reduction was generally lower at golf and urban sites (SFR, and Commercial) and higher at reference and rural residential sites. When all watersheds were combined, there was a significant difference among the different land uses ($p<0.001$). Row crop sites had lower light reduction due to shading than orchard sites. It is noteworthy to mention that the Peck industrial site in Santa Paula showed increased shading from the light meter data compared to the densiometer data. The reasons for this are unclear, but it is likely due to the orientation of the concrete box channel relative to a row of non-native trees on the south bank. Because of this orientation, the channel receives more shading than the densiometer canopy measurements would indicate. Above POTW differed significantly from reference ($p=0.002$) and rural residential ($p=0.007$), agriculture from reference ($p=0.002$) and rural residential ($p=0.008$), commercial from reference ($p=0.001$) and rural residential ($p=0.005$), and reference from single family residence ($p=0.002$).

The presence of algae is thought to correlate with nutrient levels, flow conditions, substrate, and light (Stevenson et al. 1996). Figure 96 shows that macroalgae biomass was common at more of the MC sites than in the other two watersheds. All sites with macroalgae show high variation, which supports our qualitative observation that the distribution of algae within reaches is usually highly clustered. Within MC, algae biomass was highest at the below POTW site (47.66 ± 23.97 g/m^2), but biomass was also high at the commercial site, both rural residential sites, and at Medea SFR. In CC, substantial algae biomass was collected at the commercial site (7.98 ± 2.73 g/ m^2). In SCR, the Peck commercial/industrial site had high algae biomass (39.12 ± 21.81 g/ m^2), as did the below POTW site and Blue Cut. Lower amounts of algae biomass (< 2.50 g/ m^2) were collected at some of the other sites as well including the reference sites at Soledad Canyon and Bouquet Below Dam. When all watersheds were combined, there was a significant difference among the different land uses ($p=0.041$). When combined for land use (Figure 97 and Figure 98), algae biomass was highest below POTW's, at commercial/ industrial sites, and at row crop sites, but this was mainly due to the high biomass collected at Blue Cut. Below POTW was statistically different from SFR ($P=0.039$), and nearly significantly different from reference ($p=0.051$).

As with biomass, the percent cover of macroalgae was highest in MC, but all three watersheds had sites with high macroalgae cover, and the differences were less striking than the biomass data (Figure 99). In MC, only the reference and golf course sites lacked macroalgae entirely. The Lindero SFR site had some algae cover even though no biomass was collected (Figure 96). All other MC sites had moderate levels of macroalgae (approx. 20 %), but the highest cover (30.83 ± 3.27 %) was found at the commercial site. While we don't report the composition of macroalgae species here, the most common genera present were *Rhizoclonium* and *Enteromorpha*. At the Middle Cold Creek rural residential site, most of the algae present was *Chara*, a non-nuisance genus. In CC, macroalgae were present at half of the sites sampled, though the lower Conejo row crop site, which was sand dominated, had very little. The Ventu Park commercial site had the highest cover (37.50 ± 5.44 %). In SCR, 7 of the 13 sites sampled had macroalgae, though only a trace was found at the Bouquet rural residential site. Macroalgae were the most abundant at the Peck commercial/industrial site and at Blue Cut (18.33 ± 4.77 % and 29.17 ± 5.69 %, respectively). The Blue Cut site was unique in that macroalgae was abundant despite the high flow seen at the site. This site had a cobble bottom with riffle and rapid flow regimes. In portions of the reach, macroalgae covered the bottom of these habitats throughout the wetted areas with long strands of *Rhizoclonium*/*Cladophora* extending downstream in the current. The below POTW site, upstream of Blue Cut by several miles, also had high flow (due to the outflow), but the bottom was a mixture of gravel and cobble and algae were only present mainly in backwaters and stream margins where flow was slower. When all watersheds were combined, there was a significant difference among the different land uses (p=0.001). When combined for land use (Figure 100 and Figure 101), macroalgae cover was seen to be the highest (approx. 10-18 %) at commercial/industrial sites, at row crop sites, and at POTW associated sites. All land use types had some macroalgae cover except the golf course site. Algae cover was relatively low (approx. 1.4-3.5%) at reference, rural residential, and orchard sites. Statistically, agriculture was significantly different from commercial, which differed in turn from reference (p=0.001), rural residential (p=0.002), and single family residence (p=0.002).

Diatom (>1mm thick) cover was generally lower at SCR sites compared to the two other watersheds (Figure 102). MC had the highest cover of diatoms, which were common at every site except the upper Cold Creek reference site. Diatoms were extremely common (65.83 ± 6.64 % cover) at the MC State Park site above the POTW outflow. All other MC sites had moderate diatom cover except the golf course site, in which cover was relatively low (2.50 ± 1.71 %). All of the CC sites had at least some diatom accumulation except for Young SFR, which only had diatom films. The highest cover in CC was at the two commercial sites (24.58 ± 5.13 %). At most of the SCR sites diatom cover was low or absent. The highest diatom accumulations (16.67 ± 7.49 %) were found at the Soledad Canyon reference site. When all watersheds were combined, there was a significant difference among the different land uses (p<0.001). When combined for land use (Figure 103 and Figure 104), POTW associated sites and commercial sites had the highest cover of diatoms, though much of the former was due to the high diatom cover found at the MC State Park site. Above POTW was statistically different from all other land uses (p=0.024 for below POTW; p=0.005 for commercial; p<0.001 for all others), and agriculture was nearly significantly different from commercial (p=0.054).

Aquatic vascular macrophytes were common in all three watersheds, but were in greatest abundance (up to 73.77 ± 6.28 % at Above POTW) at some of the SCR sites (Figure 105). In SCR, macrophytes were most common in the higher order sections lower in the watershed. The exception to this was at the Soledad Canyon reference site, which was a narrower stream with dense low growing watercress throughout certain portions of the reach.

The above POTW site also had a narrow stream running through a wider flood plain. The wetted areas here were densely covered by relatively tall watercress. The below POTW site had a wider stream channel (due to the outflow) with heavy flow in the center and wide margins of low growing watercress, duckweed and some cattails. The Camulos Ranch site had a wide sandy channel that had braided stream courses cutting through dense and very tall vascular macrophytes that covered most of the channel. None of the urban sites in SCR had vascular macrophytes. Data from the other two watersheds were more variable with lower cover of macrophytes distributed across most land uses. When all watersheds were combined, there was a significant difference among the different land uses (p<0.001). When combined for land use (Figure 106 and Figure 107), macrophytes cover was highest at agricultural and POTW associated sites with cover present but relatively lower across all other land uses, though much of the latter was due to the high macrophyte cover found at the SCR above POTW site. Above POTW was significantly different from commercial (p<0.001), reference (p=0.003), rural residential (p=0.002), single family residential (p<0.001), and was nearly significant from agriculture (p=0.052), but not from below POTW. In addition, agriculture differed significantly from commercial (p=0.029), and single family residence (p=0.038), and below POTW differed (not significantly) from commercial as well (p=0.085).

Unstable banks are a common feature when bank vegetation has been removed but the banks have not been artificially stabilized. The percentage of unstable banks at all sites is shown in Figure 108, and combined for land use in Figure 109 and Figure 110. Overall, SCR sites had a greater percentage of unstable banks than the other two watersheds. With the exception of the urban sites, none of the SCR sites had artificially stabilized banks. Blue Cut had the greatest occurrence of unstable banks (83.33 ± 2.81%). This is because the heavy flow moving through the area had been eroding away at the sediment accumulated during high flow events. This same phenomenon occurred at the other sites in the main SCR floodplain. In MC, unstable banks were most common at the Cold Creek sites, which had no artificially stabilized banks. All of the other MC sites had artificially stabilized banks except the POTW-associated sites, which were naturally stable. Every one of the CC sites had artificially stabilized banks. Unstable banks differed significantly overall among land uses (p<0.001), with significant pair-wise differences between agricultural and above POTW (p<0.001), commercial (p<0.001), reference (p=0.005), rural residence (p<0.001), and single family residence (p<0.001). Undercut banks differed significantly as well (p=0.026), with a nearly significant pair-wise difference between agricultural and below POTW (p=0.063). In addition, the presence of artificial structures was significantly different overall (p<0.001), with pair-wise differences between commercial and above POTW, below POTW, agricultural, reference and rural residence (p<0.001 for all). Artificial structures also exhibited a significant pair-wise difference between single family residence and above POTW, below POTW, agricultural, and reference sites (p<0.001 for all).

Total instream cover was variable across all sites (Figure 111), but was generally lower at urban sites (Figure 112 and Figure 113). The total number of fish caught at the sites (Figure 42) does not seem to correlate well with the amount of cover available. Most of the reference sites (which are usually low order streams) had adequate habitat available, but fewer fish were caught. The exception here was Soledad Canyon (not fished), where stickleback were common. Agricultural and POTW-associated sites often had fish and fish habitat, but the proportion of non-native fish was very high at these sites. Possible exceptions here were the POTW sites and Blue Cut on the SCR. These sites were not fished because threatened fish species had been reported there in the past. Moderate instream cover was present at these sites and fish were observed to be common.

4.1.3 Results from riffle sampling

Here we present the results of the BMI collections and all associated data taken at the riffles. Much of the physical data presented earlier were taken again at the exact riffle locations where the BMI samples were collected. This was done mainly to allow statistical comparisons with riffle BMI data, but we present this second set of results here for reasons of completeness. The only parameters we measured separately here were those that could have an influence at the smaller spatial scales relevant to the BMI communities, specifically water velocity, substrate features, densiometer and light measurements, and algae percent cover estimates. Most of the data obtained here have trends that are similar to the corresponding measurements taken at the transects. We limit our attention, therefore, to those patterns that represent a departure from the previous transect data. The actual BMI results will follow.

Water velocity taken at the riffles was different in nature from the discharge data presented earlier. Velocity measurements were taken right at the benthos where the invertebrates reside. The water velocity measurements at all sites is given in Figure 114. Most of the sites had velocities between 0.3 and 0.5 meters per second. Sites with higher velocity included the golf and above POTW sites in MC, upper Wildwood and Oaks Mall in CC, and Seco Canyon and all of the higher order main channel sites in SCR. The Peck Rd industrial site in SCR stood out as having lower flow, as did several other urban sites. Water velocity at the riffle sampling locations did not exhibit any obvious pattern when combined for land use (Figure 115 and Figure 116); however, the overall difference among land uses was nearly significant ($p=0.066$) when compared across watersheds.

Riffle substrates at the BMI sampling locations (Figure 117) differed substantially from the corresponding transect data reported earlier (Figure 52). At urban sites with concrete channels, these differences were usually subtle to absent. As would be expected, sites tended to have less sand and other fine sediment at the riffle locations compared to the transects. Even if a site had a large percentage of unstable substrate overall, our BMI samples were usually collected at areas with more stable sediment. Exceptions were at lower Conejo in CC and at Blue Cut and Camulos Ranch in SCR, where the BMI sample locations were sand dominated. At other sites, the BMI samples were collected at bedrock or hardpan dominated locations that are also sub-optimal habitats for invertebrates. When combined for land use (Figure 118 and Figure 119), the patterns are roughly comparable to the transect data. Urban BMI samples were mainly collected from concrete substrate; agricultural and POTW associated sites had a greater percentage of unstable substrate; and reference and rural residential sites had a greater percentage of bedrock, hardpan, and coarser substrates.

Substrate embeddedness within the riffle sampling locations (Figure 120) was roughly consistent with the data for the reach as a whole (Figure 60). At most of the sites within each of these three watersheds, the embeddedness of the substrate was at one of two extremes. At urban sites with concrete channels or where bedrock occurred, embeddedness was very low.

At the opposite extreme, agricultural or POTW associated sites which were dominated by sand or otherwise fine substrate, the embeddedness was very high. However, even at those sites with gravel, cobble, and boulders, the coarser substrates were usually surrounded by sand and other fine sediments, leaving little interstitial space for benthic invertebrates. Two sites that stood out as having a favorable combination of coarser riffle substrates and low embeddedness were the upper Cold Creek reference site in MC, and the Bouquet rural residential site in SCR. The same data combined for land use are given in Figure 121 and Figure 122.

Densiometer readings taken at the BMI riffles are displayed for all sites in Figure 123 and combined for land use in Figure 124 and Figure 125. Incident light readings taken at the BMI riffles are displayed for all sites in Figure 126 and combined for land use in Figure 127 and Figure 128. Light as percent reduction of full sun readings taken at the BMI riffles are displayed for all sites in Figure 129 and combined for land use in Figure 130 and Figure 131. None of these canopy or light data show patterns that differ from the site-wide data taken at the transects (Figure 87 through Figure 95).

The percent cover of macroalgae within the BMI sampling locations (Figure 132) was, in general, lower than the cover of algae at the site overall (Figure 99). Macroalgae tend to be more common along riffle margins than within the riffles (where BMI sampling typically occurred). Still, macroalgae were present in the riffles at numerous sites (especially in MC) and had high cover in several of them. Sites that stood out as having higher macroalgae cover were the Ventu Park commercial, and Young SFR sites in CC, and the Blue Cut row crop and Soledad Canyon reference sites in SCR. These data, combined for land use, are given in Figure 133 and Figure 134. Percent cover of macroalgae did not vary significantly with land use.

The percent cover of medium to thick diatom accumulations within the BMI sampling locations was low or nil at many of the SCR sites compared to the other watersheds (Figure 135). Diatom cover was higher at many of the MC sites compared to the other two watersheds. Within CC and SCR, most of the concrete dominated urban sites and the sediment dominated agricultural sites had low accumulations of diatoms. Diatom films (<1mm thick) were, however, common at most of the concrete dominated sites, but these were not included here. Diatom cover tended to be low to absent at the reference and rural residential sites. A notable exception here was the upper Wildwood site in CC. These patterns are less evident when the data were combined for land use (Figure 136 and Figure 137), primarily across all watersheds. Cover of medium and thick diatoms differed nearly significantly overall among land uses ($p=0.053$).

The next series of graphs presents the results from our benthic macroinvertebrate collections at the sites. We begin with the total number of individuals collected, then the total number of taxa, followed by the total number of EPT (Ephemeroptera, Plecoptera, and Trichoptera) individuals, and the total number of EPT taxa. While we only present the data for these four groupings here, much more detailed data for the various taxa we identified are available and will be submitted in our data files.

The total number of BMI individuals collected was much higher overall at the MC sites compared to the two other watersheds (Figure 138). Within MC, the sites that had the highest number of individuals were Lindero SFR (8,364.33 ± 7427.45) and Lower Cold Creek rural residential (7,274.67 ± 3,201.72), though both of these sites had high variance as well. The sites that had the lowest number of individuals were the golf course (1,496.89 ± 88.53) and the horse site. Within CC, the commercial sites and the rural residential site at upper Wildwood park had relatively higher numbers of individuals (2,027.33 ± 364.44 and 2,688.00 ± 635.45, respectively), while very few individuals (43.67 ± 26.86) were found at the lower Conejo Creek row crop site. In SCR, the rural residential and reference sites had relatively high numbers of invertebrates (1,885.33 ± 413.28 and 3,438.67 ± 547.64, respectively), as did the Haskell SFR and below POTW sites (3,327.00 ± 1,646.66 and 2,461.33 ± 1,031.89, respectively). Camulos Ranch had very few individuals (53.33 ± 6.64), as did several other sites. When combined for land use (Figure 139 and Figure 140), the total number of individuals present did not seem to follow a clear pattern relative to land use, whereas the ANOVA indicates significant overall differences ($p<0.001$) across watersheds. For the most part, agricultural sites had fewer individuals than other land uses, and these differences were significant: agriculture vs. above POTW ($p=0.005$), single family residence ($p=0.002$), and below POTW, commercial, reference, and rural residential sites ($p<0.001$ for all). Industrial was lumped with commercial for these statistical analyses, and golf was not included.

The total number of Ephemeroptera-Plecoptera-Trichoptera (EPT) individuals, taxa that are sensitive to disturbances, was greater overall at the MC sites than the two other watersheds (Figure 141). In MC, the Upper Cold Creek reference site and the Lower Cold Creek rural residential site had very high numbers of EPT individuals (4,661.33 ± 578.69 and 3,856.00 ± 1,470.03, respectively) while the horse site and the Lindero SFR sites had relatively few (128.00 ± 48.88 and 131.33 ± 68.94, respectively). The sites with concrete substrate (golf, Medea SFR, and commercial) also had lower EPT numbers, as did the Middle Cold Creek rural residential site, which had mainly bedrock. In CC, EPT individuals were found at all sites, but very few (2.00 ± 0.58) were found at the lower Conejo site. The Wildwood rural residential and Oaks Mall commercial sites had the highest number of EPT individuals (960.00 ± 64.17 and 732.00 ± 251.41, respectively) relative to the other CC sites. In SCR, the reference and rural residential sites had moderate to high numbers of EPT individuals, while most other sites had very few to none. No EPT individuals were found at Haskell SFR, Bouquet commercial, or upper Todd Barranca. When combined for land use (Figure 142 and Figure 143), reference and rural residential sites had considerably more EPT individuals than other sites, and agricultural sites had considerably fewer, as did the horse and industrial sites. Differences among land use sites were significant ($p<0.001$) across watersheds, with significant pair-wise differences as expected between agricultural sites and above POTW ($p=0.014$), below POTW ($p=0.024$), reference and rural residential ($p<0.001$). Additionally, significant differences between commercial and reference ($p=0.001$) and rural residential sites ($p=0.005$) were found, as well as between reference and single family residence sites ($p<0.001$).

The total number of taxa identified at all sites is given in Figure 144. The range in number of taxa present was greater among SCR sites than in the two other watersheds. Three of the SCR sites (Soledad reference, Bouquet rural residential, and the above POTW site) had notably more taxa (approximately 19) while the urban sites all had notably less (approx. 6).

In MC, the horse, golf, and urban sites had fewer taxa (approx. 10), while the rural, reference, and POTW-associated sites had approximately 18 taxa. The variation among the CC sites was lower, but the lower Conejo row crop, Reino SFR, Young SFR, and Oaks Mall commercial site had fewer taxa than other sites. When combined for land use (Figure 145 and Figure 146), horse, golf, urban and agricultural sites seemed to have fewer total taxa than other land uses. These results are reflected in the ANOVA, which was significant overall ($p<0.001$) across watersheds, showing a significant difference between agricultural and above POTW, reference and rural residential sites ($p<0.001$ for all), between commercial and above POTW, reference and rural residential sites ($p<0.001$ for all), and between single family residences and above POTW and reference sites ($p<0.001$ for both).

The number of EPT taxa identified at all sites in the three watersheds varied considerably in the MC and SCR watersheds, but less so in CC (Figure 147). There was essentially no difference among the CC sites in the number of EPT taxa found at individual sites and the similarity is even more striking when land uses were combined (Figure 148). In the other two watersheds, reference and rural residential sites had more EPT taxa (approx. 6) than other land uses, which had approximately 1-3 EPT taxa (Figure 147 and Figure 148). When land uses were combined across all three watersheds (Figure 149), more EPT taxa were again found at reference and rural residential sites, though POTW-associated sites had higher numbers as well. The fewest numbers of EPT taxa were found in agricultural, commercial and single family residence sites. In this ANOVA, agricultural sites differed significantly from above POTW ($p=0.003$), below POTW ($p=0.047$), reference and rural residential ($p<0.001$ for both) sites. Commercial sites also differed significantly from above POTW ($p=0.007$), reference and rural residential ($p<0.001$ for both) sites, and single family residence differed significantly from above POTW ($p=0.040$) and reference ($p<0.001$) sites.

The percent of individuals belonging to EPT taxa at all sites is given in Figure 150. In MC, the greatest percent of EPT individuals were found at the Lower Cold Creek and reference sites, though many sites had low values. The CC sites were also highly variable, with the highest values at the Reino SFR and Young SFR sites, and very low values at the Ventu Park commercial and Conejo row crop sites. SCR sites were more evenly distributed with the reference and rural residential sites having much higher values than all other sites. When combined for land use (Figure 151 and Figure 152), the highest % EPT individuals values were found at the reference sites (approx. 50-80%), while the lowest values, approximately 7-10%, were at the horse and industrial sites. The values at all the other land uses were highly variable, and the overall differences were significant ($p<0.001$) across watersheds. Reference sites varied significantly from above POTW ($p=0.034$), below POTW, agricultural, commercial and single family residence sites ($p<0.001$ for all) and rural residential sites differed significantly from agricultural ($p=0.017$) and commercial (0.019) sites.

The percent taxa that were EPT taxa at all sites were similar within MC and CC (Figure 153). The horse and Chumash commercial sites were slightly lower than the other sites in MC, while the Reino SFR and Ventu Park commercial sites were slightly higher within CC. The variation in SCR was much greater, with the highest values at the Bouquet reference and rural residential sites ($46.97 \pm 5.46\%$ and $37.67 \pm 4.73\%$, respectively) and no EPT taxa were found at the Haskell SFR, Bouquet commercial and Upper Todd Barranca orchard sites. When combined for land use (Figure 154 and Figure 155), the highest valueswere at the reference and rural residential sites (approx. 30%), with much lower values at the horse, industrial and orchard sites (approx. 13-18%). Differences among land uses were significant ($p<0.001$), with significant pair-wise differences between reference and agricultural ($p=0.001$), commercial ($p=0.003$), and single family residence ($p=0.022$) sites.

The percent Hydropsychidae, a moderately sensitive taxon, at all sites had either high or very low to zero values (Figure 156). The Lower Cold Creek rural residential (MC), above POTW (MC), Wildwood rural residential (CC), Soledad reference (SCR), and Bouquet rural residential (SCR) sites all had high percent Hydropsychidae values (approx. 29%), while at all other sites they were very low to zero. When combined for land use (Figure 157 and Figure 158), reference, rural residential and above POTW sites had higher values, with other land uses having very low to zero percent Hydropsychidae. Comparing land uses, the ANOVA across watersheds was significant ($p<0.001$), with significant pair-wise differences between above POTW sites and agricultural ($p=0.002$), commercial ($p<0.001$), rural residential ($p=0.038$) and single family residence ($p=0.001$) sites. Additionally, reference sites differed nearly significantly from rural residential (0.056) and significantly from below POTW ($p=0.010$), agricultural, commercial, and single family residential ($p<0.001$ for all) sites. Rural residential sites also differed significantly from agricultural, below POTW, and commercial ($p<0.001$ for all) sites.

The percent Baetidae (also moderately sensitive) at all sites is given in Figure 159. The MC sites all had low values, except the Lindero golf site (27.82 ± 6.88%). Reino SFR and Young SFR sites were the highest in CC at 62.38 ± 11.65% and 60.33 ± 5.00% respectively, while Oaks commercial and Leisure row crop were slightly lower at 42.08 ± 2.11% and 44.35 ± 7.60% respectively. All other CC site had low percent Baetidae values. In SCR, the Bouquet reference, above POTW, and Lower Todd orchard sites had the highest values (18.42 ± 3.42, 14.05 ± 7.42 and 20.71 ± 9.60, respectively), though they were not very high compared to the other watersheds. All other sites in SCR had very low to zero values. When combined for land use (Figure 160 and Figure 161) golf, SFR and row crop sites had the highest values, and industrial had a much lower value (1.14 ± 0.43%) than all other sites. The ANOVA for percent Baetidae among land uses showed no statistically significant differences.

The results for percent dominant taxa from all sites are given in Figure 162. Most sites in MC had similar values with Upper Cold Creek reference, Middle Cold Creek rural residential and Lindero SFR having somewhat higher values. All sites in CC were similar, with Reino SFR and Young SFR slightly higher and Wildwood rural residential, Deepwood SFR and Conejo row crop lower. The SCR sites had the greatest variability. The urban sites had the highest percent dominant taxa (approx. 80%), and the Soledad reference, Bouquet rural residential, and Above POTW sites had much lower values (approx. 30%). When combined for land use (Figure 163 and Figure 164) the industrial site had the highest value (78.07 ± 6.54%), while rural residential, horse and above POTW were the lowest (approx. 30%). Combined across watersheds, percent dominant taxa differed significantly overall among land uses ($p<0.001$), with a significant pair-wise difference between commercial and rural residential sites ($p=0.030$).

The percentages of sensitive and tolerant taxa from all sites and land uses are presented in the next series of figures. The distinction between sensitive and tolerant taxa is a useful one because some EPT taxa are quite tolerant of adverse conditions, despite the traditional role of this metric as an indicator of stream ecosystem health, and some other non-EPT taxa are either particularly sensitive or particularly tolerant. Taxa comprising these two metrics are outlined in the CSBP manual (Harrington and Born 2000). Cheseboro and Upper Cold Creek had the highest percentages of sensitive species in MC, at approx. 35% and 6%, respectively, while CC had very low to zero values at all of the sites. In SCR, the Bouquet reference site had the highest percentage (61.80 ± 1.57%), Bouquet rural residential had a low value (3.23 ± 1.67%), and all other sites had virtually zero percent sensitive taxa (Figure 165). Reference sites had the highest values in each watershed (Figure 166) and when combined for land use across watersheds (Figure 167), with rural residential sites exhibiting a low percentage and all other land uses at below 1% sensitive taxa. Combined across watersheds, percent sensitive taxa differed significantly overall among land uses ($p<0.001$), with significant pair-wise differences between reference and all other land uses ($p<0.001$ for all).

Percentages for tolerant taxa from all sites are given in Figure 168. Sites in MC were variable, with Middle Cold Creek rural residential, Lindero and Medea SFR, Chumash commercial and below POTW sites all having values above 50%, and Upper Cold Creek reference, Lower Cold Creek rural residential, Lindero golf and above POTW with values below 20%. The CC sites were more similar, with values ranging from 10.29 ± 4.59% for Wildwood rural residential to 47.13 ± 11.93% for Deepwood SFR. SCR sites had the highest variability, with the Peck industrial site at 86.04 ± 4.28%, Haskell SFR, Blue Cut row and Upper and Lower Todd Barranca orchard sites ranging from approx. 30-50%, and Bouquet commercial with the lowest value, 1.20 ± 0.09%. When combined for land use within watersheds (Figure 169), the MC watershed, urban and commercial sites had the highest percentages, approximately 60%, while reference, golf and above POTW had the lowest (below 20%). Commercial and SFR sites in CC were highest (between approx. 30-40%), with rural residential sites having the lowest value (approx. 10%). Industrial, row and orchard sites were highest in SCR and reference, rural residential and commercial sites had the lowest percentages. When combined for land use across watersheds (Figure 170), industrial sites were the highest due to the percentage at Peck Road, most other sites were at approximately 35%, and reference, golf and above POTW sites were lowest, at values below 20%. Across watersheds, the differences among land uses in tolerant taxa were nearly significant ($p=0.083$). Data on sensitive and tolerant taxa have been included here in graphical format, but statistical analyses on these metrics were limited to ANOVAs.

4.2 Statistical Relationships

4.2.1 Correlations

With the large number of variables assessed in this study, many possible correlations could be examined. Because correlation does not necessarily indicate causation, and also because calculation of many correlations will identify some spurious correlations (i.e., at a=0.05, we expect 5 “significant” correlations out of 100 by chance alone), correlation matrices are presented here simply to indicate overall patterns in the data. The significant ($p<0.05$) correlations presented in this report are not adjusted for multiple comparisons; therefore, while reviewing the correlation matrices it is important to remember that some of the “significant” correlations are probably spurious. A more formal evaluation of relationships among variables is presented using multiple regression analysis (see below).

Correlations among physical variables collected at the X-site and considered to represent conditions at the scale of the entire site are shown in Table 6. Correlations between physical and biological variables collected at each of the six transects within the reach are shown in Table 7. Correlations among biological variables collected at each of the six transects within the reach are shown in Table 8. Algal cover and biomass were positively correlated as expected, but not very strongly (r=0.595). Also as expected, total vegetation cover was positively correlated with all of its individual components. Interestingly, this correlation was relatively constant for each component, ranging from r=0.223 for algal biomass to r=0.339 for medium and thick diatoms. Correlations between physical and biological variables collected at the benthic macroinvertebrate sample locations within riffles are shown in Table 9. Correlations between primary producers (macroalgae and diatoms) and benthic macroinvertebrates collected within riffles are shown in Table 10. No correlations between algae (cover and biomass) and diatoms/macrophytes were found.

Several of the physical variables measured at the transect scale were highly correlated with each other. Total nitrogen was highly correlated with ammonia, the N:P ratio and log total nitrogen, with correlation coefficients ranging from 0.835 to 0.991. The N:P ratio was highly correlated with ammonia (r=0.990) as well. Total phosphorus was highly correlated with phosphate (r=0.990). Total nitrate+nitrite was correlated with total nitrate+nitrite as nitrogen (r=0.997). Discharge was also highly positively correlated with nutrient levels.

Incident light was strongly negatively correlated with both densitometer data (r= - 0.761) and light % reduction (r= - 0.983). Fine+sand substrate was strongly correlated with fine+sand+gravel, with sand, and with mean embeddedness and embeddedness greater than 60% (correlation coefficients ranging from 0.809 to 0.929). Additionally, fine+sand+gravel vs. sand had a correlation coefficient of 0.793 and embeddedness greater than 60% vs. mean embeddedness had an r = 0.968. Finally, root mass and dissolved oxygen were correlated strongly (r= 0.873).

4.2.2 Multiple regressions

4.2.2.1 Algae, diatoms and macrophytes

Multiple regression analyses were conducted to assess the influence of different physical factors on vegetation (algal biomass and cover, diatom cover, macrophytes, and total vegetation cover). Unlike the simple correlations presented earlier, multiple regression analysis considers the possible influence of many factors simultaneously.

The variables most likely to influence vegetation cover were included in the multiple regressions. The vegetation multiple regressions were performed on the transect data. In cases where suites of similar variables were highly correlated, a single variable was chosen for inclusion in the multiple regression. Initially, the multiple regressions included discharge; however, discharge had unacceptably low tolerance values when the data for shaded and unshaded sites were analyzed separately, so for consistency discharge was dropped from the analyses using the full data set. The vegetation multiple regressions were performed on the transect data.

A summary of the vegetation multiple regression analyses is given in Table 11, with detailed results in Table 12 through Table 16. Standardized coefficients are given to facilitate comparison among the different factors (which were measured using dissimilar units). When all cases are included, two factors stand out as being influential for many of the different vegetation categories: shading and total phosphorus (TP). Perhaps not unexpectedly, most vegetation types were significantly negatively related to light reduction; that is, cover or biomass was lower in areas that were more shaded. The sole exception was diatoms, which were not related to shading. For TP, the results are counterintuitive. Macroalgal biomass, total vegetation cover, and macrophytes were significantly negatively related to TP; that is, cover or biomass was *lower* in areas with higher TP. Macrolgal cover was not significantly related to TP, although the trend was negative. Since P is a nutrient that should enhance vegetation growth, this negative correlation is likely due to an interaction with another factor. In contrast to all other vegetation types, diatoms were significantly positively related to TP. Macroalgal cover, macroalgal biomass and macrophytes were significantly related to relatively few other factors, while diatoms were positively related to temperature, pH, conductivity, TN, and TP.

Because light can limit plant growth irrespective of nutrient concentrations, it might be expected that algae would not respond to excess nutrients in shaded areas, where light would be limiting. Anecdotal observations suggest that this occurs, where a reach of stream with a dense canopy and low light levels has little algal cover but an adjacent reach in full sun has dense algal mats. To explore the possibility that there might be different relationships between physical factors, including nutrients, and vegetation in sun versus shade, we performed separate multiple regression analyses for data categorized as shaded (>30% light reduction) and unshaded (<30% light reduction).

In shaded sites, algal cover, algal biomass and macrophyte cover were not significantly related to nutrient concentrations (Table 11 B). As argued above, this makes sense if light limits vegetation growth. Diatom cover was significantly positively related to TP and significantly negatively related to TN. In the shade, diatom cover was 12.4±22.3% (Mean±SD) while algal cover was 4.7±10.1% and macrophytes 11.3±21.4%.

In unshaded sites, many more vegetation types were significantly associated with nutrient concentrations (Table 11 C). Algal cover and biomass were positively related to TN and negatively related to TP. In contrast, diatom cover was negatively related to TN. Vascular macrophytes were negatively related to TN and TP.

The negative relationships with TP and the contrasting influences of TN on algae compared to diatoms and macrophytes in unshaded sites illustrate the complex relationship between nutrients and vegetation growth. It appears that interactions between diatoms and macroalgae in sun versus shade may be responsible for some of this complexity. In unshaded sites, the relative cover of algae (12.5 ± 16.8%) and diatoms (7.8 ± 12.7%) was the opposite of their covers in shade. Without more information about the growth physiology of these groups, it is not possible to identify the important causative factor(s). Nonetheless, these data indicate that algae are most abundant in sunny sites where they are positively influenced by total nitrogen, whereas diatoms are most abundant in shady sites where they are positively influence by total phosphorus. Since nutrients should in general enhance plant growth, it is interesting to note that algae in sun are negatively associated with total phosphorus, and diatoms in shade are negatively associated with total nitrogen.

These multiple regressions were performed on data combined across all three watersheds, and only the broader total nutrient metrics (Total N and Total P) were used. Although we could have done separate analyses for each watershed, these analyses would have had smaller sample sizes.

4.2.2.2 Invertebrates

As with vegetation types, multiple regression analyses were conducted to assess the influence of different physical and biological factors on different aspects of the benthic macroinvertebrate community.

The variables most likely to influence invertebrate abundances were included in the multiple regressions. These included all of the physical variables used in the vegetation multiple regression analyses, plus diatom and macroalgal cover. As discussed earlier, in cases where suites of similar variables were highly correlated, a single variable was chosen for inclusion. Initially, the multiple regressions included pH; however, pH had unacceptably low tolerance values when the data for shaded and unshaded sites were analyzed separately, so for consistency it was dropped from the analyses using the full data set. The invertebrate multiple regressions were performed on the riffle data. Velocity, which was measured at the riffle sampling locations (not the transects), was included in the invertebrate multiple regression models.

A summary of the invertebrate multiple regression analyses is given in Table 17, with detailed results in Table 18 through Table 26. Standardized coefficients are given to facilitate comparison among the different factors (which were measured using dissimilar units). When all cases are included (Table 17A), it is clear that each taxonomic category was influenced by a number of different factors. The two biological factors, diatom and algal cover, had relatively little influence on the invertebrate taxonomic categories: diatoms were positively associated with four indicators while algal cover was positively associated with two indicators. One physical factor, temperature, was significantly negatively associated with six of the taxonomic categories and positively associated with %dominant taxa. Conductivity and fine-grained substrate (fine+sand+gravel) were each negatively associated with five metrics.

Although nutrients likely do not have a direct effect on invertebrates, they may have an indirect effect through facilitation of food resources (positive) or inhibition of food or suitable habitat (negative). Total nitrogen was negatively associated with two indicators of invertebrate biotic integrity (taxa richness and % Hydropsychidae) and positively associated with an indicator of degradation (% dominant taxa). Total nitrogen was also positively associated with total invertebrate abundance (which can be an indicator of either good or bad condition). Total phosphorus was negatively associated with two indicators of biotic integrity (taxa richness and EPT richness), positively associated with % Baetidae, and negatively associated with total invertebrate abundance, which as mentioned above may or may not be an indicator of biotic integrity. Percent Baetidae and % Hydropsychidae should not be viewed as indicators of exceptionally high biotic integrity. While their presence indicates that conditions are suitable for at least moderately healthy benthic invertebrate communities, they are actually some of the more tolerant members of the broader EPT grouping (Harrington and Born 2000).

Because invertebrates are not likely to be as directly influenced by sunlight as plants, we expect that any differences in the multiple regression analyses in sun versus shade would be an indirect effect through diatoms or algae. In fact, the differences were minor except for nutrients and light. In shaded sites (Table 17B), total nitrogen was negatively associated with taxa richness, EPT abundance, EPT richness, and % Hydropsychidae and positively associated with % dominant taxa. Total phosphorus was negatively associated with total abundance, taxa richness, EPT abundance, EPT richness, % EPT taxa, and % Baetidae. Thus, in shaded sites high nutrient concentrations (both nitrogen and phosphorus) were consistently associated with reduced biotic integrity.

In unshaded sites (Table 17C), % light reduction was positively associated with five indicators of biotic integrity and negatively associated with % dominant taxa. Thus, in generally sunny sites, the more shading present, the better the condition of the invertebrate community. In contrast to shaded sites, nutrients had few associations with macroinvertebrate indicators in unshaded sites.

For the physical factors, temperature and fine-grained substrate remain negatively associated with many metrics, although fine-grained substrate had fewer associations in unshaded sites than in shaded sites. The association with conductivity was not consistent across shading conditions, however. In shaded sites, conductivity was negatively associated with four metrics and positively associated with one. In contrast, in unshaded sites conductivity was positively associated with four metrics and negatively associated with one. Although this is an intriguing result, the factors influencing conductivity at these sites and the role of shading, if any, remain unexplained.

5. General Discussion

The primary objectives of this project were to (1) provide the LARWQCB with water quality data for a variety of sites in the Malibu Creek, Calleguas Creek and Santa Clara River watersheds, (2) explore the relationship between stream nutrient concentrations and the ecological health of the stream communities, and (3) examine the influence of land use on nutrients and the biotic integrity of stream communities. Due to the magnitude of data collected and space limitations of this report, we have focused our discussion on elements of the data that are most relevant to the development of nutrient TMDLs or where notable patterns were found, rather than discussing every aspect of the data. Much of the water quality data (other than nutrients) are simply presented in the data files submitted concurrently with this report.

The watersheds studied include a wide range of habitat types, land uses, topographic variation, geology, and hydrology. Most of the sites sampled, except those located below wastewater treatment outflows, had relatively low flow. This pattern is not surprising given the time of year (mid-fall) when sampling occurred. In Calleguas Creek, flow at most of the sites was due to urban runoff or POTW discharge, except the site in upper Wildwood Park, where natural springs contributed. Agricultural inputs were also present in the upper sections of Arroyo Santa Rosa and the lower portion of Conejo Creek. In Malibu Creek, spring activity was present in the upper portions of most tributaries, but urban runoff overwhelmed most of this spring water further downstream. In the Santa Clara River, stream water sources were more complex, consisting of spring water (e.g., Soledad Canyon), imported aquaduct water (Bouquet Canyon), rising ground water (Blue Cut area), dam release, and other sources of non-natural release water (e.g., upper Todd Barranca, and Fillmore Fish Hatchery overflows) as well as POTW and agricultural discharges.

Given the diversity of study sites, it is not surprising that it is difficult to find universal generalizations about the impacts of nutrients on algae and invertebrates. Moreover, the relationships among factors influencing algal growth alone are very complex. For example, increased nutrients should be associated with increased algal growth. However, algae are limited by a number of other factors, too. The substrate must be suitable for attachment, water flow rates cannot be too high, and there must be adequate sunlight. We attempted to consider the simultaneous influence of all of these factors (and more) by using multiple regression analyses. However, the results of these analyses must be interpreted in light of a significant statistical constraint. The multiple regression analysis assumes a linear relationship among the predictor (independent) variables, and this is certainly not the case. In general, these factors are more likely to have thresholds. For example, light may strongly inhibit algal growth below a certain threshold, then growth might be linearly related to light level, and then above a second threshold growth may not increase at all with increasing light. Other factors may be step functions. For example, algal growth may be prevented when substrate is below a certain size, then possible above that size. It is possible to model some of these processes with more sophisticated statistical approaches (e.g., logistic regression), but there is insufficient knowledge about the form of the various functions, so such approaches were beyond the scope of this report. Finally, interpreting the influence of possible factors in complicated because of possible indirect as well as direct effects.

In spite of the complex relationships, some general trends are apparent. The amount of light available was important to plant abundance. Most vegetation types were negatively associated with light reduction; that is, the more light was reduced, the lower the cover or biomass. The sole exception was diatom cover, which was not related to shading. More importantly, the amount of shade had a fundamental influence on the *relationships* between nutrients and plant abundance. In areas with more than 30% reduction in light, algal cover and biomass were not related to nutrient concentrations; diatoms, on the other hand, were positively related to total phosphorus concentrations. In areas with more light, algal cover and biomass were positively related to total nitrogen concentrations. Thus, in shaded areas more phosphorus seems to lead to higher diatom cover, while in sunny areas more nitrogen seems to lead to higher algal cover. These relationships match the abundance patterns of diatoms and algae, with diatoms more abundant in shade and algae more abundant in sun.

In addition to algae, we assessed the relationship between nutrients (and other factors) and benthic macroinvertebrates. We summarized the macroinvertebrate data (according to categories established by the Department of Fish and Game) into indicators of high biotic integrity and, in the case of percent dominant taxa, degradation. We used a similar multiple regression approach to examine the influence of physical characteristics and algal/diatom cover and the invertebrate community characteristics. The interpretation of the benthic macroinvertebrate analyses must consider a logistical constraint concerning the locations where invertebrate samples were taken. In order to coordinate with the Stream Bioassessment data being collected throughout the state by the Department of Fish and Game, we met with Regional Board staff and Jim Harrington of DFG before data collection began. We decided to adopt the CSBP protocol for stream benthic macroinvertebrate sampling. The major implication of this decision is that we collected invertebrate samples (and associated physical and algal samples) only in riffles, and not in glides or pools. In many cases, nuisance accumulations of macroalgae are more common in glides and pools than in riffles due to lower water flow. Thus, our relationships between algae/diatoms (plus vascular macrophytes, and some physical habitat measures) and the macroinvertebrate community characteristics do not represent the worst case, since we did not sample the areas with the highest potential algal cover.

Several factors consistently influenced the macroinvertebrate characteristics. High temperature and a high proportion of fine-grained substrate, which relates to the natural history of the benthic macroinvertebrates and the fact that their suitable habitat is coarser substrate types with ample interstitial microhabitat, were consistently associated with lower biotic integrity. Conductivity, light and nutrients were also important factors, but their associations varied with degree of shading at a site (see below). Two biological factors, the cover of diatoms and algae, generally were not associated with invertebrate indicators (but see previous caveat that we did not sample the areas with the highest potential algal cover).

Although the invertebrate patterns in shaded versus unshaded sites were generally consistent with those derived by looking at all sites combined, three new patterns emerged. (1) In shaded sites, high nitrogen and phosphorus concentrations were associated with low biotic integrity; there was only a slight indication of this association in unshaded sites. (2) In unshaded sites, light reduction was positively associated with six indicators of biotic integrity and negatively associated with the one indicator of degradation. Thus, among the sites with little shade, the more shading present, the better the condition of the invertebrate community. (It is interesting to note that diatom cover had the same pattern in unshaded sites, with increasing cover associated with more shading.) (3) In unshaded sites, conductivity was positively associated with biotic integrity, whereas in shaded sites it tended to be negatively associated with biotic integrity.

Because the multiple regression analyses indicate that the factors influencing both algae/diatoms and invertebrates differ in shaded versus unshaded sites, we have attempted to synthesize some of the relevant relationships below.

Shaded	Unshaded
• diatoms more abundant positively related to phosphorus	• fewer diatoms
• fewer algae not related to nutrient concentrations	• more algae positively related to nitrogen
• high nutrients (N & P) related to poor condition of invertebrate community	• light reduction related to good condition of invertebrate community

With the caveats that these patterns are based on correlations (and therefore do not necessarily indicate causation) and that the invertebrate data are from riffles only, which might not reflect the worse-case scenario for algal influence, we suggest the following scenario. In shade, diatoms (medium to thick) seem more able to handle the low light conditions than algae, and diatoms are more abundant. Although light limitation may prevent algae from responding to increases in nutrients, diatoms do increase in cover as phosphorus concentration increases. Increases in both nutrients, nitrogen as well as phosphorus, lead to reduced integrity of the invertebrate community. The actual cause of this reduced integrity is not clear; it may be related to a number of factors. There could be a direct interaction between high diatom abundance and invertebrate community condition, although this relationship was not picked up by the invertebrate multiple regression analyses. It is possible that the nutrients themselves are directly affecting the invertebrates, though this does not seem likely. It is possible that the nutrients are directly affecting some aspect of the ecosystem that we did not measure. For example, the *species composition* of the diatom (or macroalgal) assemblage might change in a way that does not favor the invertebrates. Finally, there may be a factor associated with nutrient concentrations, such as pesticides or metals, that directly impact the invertebrates.

In contrast to the shade, algae are more abundant than diatoms in the sun. This could reflect a competitive advantage of algae over diatoms with sufficient sunlight. When there is sufficient light, algae respond to increased nitrogen concentrations. The condition of the invertebrate community was higher at the sites with the most shading. It is not clear how light influences the invertebrate community. It could be direct; for example, the increased UV radiation might affect some invertebrate species, as has been shown for amphibians. It might also be indirect; more full sun (perhaps because vegetation was cleared from the stream banks) could result in higher water temperatures, which might directly impact the invertebrate community.

In addition to the relationships among nutrients, algae and invertebrates, we have examined the influence of different land uses on the physical and biological parameters we studied. Land use had a strong influence on many of the parameters. For nutrient concentrations, total nitrogen and NO_2+NO_3 were significantly different among different land uses. For total nitrogen, the difference was driven by the very high value below POTWs. For

NO_2+NO_3, the difference was driven by high values at agricultural sites and below POTWs. For the vegetation characteristics, algae biomass, algae cover, diatom cover, and macrophyte cover were all significantly different among different land uses. For algal biomass, the difference was driven by high biomass values below POTWs. For algal cover, the difference was driven by higher cover at commercial sites compared to reference, rural residential, and single family residential sites. For diatom and macrophyte cover, the difference was driven by high values above POTWs. All of the invertebrate indicators (except percent Baetidae) were significantly different among different land uses. These were frequently driven by low values in agriculture, commercial and single family residences. Generally, rural residential and reference sites had nearly equally high indicators of biotic integrity.

5.1 Discussion about specific situations

The preceding section and most of the Results presented in Section 5 provide an overview of the patterns seen across all three watersheds, without detailed discussion about particular watersheds, land uses or specific sites. In this section we address issues relevant to each of these three topics, where appropriate.

5.1.1 Watersheds

Malibu Creek watershed differed from the other watersheds in several notable ways. On average the MC sites had lower flow, steeper gradients, reduced influence of sand and other fine sediments, less *Arundo donax*, greater diatom cover (transect data), greater macroalgae cover, more benthic macroinvertebrate (and EPT) individuals and taxa, and fewer anomalous sites. The reasons for this may be two fold. First, MC is a more discrete coastal watershed with less agricultural influence and a proportionally greater influence of steep terrain features. The other two watersheds are larger and more diverse with lower sections that traverse wide, low-gradient valleys dominated by agriculture. However, another possible reason for the differences may be different objectives in site selection. As stated earlier the MC sites were selected through a collaboration of different research groups and many sites were chosen with the principle objective of studying algae/nutrient relationships. These sites were selectively chosen to be in more open areas with a prevalence of macroalgae. Among the other two watersheds, SCR had notably few crayfish, regions of comparatively high pH and comparatively high nitrogen, while CC had a region of comparatively high phosphorous and a greater occurrence of baetids, which (among the EPT) are indicative of disturbance, sedimentation, and nutrient enrichment (Harrington and Born 2000).

5.1.2 Land Use

Some of the results found within specific land uses require further discussion. As mentioned earlier, for most of the parameters we looked at, single family residence and rural residential sites were consistently similar. While there are certainly differences between them that could be discerned through more comprehensive sampling, we found them to very similar compared to other land uses which is why we lumped these in our analyses. Urban sites are clearly different from other land uses (prevalence of channelization, concrete, lack of vegetation etc.), but we found unexpectedly high pH levels (pH between 9.5 and 11) in the SCR urban sites compared to urban sites in the other watersheds. We do not have any explanation for this pattern, but recognize that pH is usually high in many household cleaning solutions. As could be expected, our agricultural sites could be characterized by having elevated nutrients, turbidity, and fine grained sediments, and reduced diversity of natural vegetation and benthic macroinvertebrates. One notable result was seen at our orchard sites along the Todd Barranca drainage in SCR. There was a marked increase in nitrogen, especially NO2+NO3, between the upstream site and the downstream site though no obvious change in habitat features occurred. The source of the water in this drainage was a pressure overflow of clean irrigation water located just upstream of the “upper Todd Barranca” site. While we did not search exhaustively for point source inputs between these two sites, we believe that the elevated nitrogen was due to the many tile drains located throughout the orchards in the area.

The other pair-wise above versus below comparison we made was associated with POTW inputs in MC and SCR. As would be expected, discharge showed substantial increases at the below POTW sites, as did nitrogen and other measures of water quality. In contrast some indicators of the general health of the stream (i.e. benthic macroinvertebrate metrics) declined. However, other indicators of biological health (e.g. algae and diatoms) did not consistently change. In SCR, vascular macrophyte cover apparently declined, but this result should be interpreted with caution. At the upstream site the base flow stream width was narrow (<2m) with dense macrophytes covering much of the surface in places. At the downstream site, flow increased substantially as did the wetted width and wide bands of vascular macrophytes were present on the banks. If measured, the biomass of vascular macrophytes would have increased substantially at the downstream site, but cover, as a percentage of the wetted width declined. In comparing the POTW associated sites between MC and SCR it should be noted that the “above versus below” linkage in SCR is stronger than in MC. In SCR the paired sites were located very close together (within a few hundred meters) with only minimal changes in habitat features. In MC, however, these two sites were several kilometers apart with marked differences in habitat features. The above POTW site was unique in having high levels of recreational (swimming) human use with deep rock pools and steeper gradients, and had among the highest cover of native trees and other vegetation. The below POTW site was in a steeper canyon with much shallower water, few tall trees, and very low human use. Again, site selection in MC was done in collaboration with several research groups and the resulting above/below POTW comparison was diminished to a certain extent. Another important difference between the SCR and MC POTWs is that these two POTWs are different operationally. While the Valencia POTW (SCR) releases treated water year round, the Tapia POTW does not. The Tapia POTW has a permit to release only between the months of November and April (State Water Resources Control Board, Waste Discharge Requirements Order No. 99-142 for the Tapia Water Reclamation Facility); the water quality (nutrient) samples and benthic macroinvertebrates samples for this study were collected prior to this release window in October.

5.1.3 Individual Sites or Regions

While our study did not target individual sites, certain locations did stand out as having unique, anomalous or unexpected results. One such area was the set of our sites located on the main Santa Clara River channel between the Valencia area and Camulous Ranch. This stretch of the river appeared to have more of the characteristics that are generally considered indicative of a healthy stream community than most other locations in southern California. Water flow is perennial and substantial, the stream channel is wide and mostly unaltered, and there often are extensive riparian buffer zones and abundant native arboreal taxa. Substrate composition appears less sand-dominated than reaches both above, and especially below this section, with what should be adequate gravel and cobble to support healthy benthic macroinvertebrate communities. At least one endangered species of fish has been reported in this area in the past (M. Subbotin, *personal communication*). Despite the apparent quality of habitat, our benthic macroinvertebrate samples showed relatively low diversity, especially of the more sensitive taxa that are indicators of ecosystem health. Our sites just below the Valencia POTW outflow and further downstream at Blue Cut showed marked reductions in total macroinvertebrate taxa and sensitive taxa, and increases in dominant taxa (frequently an indicator of stressed conditions) compared to reference sites and the site just upstream of the POTW outflow. The only other section of the Santa Clara River where flow and channel morphology characteristics are similar to this region is the section between the Fillmore fish hatchery and the Santa Paula POTW outflow. While we were not able to include this region in our surveys, our reconnaissance observations indicate the presence of healthy benthic macroinvertebrate communities. The other notable result that set this area apart from all of our other sites was a sharp peak in nitrogen present (mostly as NH_3) at the below POTW site. This peak in ammonia (~20mg/L) was several orders of magnitude greater than our other sites (mostly <1mg/L). Downstream at Blue Cut ammonia had diminished to ~3mg/L, and had returned to background levels (<1mg/L) by Camulos Ranch. Camulos Ranch had the highest discharge of all our sites (suggesting ground water input), but this site marks the beginning of a wide sand dominated flood plain that characterizes the main SCR channel downstream of the Blue Cut area. Despite the high flow, all of the water present at the Camulos Ranch site disappears within a few hundred meters downstream of our site. Other sites that stood out as having unique characteristics included the following: The Peck Road industrial site in Santa Paula had particularly bad water quality with high pH and dissolved oxygen, high cover and biomass of macroalgae and low diversity of benthic macroinvertebrates. The Haskell SFR site (also in SCR) was similar, and also had the highest water temperature of all the sites.

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7. Tables

Table 1. 2001 Sampling Sites.

Watershed	Site	Land Use	Date	GPS at X-site	H_20 Chem.		BMI	Phys. Hab.	Fish
					In situ	Grab			
Malibu	Chesebro	Reference	10/15/01	N 34° 09.302' W 118° 43.617'	✓		✓		
Malibu	Lindero @ Falling Star	Sing Fam Res	09/19/01	N 34° 11.169' W 118° 47.401'	✓	✓ *	✓	✓	✓
Malibu	Medea Creek Park	Sing Fam Res	09/27/01	N 34° 10.261' W 118° 45.764'	✓	✓ *	✓	✓	✓
Malibu	Chumash Park	Commercial	10/04/01	N 34° 09.025' W 118° 45.495'	✓	✓ *	✓	✓	
Malibu	Lindero Country Club	Golf	11/02/01	N 34° 09.310' W 118° 47.486'	✓	✓ *	✓	✓	✓
Malibu	Triunfo	Horse	08/23/01	N 34° 07.285' W 118° 47.323'	✓	✓ *	✓		
Malibu	Upper Cold Creek	Reference	10/10/01	N 34° 05.526' W 118° 38.853'	✓	✓ *	✓	✓	
Malibu	Middle Cold Creek	Rural Res.	09/20/01	N 34° 05.376' W 118° 40.796'	✓	✓ *	✓	✓	✓
Malibu	Lower Cold Creek	Rural Res.	09/20/01	N 34° 04.710' W 118° 42.074'	✓	✓ *	✓	✓	✓
Malibu	Malibu Cr. Above Tapia	Above POTW	10/03/01	N 34° 05.802' W 118° 43.753'	✓	✓ *	✓	✓	✓
Malibu	Malibu Cr. Below Tapia	Below POTW	09/18/01	N 34° 04.674' W 118° 42.083'	✓	✓ *	✓	✓	✓
Santa Clara	Soledad Canyon	Reference	10/30/01	N 34° 26.467' W 118° 18.592'	✓	✓	✓	✓	
Santa Clara	Bouquet Below Dam	Reference	10/18/01	N 34° 34.404' W 118° 23.296'	✓	✓	✓	✓	✓
Santa Clara	Bouquet Rural	Rural Res.	10/17/01	N 34° 32.463' W 118° 26.302'	✓	✓	✓	✓	✓
Santa Clara	Bouquet Horse	Horse	10/17/01	ND**		NH_3			
Santa Clara	Haskell Canyon	Sing Fam Res	10/25/01	N 34° 26.791' W 118° 30.687'	✓		✓	✓	
Santa Clara	Seco Canyon	Sing Fam Res	10/19/01	N 34° 26.232' W 118° 32.105'	✓	✓	✓	✓	
Santa Clara	Bouquet Commercial	Commercial	10/19/01	N 34° 25.705' W 118° 32.391'	✓	✓	✓	✓	
Santa Clara	Peck Rd. Santa Paula	Industrial	10/31/01	N 34° 20.319' W 119° 05.029'	✓	✓	✓	✓	
Santa Clara	The Old Road Bridge	Above POTW	10/24/01	N 34° 25.607' W 118° 35.262'	✓	✓	✓	✓	
Santa Clara	Magic Mountain	Below POTW	10/24/01	N 34° 25.966' W 118° 35.678'	✓	✓	✓	✓	
Santa Clara	Blue Cut	Row Crop	10/22/01	N 34° 24.040' W 118° 42.263'	✓	✓	✓	✓	
Santa Clara	Camulos Ranch	Orchard	10/23/01	N 34° 24.139' W 118° 44.719'	✓	✓	✓	✓	✓
Santa Clara	SCR at Peck Rd.	Orchard	11/07/01	ND**	✓	✓			
Santa Clara	Wheeler Cyn	Livestock	11/07/01	N 34° 20.976' W 119° 08.805'	✓	✓			
Santa Clara	Upper Todd Barranca	Orchard	10/01/01	N 34° 19.887' W 119° 08.246'	✓	✓	✓	✓	
Santa Clara	Lower Todd Barranca	Orchard	10/01/01	N 34° 18.455' W 119° 06.806'	✓	✓	✓	✓	✓
Calleguas	Conejo Cr. @ Deepwood	Sing Fam Res	09/14/01	N 34° 10.823' W 118° 49.197'	✓	✓ *	✓	✓	✓
Calleguas	Oaks Mall	Commercial	11/08/01	N 34° 10.869' W 118° 53.139'	✓		✓	✓	✓ †
Calleguas	Reino Rd.	Sing Fam Res	11/06/01	N 34° 10.485' W 118° 57.252'	✓		✓	✓	
Calleguas	FC @ Ventu Park Rd.	Commercial	11/06/01	N 34° 11.101' W 118° 54.732'	✓		✓	✓	
Calleguas	FC @ Young Rd.	Sing Fam Res	11/13/01	N 34° 12.450' W 118° 52.620'	✓		✓	✓	
Calleguas	Upper Wildwood	Rural Res.	10/02/01	N 34° 12.685' W 118° 53.452'	✓		✓	✓	✓
Calleguas	Arroyo S.R. @ Moorpark	Row Crop	11/07/01	N 34° 15.180' W 118° 51.961'	✓	✓			
Calleguas	Arroyo S.R. @ Las Posas	Horse	11/07/01	N 34° 14.543' W 118° 54.012'	✓	✓			
Calleguas	Leisure Village	Row Crop	11/20/01	N 34° 13.755' W 118° 58.313'	✓	✓	✓	✓	✓
Calleguas	Bottom Conejo Creek	Row Crop	11/19/01	N 34° 11.810' W 118° 59.989'	✓	✓	✓	✓	✓

ND** = Not Determined *-UCSB samples–nutrients only †-Fish data from 2000 EMAP sampling

Table 2. Possible targeted-reach land use choices for sites.

Target Reach	Description
Reference	Open space, only recreational activities upstream.
Rural Residence	Sparsely developed, few homes or paved roads.
Horse/Livestock	Heavy equestrian or other livestock use.
Golf	Golf course.
Single Family Residence	Densely populated, many homes and paved roads.
Commercial	Heavy commercial use, e.g. mall
Industrial	Heavy industrial use, e.g. packing plant.
Above POTW	Immediately upstream of POTW
Below POTW	Immediately downstream of POTW
Row Crop	Heavy furrowed and/or multi-crop-per-year agricultural use.
Orchard	Heavy single-crop, mainly fruit tree agricultural use.

Table 3. Water quality parameters measured at each sampling site.

Nitrate Nitrite Ammonia Total Kjeldahl Nitrogen (TKN) Total Dissolved Phosphorus Phosphate Total Suspended Sediment (Turbidity)	Calcium Manganese Sodium Potassium Silicate
	Anions (Br^-, Cl^-, F^-, SO_4^{2-})
pH Alkalinity Hardness	**Trace Elements** (Al, B, Cd, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Zn)

Table 4. Substrate Class and Algae/Macrophyte Cover Codes

Substrate Size Class Codes			
RS/RR	Bedrock (smooth/rough) – (larger than a car)		
BL	Boulder – (basketball to car)		
CB	Cobble – (tennis ball to basketball)		
GC	Coarse Gravel – (marble to tennis ball)		
GF	Fine Gravel – (lady bug to marble)		
SA	Sand – (gritty to lady bug)		
FN	Silt/Clay – (not gritty)		
HP	Hard Pan – (firm, consolidated fine substrate)		
CON	Concrete	RM	Root Mass
Algae Cover Codes			
RZ	*Rhizoclonium*	DF	Diatom Film
EN	*Enteromorpha*	DM	Diatom Medium
SP	*Spyrogyra*	DT	Diatom Thick
CL	*Cladophora*	WC	Watercress
CH	*Chara*	DW	Duck Weed
UMA	Unidentified Macroalgae	CT	Cat Tails
N	None	UMP	Unidentified Macrophytes

Table 5. Riparian vegetation cover data collected along the banks at each transect.

Vegetation Survey **(10m x 10m from wetted width)**		
0=Ø **1**<5% 5%<**2**<25% 25%<**3**<50% 50%<**4**<75% **5**>75%	**Left Bank**	**Right Bank**
Canopy Cover (>5m)	0 1 2 3 4 5	0 1 2 3 4 5
Understory (0.5 to 5m)	0 1 2 3 4 5	0 1 2 3 4 5
Ground Cover (<0.5m)	0 1 2 3 4 5	0 1 2 3 4 5
Bare Ground	0 1 2 3 4 5	0 1 2 3 4 5
Arundo donax	0 1 2 3 4 5	0 1 2 3 4 5
Tree Species (note: sycamore, cottonwood, maple, alder, ash)		
Total Native	0 1 2 3 4 5	0 1 2 3 4 5
Willow trees	0 1 2 3 4 5	0 1 2 3 4 5
Oak	0 1 2 3 4 5	0 1 2 3 4 5
	0 1 2 3 4 5	0 1 2 3 4 5
	0 1 2 3 4 5	0 1 2 3 4 5
Total Non-Native	0 1 2 3 4 5	0 1 2 3 4 5
Eucalyptus	0 1 2 3 4 5	0 1 2 3 4 5
	0 1 2 3 4 5	0 1 2 3 4 5
Understory (note: p.hem, Euph, hym.berry, ivy, Vinca, bl. must.)		
Willow saplings	0 1 2 3 4 5	0 1 2 3 4 5
Castorbean	0 1 2 3 4 5	0 1 2 3 4 5
	0 1 2 3 4 5	0 1 2 3 4 5
	0 1 2 3 4 5	0 1 2 3 4 5
	0 1 2 3 4 5	0 1 2 3 4 5
	0 1 2 3 4 5	0 1 2 3 4 5
Unstable Banks	0 1 2 3 4 5	0 1 2 3 4 5

Table 6. Correlations among physical variables measured at X-site.

These data are considered to be representative at the scale of the reach. Only significant (P<0.05) or nearly significant (indicated by parentheses, P<0.10) correlations are shown.

	Log Discharge	Temperature	pH	Conductivity	Log N (µg/L)	Log P (µg/L)	Log TN:TP	Log PO4	Log NO2 + NO3	Log NH4	Turbidity
Log Discharge											
Temperature											
pH		0.511									
Conductivity											
Log N (µg/L)	0.486	0.404									
Log P (µg/L)	0.479										
Log TN:TP		(0.357)			0.606	-0.545					
Log PO4	0.721				(0.354)	0.834	(-0.389)				
Log NO2 + NO3	0.772				0.521	(0.392)		0.452			
Log NH4	0.650			-0.384	0.616		(0.371)	0.544	0.457		
Turbidity						0.527		0.543			

Table 7. Correlations between physical and biological variables collected at the six transects within each reach.

Only significant ($P<0.05$) or nearly significant (indicated by parentheses, $P<0.10$) correlations are shown.

	Algae biomass	Diatoms > 1 mm	Macro-algae	Macro-phytes	Total veg. cover	Canopy cover	Under-story	Ground cover	Bare ground	*Arundo*	Native trees	Non-Native trees
Log Discharge				0.418			0.275	0.228	-(0.150)	0.615		-0.312
Temperature			(0.140)	-0.179	0.428	-0.479	-0.406	-0.435	0.309	-0.174	-0.493	
pH		-0.207		-0.273	0.326	-0.401	-0.515	-0.538	0.433	-0.215	-0.442	
Conductivity		0.314	0.195		0.151		(-0.134)	-0.149	0.163			
Log N (µg/L)		-0.214				-0.441				0.284	-0.411	-0.187
Log P (µg/L)						-0.414	-0.200			(0.161)	-0.273	-0.294
Log TN:TP	0.178	(-0.143)										
Log PO4		-0.172		0.169		-0.385				0.333	-0.273	-0.364
Log NO2 + NO3		-0.279		0.346						0.489	-0.259	0.230
Log NH4		-0.391		0.197		-0.254	0.205				-0.294	-0.170
Incident light	0.151		0.304		0.288	-0.709	-0.440	-0.282	0.270		-0.593	-0.300
Asn Light reduc (%)	(-0.149)		-0.423	-0.159	-0.217	0.721	0.435	0.209	-0.223		0.615	0.280
Fine + Sand + Gravel		-0.154		0.466	-0.157	0.227	0.353	0.248	(-0.133)	0.367	(0.143)	
Fine						0.227						0.266
Sand				0.450	-0.161		0.361	0.315	-0.222	0.409		
Fine gravel		-0.152		0.316	-0.181	0.225	0.309	0.217		0.189	0.198	
Coarse gravel				0.205		0.283	0.226	0.198	(-0.141)		0.183	0.214
Cobble		0.384		(-0.137)		0.343	0.291	0.172	-0.171	0.506	0.506	
Boulder		0.417		-0.164		0.266	0.204	(0.143)	-0.152		0.375	
Bedrock			(-0.142)		-0.209	0.238	0.270	0.272	-0.316		0.338	
Hardpan												0.389
Concrete			0.196	-0.232	0.369	-0.648	-0.666	-0.538	0.440	-0.282	-0.662	
Root mass			(-0.129)		-0.259	0.184		0.157	(-0.138)		0.210	
Embeddedness >60%				0.433		0.312	0.422	0.300	-0.180	0.367	0.223	
Embeddedness mean				0.415	-0.158	0.370	0.468	0.339	-0.220	0.376	0.305	
Unstable banks	0.204	-0.238	(0.130)	(0.137)	(-0.129)	0.166						0.323
Undercut banks			(-0.131)	-0.150	-0.164	0.270	0.274	0.244	-0.219		0.434	
Artificial structures			0.233	-0.222	0.381	-0.666	-0.673	-0.533	0.438	-0.282	-0.671	

Table 8. Correlations among macroalgae percent cover and biomass, diatoms, macrophytes and total vegetation cover collected at the six transects within each reach.

Only significant (P<0.05) or nearly significant (indicated by parentheses, P<0.10) correlations are shown.

	Algal Biomass	Diatoms > 1mm	Algal Cover	Macrophytes	Total Veg. Cover
Algal Biomass					
Diatoms M & T					
Algal Cover	0.595				
Macrophytes					
Total Veg. Cover	0.223	0.339	0.247	0.301	

Table 9. Correlations between physical and biological variables collected at the benthic macroinvertebrate sample locations within riffles.

Only significant ($P<0.05$) or nearly significant (indicated by parentheses, $P<0.10$) correlations are shown. Velocity, invertebrate abundance, EPT abundance, % Hydropsychidae and %Baetidae were log transformed.

	Algae	Diatoms > 1mm	Log Invert Abund	Taxa Richness	Log EPT Abund	EPT Richness	Percent EPT indivs.	Percent EPT taxa	Log Percent Hydropsy.	Log Percent Baetidae	Percent Dominant taxa
Log Discharge			-0.343								(-0.200)
Log Velocity											
Temperature				-0.384	-0.446	-0.480	-0.560	-0.540	-0.474	-0.267	0.369
pH		-0.208	-0.253	-0.545	-0.611	-0.514	-0.333	-0.573	-0.271	-0.274	0.587
Conductivity		0.351			0.204						-0.274
Log N (µg/L)				-0.391	(-0.215)	-0.302	-0.295		-0.484		0.342
Log P (µg/L)			-0.469	-0.296	-0.283	(-0.206)					
Log TN:TP			0.273				-0.228		-0.308		0.308
Log PO4			-0.450	-0.269	-0.274						
Log NO2 + NO3			-0.499		-0.260	(-0.210)			-0.251		
Log NH4		-0.308	-0.211	-0.328	-0.313	-0.235	(-0.180)				0.269
Incident Light	0.215			-0.300	-0.245	-0.212	(-0.180)		-0.245		
Asn Light reduc (%)	(-0.204)		0.216	0.393	0.329	0.303	0.219	0.231	0.334		(-0.187)
Densiometer	-0.254		0.285	0.541	0.383	0.472	0.315	0.307	0.487		-0.289
Embeddedness			-0.378		(-0.187)		(-0.182)			(-0.172)	-0.320
Fine + Sand + Gravel			-0.430		-0.217		-0.214				-0.239
Fine											
Sand			-0.478		-0.309		-0.315			-0.231	(-0.195)
Fine gravel				0.270		(0.204)					
Coarse gravel		(-0.205)		0.327	0.268	0.284	0.353	(0.185)	(0.198)	0.210	
Cobble			(0.204)	0.421	0.317	0.399	0.286	0.233	0.249		(-0.178)
Boulder				0.243							
Bedrock		0.191	0.219	(0.177)	0.300		(0.173)		0.333		-0.228
Hardpan			(-0.205)		-0.354	-0.316	-0.218	-0.378			
Concrete	0.236			-0.532	-0.303	-0.408	-0.210	-0.280	-0.409		0.458
Root mass			0.305		0.234	0.229	(0.173)	0.286			

Table 10. Correlations between macroalgae/diatoms and benthic macroinvertebrates.

Only significant ($P<0.05$) or nearly significant (indicated by parentheses, $P<0.10$) correlations are shown. Invertebrate abundance, EPT abundance, percent Hydropsychidae and percent Baetidae were log-transformed.

	Log Invert Abund	Taxa Richness	Log EPT Abund	EPT Richness	Percent EPT indivs.	Percent EPT taxa	Log Percent Hydropsy.	Log Percent Baetidae	Percent Dominant taxa
Algae			(0.184)						
Diatoms > 1mm	0.288		0.252			(0.177)			-0.206

Table 11. Summary of multiple regression analyses for algae, diatoms and vegetation using transect data.

Figures given are standardized coefficients. Only values with P<0.10 are given. Details of each multiple regression model are given in Table 12 through Table 16.

A. All cases. N=134; 46 cases deleted due to missing data.

	Algal Cover	Algal biomass	Diatoms > 1mm	Macrophytes	Total Veg Cover
Temp			+ 0.450		+ 0.232
pH			+ 0.735		
Cond			+ 0.728		+ 0.273
Log TN			+ 0.537		
Log TP		- 0.195	+ 0.706	- 0.172	- 0.170
Asn Light reduct	- 0.410	- 0.209		- 0.289	- 0.261
Fine+Sand+gravel				+ 0.380	
Multiple R2	0.215	0.082	0.327	0.252	0.278

B. Shaded. N=95; 17 cases deleted due to missing data.

	Algal Cover	Algal biomass	Diatoms > 1mm	Macrophytes	Total Veg Cover
Temp	+ 0.319		+ 0.384		+ 0.419
pH			- 0.358		
Cond			+ 0.216		
Log TN			- 0.478		- 0.272
Log TP			+ 0.198		
Asn Light reduct					- 0.237
Fine+Sand+gravel			- 0.197	+ 0.384	
Multiple R2	0.116	0.054	0.359	0.205	0.281

C. Unshaded. N=39; 29 cases deleted due to missing data.

	Algal Cover	Algal biomass	Diatoms > 1mm	Macrophytes	Total Veg Cover
Temp					
pH	+ 0.455			- 0.318	
Cond	+ 0.397		+ 0.799		+ 0.351
Log TN	+ 0.399	+ 0.346	- 0.263	- 0.385	
Log TP	- 0.380	- 0.347		- 0.311	- 0.506
Asn Light reduct			+ 0.315		
Fine+Sand+gravel			+ 0.287	+ 0.341	
Multiple R2	0.313	0.202	0.639	0.599	0.611

Table 12. Multiple regression models for algal cover using the transect data.

Values with p<0.05 are in bold; values with p<0.10 are in parentheses.

All Cases. Squared Multiple R = 0.215.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	1.954	19.649	0.000	.	0.099	0.921
TEMP	-0.049	0.430	-0.014	0.450	-0.115	0.909
PH	1.559	2.289	0.063	0.735	0.681	0.497
COND	2.098	1.402	0.138	0.728	1.496	0.137
LOGTN	1.343	1.503	0.096	0.537	0.893	0.373
LOGTP	-2.081	1.346	-0.145	0.706	-1.546	0.125
ASN_LITREDUC	-11.884	2.714	-0.410	0.710	-4.379	0.000
FINESANDGRAV	-0.036	0.035	-0.095	0.744	-1.037	0.302

Shaded. Squared Multiple R = 0.116.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	14.404	17.777	0.000	.	0.810	0.420
TEMP	(0.759)	0.433	(0.319)	0.307	1.755	0.083
PH	-1.506	1.951	-0.092	0.717	-0.772	0.442
COND	-0.548	1.586	-0.044	0.629	-0.346	0.730
LOGTN	-1.256	1.449	-0.130	0.455	-0.867	0.389
LOGTP	1.638	1.741	0.125	0.580	0.941	0.349
ASN_LITREDUC	-6.462	5.089	-0.164	0.607	-1.270	0.208
FINESANDGRAV	-0.004	0.038	-0.014	0.611	-0.110	0.913

Unshaded. Squared Multiple R = 0.313.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-189.511	80.698	0.000	.	-2.348	0.025
TEMP	-2.213	1.971	-0.232	0.522	-1.123	0.270
PH	24.252	9.932	0.455	0.639	2.442	0.021
COND	(6.966)	3.610	(0.397)	0.525	1.930	0.063
LOGTN	9.149	4.299	0.399	0.631	2.128	0.041
LOGTP	-5.608	2.495	-0.380	0.777	-2.247	0.032
ASN_LITREDUC	16.129	19.545	0.132	0.871	0.825	0.416
FINESANDGRAV	0.062	0.086	0.140	0.596	0.723	0.475

Table 13. Multiple regression models for algal biomass using the transect data. Values with p<0.05 are in bold; values with p<0.10 are in parentheses.

All Cases. Squared Multiple R = 0.082.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-15.124	47.575	0.000	.	-0.318	0.751
TEMP	0.310	1.042	0.038	0.450	0.297	0.767
PH	2.690	5.543	0.048	0.735	0.485	0.628
COND	1.356	3.395	0.040	0.728	0.399	0.690
LOGTN	3.930	3.639	0.126	0.537	1.080	0.282
LOGTP	(-6.262)	3.259	(-0.195)	0.706	-1.921	0.057
ASN_LITREDUC	-13.593	6.572	-0.209	0.710	-2.069	0.041
FINESANDGRAV	0.008	0.085	0.009	0.744	0.092	0.927

Shaded. Squared Multiple R = 0.054.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	10.104	52.590	0.000	.	0.192	0.848
TEMP	0.986	1.280	0.145	0.307	0.770	0.443
PH	0.647	5.772	0.014	0.717	0.112	0.911
COND	-0.511	4.691	-0.014	0.629	-0.109	0.914
LOGTN	0.071	4.287	0.003	0.455	0.017	0.987
LOGTP	-2.500	5.150	-0.067	0.580	-0.485	0.629
ASN_LITREDUC	-19.293	15.055	-0.172	0.607	-1.282	0.203
FINESANDGRAV	0.018	0.114	0.021	0.611	0.158	0.875

Unshaded Squared Multiple R = 0.202.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-119.520	168.148	0.000	.	-0.711	0.483
TEMP	-2.234	4.106	-0.121	0.522	-0.544	0.590
PH	13.634	20.696	0.132	0.639	0.659	0.515
COND	8.311	7.522	0.245	0.525	1.105	0.278
LOGTN	(15.340)	8.958	(0.346)	0.631	1.712	0.097
LOGTP	(-9.916)	5.200	(-0.347)	0.777	-1.907	0.066
ASN_LITREDUC	-15.128	40.726	-0.064	0.871	-0.371	0.713
FINESANDGRAV	0.139	0.180	0.160	0.596	0.770	0.447

Table 14. Multiple regression models for diatoms > 1mm using the transect data. Values with p<0.05 are in bold; values with p<0.10 are in parentheses.

All Cases. Squared Multiple R = 0.327.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	92.809	28.116	0.000	.	3.301	0.001
TEMP	**2.082**	0.616	0.368	**0.450**	3.381	0.001
PH	**-11.772**	3.276	-0.306	**0.735**	-3.594	0.000
COND	**5.973**	2.006	0.255	**0.728**	2.977	0.003
LOGTN	**-9.756**	2.150	-0.453	**0.537**	-4.537	0.000
LOGTP	**4.154**	1.926	0.188	**0.706**	2.157	0.033
ASN_LITREDUC	2.535	3.884	0.057	0.710	0.653	0.515
FINESANDGRAV	-0.082	0.050	-0.138	0.744	-1.628	0.106

Shaded. Squared Multiple R = 0.359.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	122.930	34.603	0.000	.	3.553	0.001
TEMP	**2.089**	0.842	**0.384**	0.307	2.481	0.015
PH	**-13.410**	3.798	**-0.358**	0.717	-3.531	0.001
COND	**6.174**	3.087	**0.216**	0.629	2.000	0.049
LOGTN	**-10.585**	2.821	**-0.478**	0.455	-3.752	0.000
LOGTP	(5.944)	3.389	(0.198)	0.580	1.754	0.083
ASN_LITREDUC	-8.920	9.906	-0.099	0.607	-0.900	0.370
FINESANDGRAV	(-0.134)	0.075	(-0.197)	0.611	-1.798	0.076

Unshaded. Squared Multiple R = 0.639.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-63.426	50.415	0.000	.	-1.258	0.218
TEMP	-0.863	1.231	-0.105	0.522	-0.701	0.489
PH	9.090	6.205	0.198	0.639	1.465	0.153
COND	**12.107**	2.255	**0.799**	0.525	5.368	0.000
LOGTN	(-5.199)	2.686	(-0.263)	0.631	-1.936	0.062
LOGTP	0.172	1.559	0.014	0.777	0.111	0.913
ASN_LITREDUC	**33.211**	12.211	**0.315**	0.871	2.720	0.011
FINESANDGRAV	**0.111**	0.054	**0.287**	0.596	2.054	0.049

Table 15. Multiple regression models for macrophytes using the transect data. Values with p<0.05 are in bold; values with p<0.10 are in parentheses.

All Cases. Squared Multiple R = 0.252.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	76.768	33.315	0.000	.	2.304	0.023
TEMP	0.362	0.730	0.057	0.450	0.496	0.621
PH	-6.318	3.881	-0.146	0.735	-1.628	0.106
COND	-2.780	2.377	-0.106	0.728	-1.170	0.244
LOGTN	-1.207	2.548	-0.050	0.537	-0.474	0.636
LOGTP	(-4.292)	2.282	(-0.172)	0.706	-1.880	0.062
ASN_LITREDUC	**-14.557**	4.602	**-0.289**	0.710	-3.163	0.002
FINESANDGRAV	**0.253**	0.059	**0.380**	0.744	4.251	0.000

Shaded. Squared Multiple R = 0.205.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	33.100	36.126	0.000	.	0.916	0.362
TEMP	0.583	0.879	0.114	0.307	0.664	0.509
PH	-4.498	3.965	-0.128	0.717	-1.134	0.260
COND	-4.082	3.222	-0.153	0.629	-1.267	0.209
LOGTN	1.219	2.945	0.059	0.455	0.414	0.680
LOGTP	1.861	3.538	0.066	0.580	0.526	0.600
ASN_LITREDUC	-5.385	10.342	-0.064	0.607	-0.521	0.604
FINESANDGRAV	**0.245**	0.078	**0.384**	0.611	3.138	0.002

Unshaded. Squared Multiple R = 0.599.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	323.751	95.560	0.000	.	3.388	0.002
TEMP	-0.533	2.334	-0.036	0.522	-0.228	0.821
PH	**-26.301**	11.762	**-0.318**	0.639	-2.236	0.033
COND	-5.149	4.275	-0.189	0.525	-1.205	0.238
LOGTN	**-13.683**	5.091	**-0.385**	0.631	-2.688	0.011
LOGTP	**-7.122**	2.955	**-0.311**	0.777	-2.410	0.022
ASN_LITREDUC	-27.294	23.145	-0.144	0.871	-1.179	0.247
FINESANDGRAV	**0.237**	0.102	**0.341**	0.596	2.315	0.027

Table 16. Multiple regression models for total veg. cover using the transect data. Values with p<0.05 are in bold; values with p<0.10 are in parentheses.

All Cases. Squared Multiple R = 0.278.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-18.227	49.139	0.000	.	-0.371	0.711
TEMP	**2.214**	1.077	**0.232**	0.450	2.056	0.042
PH	7.990	5.725	0.123	0.735	1.396	0.165
COND	**10.776**	3.507	**0.273**	0.728	3.073	0.003
LOGTN	-5.766	3.758	-0.159	0.537	-1.534	0.127
LOGTP	(-6.335)	3.366	(-0.170)	0.706	-1.882	0.062
ASN_LITREDUC	**-19.741**	6.788	**-0.261**	0.710	-2.908	0.004
FINESANDGRAV	0.027	0.088	0.027	0.744	0.307	0.760

Shaded. Squared Multiple R = 0.281.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-15.836	56.458	0.000	.	-0.281	0.780
TEMP	**3.513**	1.374	**0.419**	0.307	2.557	0.012
PH	7.295	6.197	0.126	0.717	1.177	0.242
COND	7.757	5.036	0.177	0.629	1.540	0.127
LOGTN	**-9.295**	4.602	**-0.272**	0.455	-2.020	0.046
LOGTP	3.923	5.529	0.085	0.580	0.709	0.480
ASN_LITREDUC	**-32.840**	16.162	**-0.237**	0.607	-2.032	0.045
FINESANDGRAV	0.124	0.122	0.118	0.611	1.014	0.314

Unshaded. Squared Multiple R = 0.611.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	118.427	118.407	0.000	.	1.000	0.325
TEMP	-2.626	2.892	-0.141	0.522	-0.908	0.371
PH	5.230	14.574	0.050	0.639	0.359	0.722
COND	**12.013**	5.297	**0.351**	0.525	2.268	0.030
LOGTN	-7.380	6.308	-0.165	0.631	-1.170	0.251
LOGTP	**-14.570**	3.661	**-0.506**	0.777	-3.979	0.000
ASN_LITREDUC	-32.276	28.679	-0.135	0.871	-1.125	0.269
FINESANDGRAV	-0.034	0.127	-0.039	0.596	-0.268	0.791

Table 17. Summary of multiple regression analyses for benthic macroinvertebrates using riffle data.

Figures given are standardized coefficients. Only values with P<0.10 are given. Details of each multiple regression model are given in Table 18 through Table 26.

A. All cases. N=61; 35 cases deleted due to missing data.

	Log Invert Abund	Taxa Richness	Log EPT Abund	EPT Richness	% EPT indivs	% EPT taxa	Log % hydro	Log % baetid	% Dom. Taxa
Log Velocity									
Temp	-0.304		-0.508	-0.293	-0.577	-0.582		-0.505	+0.280
Cond		-0.255		-0.308	-0.200		-0.303		-0.410
Log TN	+0.274	-0.319					-0.507		+0.377
Log TP	-0.433	-0.231		-0.226				+0.370	
Asn Light reduct			+0.234		+0.250	+0.323			
Fine+Sand+gravel	-0.556		-0.383		-0.424			-0.411	-0.370
Diatoms > 1mm	+0.264	+0.287		+0.319		+0.248			
Macroalgae	+0.202		+0.229						
Multiple R2	0.664	0.477	0.543	0.584	0.576	0.523	0.537	0.295	0.439

B. Shaded. N=34; 19 cases deleted due to missing data.

	Log Invert Abund	Taxa Richness	Log EPT Abund	EPT Richness	% EPT indivs	% EPT taxa	Log % hydro	Log % baetid	% Dom. Taxa
Log Velocity					+0.253				+0.250
Temp	-0.273		-0.469	-0.377	-0.489	-0.672		-0.858	
Cond				-0.358	-0.335	-0.355		+0.638	-0.927
Log TN		-0.600	-0.300	-0.309			-0.903		+0.829
Log TP	-0.365	-0.571	-0.366	-0.564		-0.276		-0.269	
Asn Light reduct						-0.251			
Fine+Sand+gravel	-0.553		-0.531		-0.479	-0.368		-0.765	
Diatoms > 1mm	+0.526			+0.465		+0.496		-0.515	+0.703
Macroalgae									
Multiple R2	0.721	0.580	0.756	0.701	0.687	0.700	0.818	0.664	0.691

C. Unshaded. N=27; 13 cases deleted due to missing data.

	Log Invert Abund	Taxa Richness	Log EPT Abund	EPT Richness	% EPT indivs	% EPT taxa	Log % hydro	Log % baetid	% Dom. Taxa
Log Velocity		+0.327						+0.465	
Temp	-0.397		-0.641	-0.526	-0.673	-0.631			+0.364
Cond	+0.231		+0.550			+0.387		+0.418	-0.500
Log TN									+0.403
Log TP	-0.664							+0.589	
Asn Light reduct		+0.421	+0.316	+0.408		+0.351	+0.495		-0.338
Fine+Sand+gravel	-0.407								-0.480
Diatoms > 1mm		+0.305							
Macroalgae									
Multiple R2	0.861	0.737	0.819	0.758	0.516	0.687	0.619	0.545	0.858

Table 18. Multiple regression models for invertebrate abundance using riffle data.

Values with p<0.05 are in bold; values with p<0.10 are in parentheses. Invertebrate abundance was log transformed. DIATOM_MANDT = diatoms > 1mm.

All cases. Squared multiple R = 0.664.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	8.867	0.988	0.000	.	8.971	0.000
LOGVELOCITY	-0.061	0.339	-0.017	0.727	-0.180	0.858
TEMP	**-0.118**	0.043	**-0.304**	0.520	-2.756	0.008
COND	-0.140	0.188	-0.077	0.600	-0.744	0.460
LOGTN	**0.466**	0.203	**0.274**	0.447	2.301	0.025
LOGTP	**-0.770**	0.192	**-0.433**	0.520	-4.008	0.000
ASN_LITREDUC	0.118	0.347	0.039	0.488	0.340	0.735
FINESANDGRA	**-0.026**	0.005	**-0.556**	0.679	-5.757	0.000
DIATOM_MANDT	**0.031**	0.012	**0.264**	0.598	2.560	0.013
MACROALGAE	**0.033**	0.014	**0.202**	0.810	2.277	0.027

Shaded. Squared multiple R = 0.721.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	11.768	1.730	0.000	.	6.803	0.000
LOGVELOCITY	-0.178	0.442	-0.051	0.728	-0.402	0.691
TEMP	(-0.098)	0.057	(-0.273)	0.468	-1.732	0.096
COND	-0.494	0.315	-0.285	0.351	-1.567	0.130
LOGTN	-0.351	0.434	-0.112	0.610	-0.809	0.426
LOGTP	**-1.436**	0.562	**-0.365**	0.571	-2.554	0.017
ASN_LITREDUC	0.703	0.692	0.128	0.737	1.017	0.319
FINESANDGRA	**-0.027**	0.007	**-0.553**	0.603	-3.981	0.001
DIATOM_MANDT	**0.064**	0.023	**0.526**	0.314	2.732	0.012
MACROALGAE	0.025	0.019	0.170	0.686	1.308	0.203

Unshaded. Squared multiple R = 0.861.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	9.145	1.105	0.000	.	8.278	0.000
LOGVELOCITY	-0.442	0.449	-0.112	0.563	-0.984	0.337
TEMP	**-0.175**	0.065	**-0.397**	0.336	-2.698	0.014
COND	(0.420)	0.203	(0.231)	0.585	2.069	0.052
LOGTN	0.449	0.263	0.299	0.239	1.710	0.104
LOGTP	**-0.949**	0.174	**-0.664**	0.492	-5.453	0.000
ASN_LITREDUC	1.565	1.074	0.178	0.490	1.457	0.162
FINESANDGRA	**-0.018**	0.005	**-0.407**	0.556	-3.555	0.002
DIATOM_MANDT	-0.003	0.012	-0.030	0.581	-0.269	0.791
MACROALGAE	0.002	0.018	0.012	0.676	0.117	0.908

Table 19. Multiple regression models for taxa richness using riffle data.

Values with p<0.05 are in bold; values with p<0.10 are in parentheses.
DIATOM_MANDT = diatoms > 1mm.

All Cases. Squared multiple R = 0.477.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	23.705	3.959	0.000	.	5.988	0.000
LOGVELOCITY	0.782	1.356	0.067	0.727	0.576	0.567
TEMP	-0.052	0.172	-0.041	0.520	-0.301	0.765
COND	(-1.501)	0.755	(-0.255)	0.600	-1.990	0.052
LOGTN	**-1.742**	0.811	**-0.319**	0.447	-2.147	0.036
LOGTP	(-1.292)	0.770	(-0.231)	0.520	-1.679	0.099
ASN_LITREDUC	2.243	1.390	0.229	0.488	1.614	0.113
FINESANDGRA	0.012	0.018	0.082	0.679	0.679	0.500
DIATOM_MANDT	**0.109**	0.049	**0.287**	0.598	2.231	0.030
MACROALGAE	0.051	0.058	0.097	0.810	0.882	0.382

Shaded. Squared multiple R = 0.580.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	40.597	6.557	0.000	.	6.191	0.000
LOGVELOCITY	-2.593	1.676	-0.240	0.728	-1.547	0.135
TEMP	-0.078	0.215	-0.070	0.468	-0.364	0.719
COND	-0.159	1.194	-0.030	0.351	-0.133	0.895
LOGTN	**-5.826**	1.644	**-0.600**	0.610	-3.543	0.002
LOGTP	**-6.944**	2.131	**-0.571**	0.571	-3.258	0.003
ASN_LITREDUC	1.776	2.622	0.104	0.737	0.677	0.505
FINESANDGRA	0.005	0.026	0.034	0.603	0.201	0.842
DIATOM_MANDT	0.069	0.088	0.183	0.314	0.776	0.445
MACROALGAE	-0.032	0.071	-0.072	0.686	-0.453	0.655

Unshaded. Squared multiple R = 0.737.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	28.103	4.366	0.000	.	6.437	0.000
LOGVELOCITY	(3.692)	1.775	(0.327)	0.563	2.080	0.051
TEMP	-0.401	0.257	-0.317	0.336	-1.562	0.135
COND	-0.543	0.802	-0.104	0.585	-0.677	0.506
LOGTN	-1.568	1.038	-0.364	0.239	-1.511	0.147
LOGTP	-0.486	0.688	-0.119	0.492	-0.706	0.489
ASN_LITREDUC	**10.625**	4.245	**0.421**	0.490	2.503	0.022
FINESANDGRA	0.019	0.020	0.157	0.556	0.993	0.333
DIATOM_MANDT	(0.093)	0.047	(0.305)	0.581	1.972	0.063
MACROALGAE	-0.018	0.072	-0.035	0.676	-0.246	0.808

Table 20. Multiple regression models for EPT abundance using riffle data.

Values with p<0.05 are in bold; values with p<0.10 are in parentheses. Invertebrate abundance was log transformed. DIATOM_MANDT = diatoms > 1mm.

All Cases. Squared multiple R = 0.543.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	10.409	1.932	0.000	.	5.388	0.000
LOGVELOCITY	0.545	0.662	0.090	0.727	0.824	0.414
TEMP	**-0.331**	0.084	**-0.508**	0.520	-3.946	0.000
COND	0.223	0.368	0.073	0.600	0.606	0.547
LOGTN	0.307	0.396	0.108	0.447	0.774	0.442
LOGTP	-0.475	0.376	-0.163	0.520	-1.266	0.211
ASN_LITREDUC	(1.192)	0.678	(0.234)	0.488	1.758	0.084
FINESANDGRA	**-0.030**	0.009	**-0.383**	0.679	-3.403	0.001
DIATOM_MANDT	0.030	0.024	0.150	0.598	1.245	0.218
MACROALGAE	**0.062**	0.028	**0.229**	0.810	2.215	0.031

Shaded. Squared multiple R = 0.756.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	18.082	2.598	0.000	.	6.959	0.000
LOGVELOCITY	0.365	0.664	0.065	0.728	0.550	0.588
TEMP	**-0.272**	0.085	**-0.469**	0.468	-3.184	0.004
COND	-0.283	0.473	-0.102	0.351	-0.597	0.556
LOGTN	**-1.514**	0.652	**-0.300**	0.610	-2.323	0.029
LOGTP	**-2.316**	0.845	**-0.366**	0.571	-2.743	0.011
ASN_LITREDUC	1.738	1.039	0.196	0.737	1.672	0.107
FINESANDGRA	**-0.042**	0.010	**-0.531**	0.603	-4.089	0.000
DIATOM_MANDT	0.046	0.035	0.236	0.314	1.310	0.203
MACROALGAE	0.033	0.028	0.141	0.686	1.161	0.257

Unshaded. Squared multiple R = 0.819.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	10.309	2.104	0.000	.	4.899	0.000
LOGVELOCITY	0.380	0.855	0.058	0.563	0.445	0.662
TEMP	**-0.472**	0.124	**-0.641**	0.336	-3.807	0.001
COND	**1.666**	0.387	**0.550**	0.585	4.309	0.000
LOGTN	0.300	0.500	0.120	0.239	0.599	0.556
LOGTP	-0.529	0.332	-0.222	0.492	-1.594	0.127
ASN_LITREDUC	**4.626**	2.046	**0.316**	0.490	2.261	0.036
FINESANDGRA	-0.008	0.009	-0.117	0.556	-0.893	0.383
DIATOM_MANDT	-0.016	0.023	-0.088	0.581	-0.683	0.503
MACROALGAE	0.001	0.035	0.003	0.676	0.028	0.978

Table 21. Multiple regression models for EPT richness using riffle data.

Values with p<0.05 are in bold; values with p<0.10 are in parentheses.
DIATOM_MANDT = diatoms > 1mm.

All Cases. Squared multiple R = 0.584.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	9.832	1.465	0.000	.	6.712	0.000
LOGVELOCITY	0.517	0.502	0.107	0.707	1.031	0.307
TEMP	**-0.152**	0.064	**-0.293**	0.448	-2.389	0.020
COND	**-0.752**	0.279	**-0.308**	0.791	-2.693	0.009
LOGTN	-0.437	0.300	-0.193	0.555	-1.456	0.151
LOGTP	(-0.525)	0.285	(-0.226)	0.488	-1.843	0.071
ASN_LITREDUC	0.823	0.514	0.203	0.407	1.602	0.115
FINESANDGRA	-0.004	0.007	-0.069	0.624	-0.643	0.523
DIATOM_MANDT	**0.050**	0.018	**0.319**	0.451	2.787	0.009
MACROALGAE	0.008	0.021	0.036	0.778	0.365	0.717

Shaded. Squared multiple R = 0.701.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	14.507	2.274	0.000	.	6.380	0.000
LOGVELOCITY	-0.104	0.581	-0.023	0.728	-0.179	0.859
TEMP	**-0.172**	0.075	**-0.377**	0.468	-2.309	0.030
COND	(-0.788)	0.414	(-0.358)	0.351	-1.902	0.069
LOGTN	**-1.232**	0.570	**-0.309**	0.610	-2.161	0.041
LOGTP	**-2.823**	0.739	**-0.564**	0.571	-3.820	0.001
ASN_LITREDUC	1.031	0.909	0.147	0.737	1.134	0.268
FINESANDGRA	-0.010	0.009	-0.160	0.603	-1.115	0.276
DIATOM_MANDT	**0.071**	0.031	**0.465**	0.314	2.332	0.028
MACROALGAE	-0.002	0.025	-0.009	0.686	-0.068	0.946

Unshaded. Squared multiple R = 0.758.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	11.617	1.740	0.000	.	6.675	0.000
LOGVELOCITY	0.743	0.708	0.158	0.563	1.050	0.307
TEMP	**-0.277**	0.102	**-0.526**	0.336	-2.702	0.014
COND	-0.047	0.320	-0.022	0.585	-0.147	0.885
LOGTN	-0.580	0.414	-0.324	0.239	-1.403	0.177
LOGTP	-0.474	0.274	-0.278	0.492	-1.729	0.100
ASN_LITREDUC	**4.283**	1.692	**0.408**	0.490	2.531	0.020
FINESANDGRA	0.006	0.008	0.112	0.556	0.741	0.468
DIATOM_MANDT	0.019	0.019	0.148	0.581	1.000	0.330
MACROALGAE	-0.046	0.029	-0.220	0.676	-1.601	0.330

Table 22. Multiple regression models for percent EPT individuals using riffle data.

Values with p<0.05 are in bold; values with p<0.10 are in parentheses.
DIATOM_MANDT = diatoms > 1mm.

All Cases. Squared multiple R = 0.576.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	113.571	18.775	0.000	.	6.049	0.000
LOGVELOCITY	10.772	6.430	0.176	0.727	1.675	0.100
TEMP	**-3.791**	0.816	**-0.577**	0.520	-4.648	0.000
COND	(-6.211)	3.578	(-0.200)	0.600	-1.736	0.088
LOGTN	0.038	3.847	0.001	0.447	0.010	0.992
LOGTP	5.422	3.650	0.184	0.520	1.486	0.143
ASN_LITREDUC	(12.877)	6.590	(0.250)	0.488	1.954	0.056
FINESANDGRA	**-0.338**	0.086	**-0.424**	0.679	-3.910	0.000
DIATOM_MANDT	0.001	0.232	0.000	0.598	0.003	0.997
MACROALGAE	0.171	0.273	0.062	0.810	0.627	0.533

Shaded. Squared multiple R = 0.687.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	150.635	35.257	0.000	.	4.272	0.000
LOGVELOCITY	(17.032)	9.014	(0.253)	0.728	1.889	0.071
TEMP	**-3.396**	1.158	**-0.489**	0.468	-2.933	0.007
COND	(-11.155)	6.420	(-0.335)	0.351	-1.737	0.095
LOGTN	-5.712	8.841	-0.094	0.610	-0.646	0.524
LOGTP	0.173	11.459	0.002	0.571	0.015	0.988
ASN_LITREDUC	12.754	14.099	0.120	0.737	0.905	0.375
FINESANDGRA	**-0.455**	0.140	**-0.479**	0.603	-3.258	0.003
DIATOM_MANDT	-0.119	0.475	-0.051	0.314	-0.250	0.804
MACROALGAE	0.100	0.382	0.036	0.686	0.262	0.795

Unshaded. Squared multiple R = 0.516.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	86.956	26.595	0.000	.	3.270	0.004
LOGVELOCITY	7.784	10.812	0.153	0.563	0.720	0.480
TEMP	**-3.831**	1.566	**-0.673**	0.336	-2.446	0.024
COND	4.668	4.887	0.199	0.585	0.955	0.352
LOGTN	0.421	6.323	0.022	0.239	0.067	0.948
LOGTP	6.064	4.191	0.329	0.492	1.447	0.164
ASN_LITREDUC	17.174	25.857	0.151	0.490	0.664	0.515
FINESANDGRA	-0.174	0.120	-0.311	0.556	-1.453	0.162
DIATOM_MANDT	-0.064	0.287	-0.047	0.581	-0.224	0.825
MACROALGAE	-0.154	0.439	-0.068	0.676	-0.352	0.729

Table 23. Multiple regression models for percent EPT taxa using riffle data. Values with p<0.05 are in bold; values with p<0.10 are in parentheses. DIATOM_MANDT = diatoms > 1mm.

All Cases. Squared multiple R = 0.523.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	48.666	8.048	0.000	.	6.047	0.000
LOGVELOCITY	3.434	2.756	0.139	0.727	1.246	0.218
TEMP	**-1.547**	0.350	**-0.582**	0.520	-4.424	0.000
COND	-0.731	1.534	-0.058	0.600	-0.477	0.635
LOGTN	1.099	1.649	0.095	0.447	0.666	0.508
LOGTP	-0.521	1.564	-0.044	0.520	-0.333	0.740
ASN_LITREDUC	**6.713**	2.825	**0.323**	0.488	2.377	0.021
FINESANDGRA	-0.044	0.037	-0.135	0.679	-1.176	0.245
DIATOM_MANDT	**0.201**	0.099	**0.248**	0.598	2.025	0.048
MACROALGAE	0.085	0.117	0.076	0.810	0.724	0.472

Shaded. Squared multiple R = 0.700.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	57.561	11.026	0.000	.	5.220	0.000
LOGVELOCITY	4.186	2.819	0.195	0.728	1.485	0.151
TEMP	**-1.489**	0.362	**-0.672**	0.468	-4.113	0.000
COND	(-3.775)	2.008	(-0.355)	0.351	-1.880	0.072
LOGTN	0.825	2.765	0.043	0.610	0.298	0.768
LOGTP	(-6.688)	3.584	(-0.276)	0.571	-1.866	0.074
ASN_LITREDUC	(8.498)	4.410	(0.251)	0.737	1.927	0.066
FINESANDGRA	**-0.111**	0.044	**-0.368**	0.603	-2.553	0.017
DIATOM_MANDT	**0.369**	0.149	**0.496**	0.314	2.484	0.020
MACROALGAE	0.127	0.119	0.143	0.686	1.061	0.299

Unshaded. Squared multiple R = 0.687.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	58.100	11.841	0.000	.	4.907	0.000
LOGVELOCITY	3.385	4.814	0.120	0.563	0.703	0.491
TEMP	**-1.989**	0.697	**-0.631**	0.336	-2.853	0.010
COND	**5.020**	2.176	**0.387**	0.585	2.307	0.032
LOGTN	-1.067	2.815	-0.099	0.239	-0.379	0.709
LOGTP	-1.470	1.866	-0.144	0.492	-0.788	0.441
ASN_LITREDUC	(22.020)	11.512	(0.351)	0.490	1.913	0.071
FINESANDGRA	0.068	0.053	0.220	0.556	1.276	0.217
DIATOM_MANDT	-0.059	0.128	-0.078	0.581	-0.462	0.649
MACROALGAE	-0.287	0.195	-0.230	0.676	-1.470	0.158

Table 24. Multiple regression models for percent Hydropsychidae using riffle data. Values with p<0.05 are in bold; values with p<0.10 are in parentheses. Invertebrate abundance was log transformed. DIATOM_MANDT = diatoms > 1mm.

All Cases. Squared multiple R = 0.537.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	5.371	0.921	0.000	.	5.831	0.000
LOGVELOCITY	0.261	0.315	0.091	0.727	0.826	0.412
TEMP	-0.034	0.040	-0.109	0.520	-0.842	0.404
COND	**-0.441**	0.176	**-0.303**	0.600	-2.511	0.015
LOGTN	**-0.685**	0.189	**-0.507**	0.447	-3.629	0.001
LOGTP	-0.054	0.179	-0.039	0.520	-0.301	0.765
ASN_LITREDUC	0.247	0.323	0.102	0.488	0.765	0.448
FINESANDGRA	-0.003	0.004	-0.073	0.679	-0.645	0.521
DIATOM_MANDT	0.006	0.011	0.065	0.598	0.536	0.594
MACROALGAE	0.006	0.013	0.047	0.810	0.455	0.651

Shaded. Squared multiple R = 0.818.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	11.781	1.284	0.000	.	9.174	0.000
LOGVELOCITY	0.026	0.328	0.008	0.728	0.078	0.939
TEMP	0.012	0.042	0.036	0.468	0.285	0.778
COND	-0.200	0.234	-0.126	0.351	-0.857	0.400
LOGTN	**-2.611**	0.322	**-0.903**	0.610	-8.107	0.000
LOGTP	0.215	0.417	0.059	0.571	0.516	0.611
ASN_LITREDUC	-0.217	0.514	-0.043	0.737	-0.422	0.677
FINESANDGRA	-0.002	0.005	-0.052	0.603	-0.467	0.644
DIATOM_MANDT	-0.017	0.017	-0.151	0.314	-0.972	0.341
MACROALGAE	-0.023	0.014	-0.171	0.686	-1.630	0.116

Unshaded. Squared multiple R = 0.619.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	4.189	0.829	0.000	.	5.054	0.000
LOGVELOCITY	-0.088	0.337	-0.050	0.563	-0.262	0.796
TEMP	-0.082	0.049	-0.412	0.336	-1.686	0.108
COND	-0.250	0.152	-0.304	0.585	-1.643	0.117
LOGTN	-0.338	0.197	-0.497	0.239	-1.715	0.103
LOGTP	-0.144	0.131	-0.222	0.492	-1.099	0.285
ASN_LITREDUC	**1.971**	0.806	**0.495**	0.490	2.446	0.024
FINESANDGRA	-0.005	0.004	-0.253	0.556	-1.334	0.198
DIATOM_MANDT	-0.004	0.009	-0.086	0.581	-0.462	0.650
MACROALGAE	-0.011	0.014	-0.141	0.676	-0.817	0.424

Table 25. Multiple regression models for percent Baetidae using riffle data.

Values with p<0.05 are in bold; values with p<0.10 are in parentheses. Invertebrate abundance was log transformed. DIATOM_MANDT = diatoms > 1mm.

All Cases. Squared multiple R = 0.295.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	2.464	1.123	0.000	.	2.194	0.033
LOGVELOCITY	0.412	0.385	0.145	0.727	1.070	0.289
TEMP	**-0.154**	0.049	**-0.505**	0.520	-3.159	0.003
COND	0.315	0.214	0.219	0.600	1.473	0.147
LOGTN	0.281	0.230	0.211	0.447	1.221	0.228
LOGTP	**0.505**	0.218	**0.370**	0.520	2.312	0.025
ASN_LITREDUC	0.464	0.394	0.194	0.488	1.178	0.244
FINESANDGRA	**-0.015**	0.005	**-0.411**	0.679	-2.937	0.005
DIATOM_MANDT	-0.010	0.014	-0.108	0.598	-0.723	0.473
MACROALGAE	-0.001	0.016	-0.011	0.810	-0.083	0.934

Shaded. Squared multiple R = 0.664.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	4.243	1.306	0.000	.	3.249	0.003
LOGVELOCITY	-0.185	0.334	-0.077	0.728	-0.554	0.585
TEMP	**-0.213**	0.043	**-0.858**	0.468	-4.963	0.000
COND	**0.760**	0.238	**0.638**	0.351	3.196	0.004
LOGTN	0.209	0.327	0.097	0.610	0.639	0.529
LOGTP	(-0.730)	0.424	(-0.269)	0.571	-1.719	0.098
ASN_LITREDUC	0.276	0.522	0.073	0.737	0.528	0.602
FINESANDGRA	**-0.026**	0.005	**-0.765**	0.603	-5.017	0.000
DIATOM_MANDT	**-0.043**	0.018	**-0.515**	0.314	-2.437	0.023
MACROALGAE	0.009	0.014	0.095	0.686	0.666	0.512

Unshaded. Squared multiple R = 0.545.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	3.546	1.899	0.000	.	1.867	0.077
LOGVELOCITY	**1.739**	0.772	**0.465**	0.563	2.253	0.036
TEMP	-0.150	0.112	-0.357	0.336	-1.338	0.197
COND	(0.721)	0.349	(0.418)	0.585	2.065	0.053
LOGTN	-0.098	0.452	-0.069	0.239	-0.218	0.830
LOGTP	**0.799**	0.299	**0.589**	0.492	2.670	0.015
ASN_LITREDUC	2.801	1.846	0.335	0.490	1.517	0.146
FINESANDGRA	-0.008	0.009	-0.195	0.556	-0.940	0.359
DIATOM_MANDT	-0.002	0.021	-0.021	0.581	-0.102	0.920
MACROALGAE	-0.044	0.031	-0.262	0.676	-1.393	0.180

Table 26. Multiple regression models for percent dominant taxa using riffle data.

Values with $p<0.05$ are in bold; values with $p<0.10$ are in parentheses.
DIATOM_MANDT = diatoms > 1mm.

All Cases. Squared multiple R = 0.439.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	3.346	18.101	0.000	.	0.185	0.854
LOGVELOCITY	3.183	6.199	0.062	0.727	0.513	0.610
TEMP	(1.545)	0.786	(0.280)	0.520	1.965	0.055
COND	**-10.663**	3.450	**-0.410**	0.600	-3.091	0.003
LOGTN	**9.097**	3.709	**0.377**	0.447	2.452	0.018
LOGTP	0.777	3.519	0.031	0.520	0.221	0.826
ASN_LITREDUC	5.693	6.353	0.132	0.488	0.896	0.374
FINESANDGRA	**-0.248**	0.083	**-0.370**	0.679	-2.968	0.004
DIATOM_MANDT	0.165	0.223	0.098	0.598	0.737	0.464
MACROALGAE	-0.114	0.263	-0.049	0.810	-0.433	0.667

Shaded. Squared multiple R = 0.691.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-97.061	24.686	0.000	.	-3.932	0.001
LOGVELOCITY	(11.866)	6.311	(0.250)	0.728	1.880	0.072
TEMP	1.337	0.811	0.274	0.468	1.649	0.112
COND	**-21.746**	4.495	**-0.927**	0.351	-4.837	0.000
LOGTN	**35.325**	6.190	**0.829**	0.610	5.707	0.000
LOGTP	11.061	8.023	0.207	0.571	1.379	0.181
ASN_LITREDUC	13.168	9.872	0.176	0.737	1.334	0.195
FINESANDGRA	-0.028	0.098	-0.042	0.603	-0.286	0.777
DIATOM_MANDT	**1.154**	0.333	**0.703**	0.314	3.468	0.002
MACROALGAE	0.377	0.267	0.193	0.686	1.409	0.172

Unshaded. Squared multiple R = 0.858.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-7.066	17.984	0.000	.	-0.393	0.699
LOGVELOCITY	-4.671	7.311	-0.074	0.563	-0.639	0.530
TEMP	**2.588**	1.059	**0.364**	0.336	2.444	0.024
COND	-14.640	3.305	**-0.500**	0.585	-4.430	0.000
LOGTN	**9.757**	4.276	**0.403**	0.239	2.282	0.034
LOGTP	-0.907	2.834	-0.039	0.492	-0.320	0.752
ASN_LITREDUC	**-47.882**	17.485	**-0.338**	0.490	-2.738	0.013
FINESANDGRA	**-0.335**	0.081	**-0.480**	0.556	-4.146	0.001
DIATOM_MANDT	0.156	0.194	0.091	0.581	0.805	0.431
MACROALGAE	0.128	0.297	0.045	0.676	0.430	0.672

8. Figures

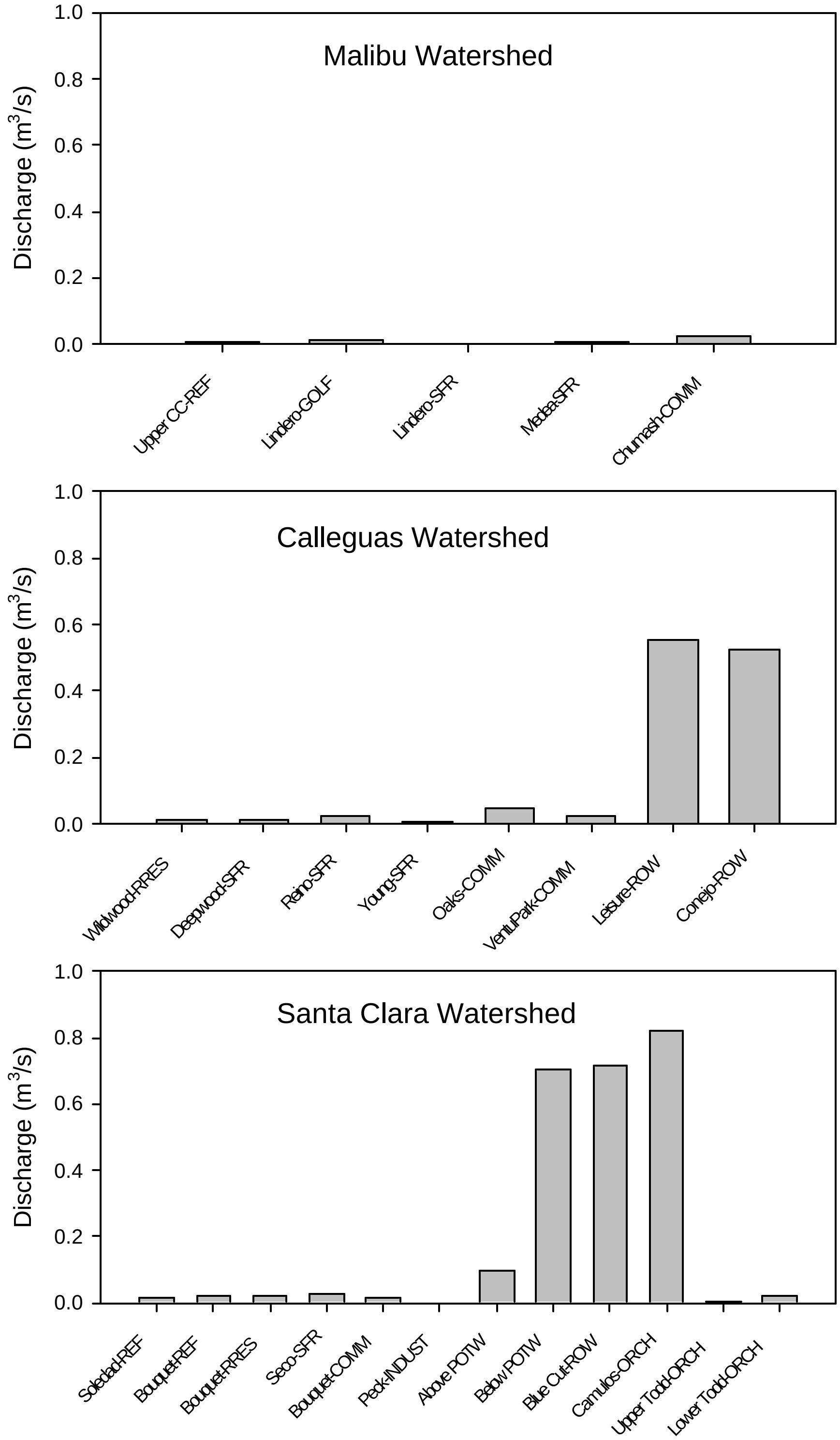


Figure 1. Stream discharge measured *in situ* at all sites.

Discharge values were obtained using the methods outlined in EMAP.

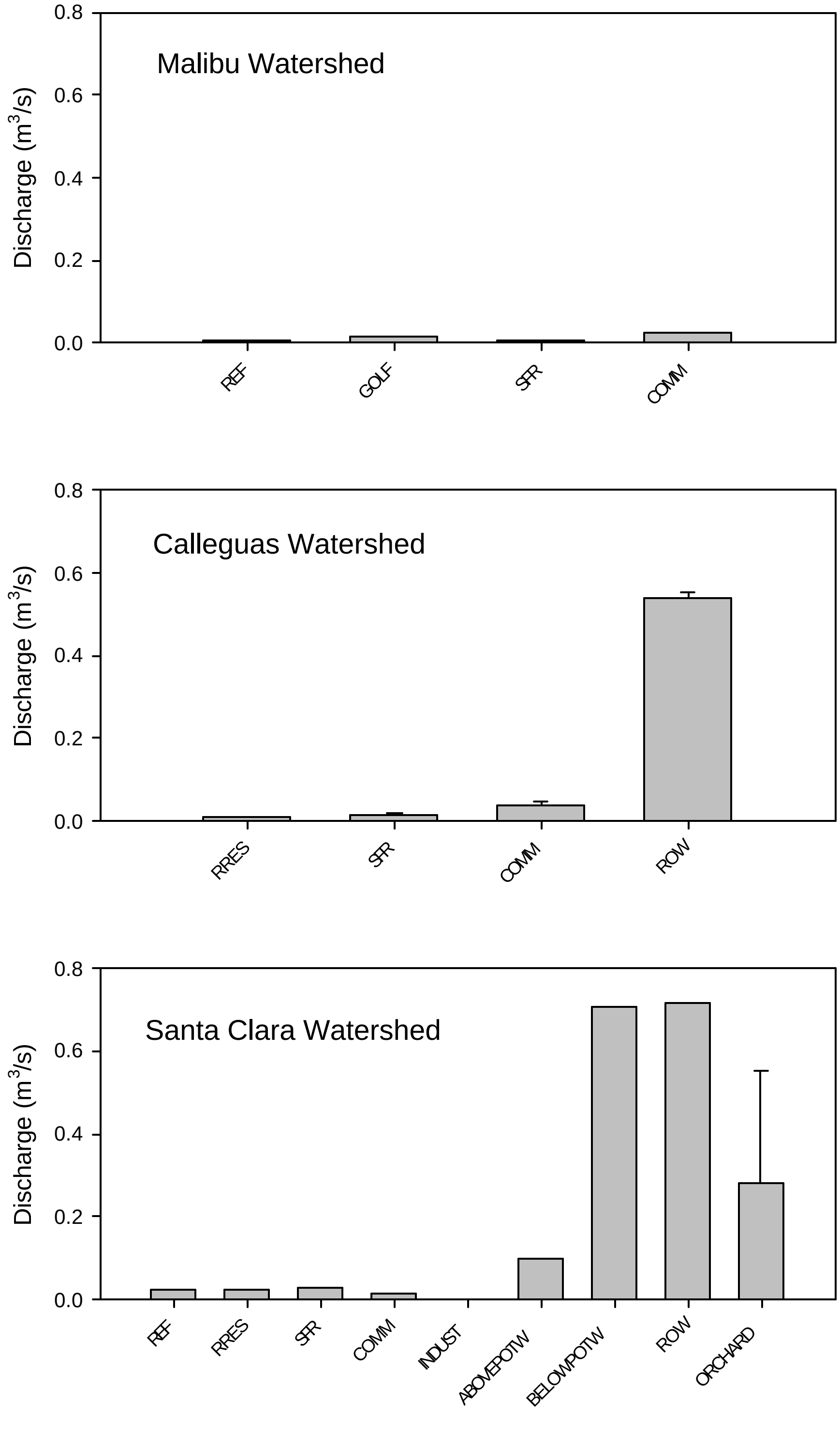


Figure 2. Stream discharge by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

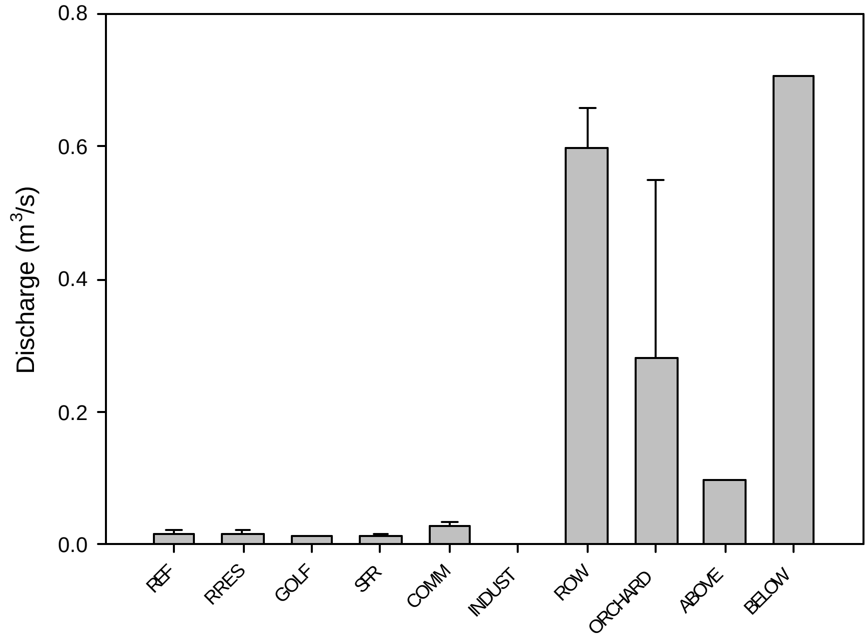


Figure 3. Stream discharge by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

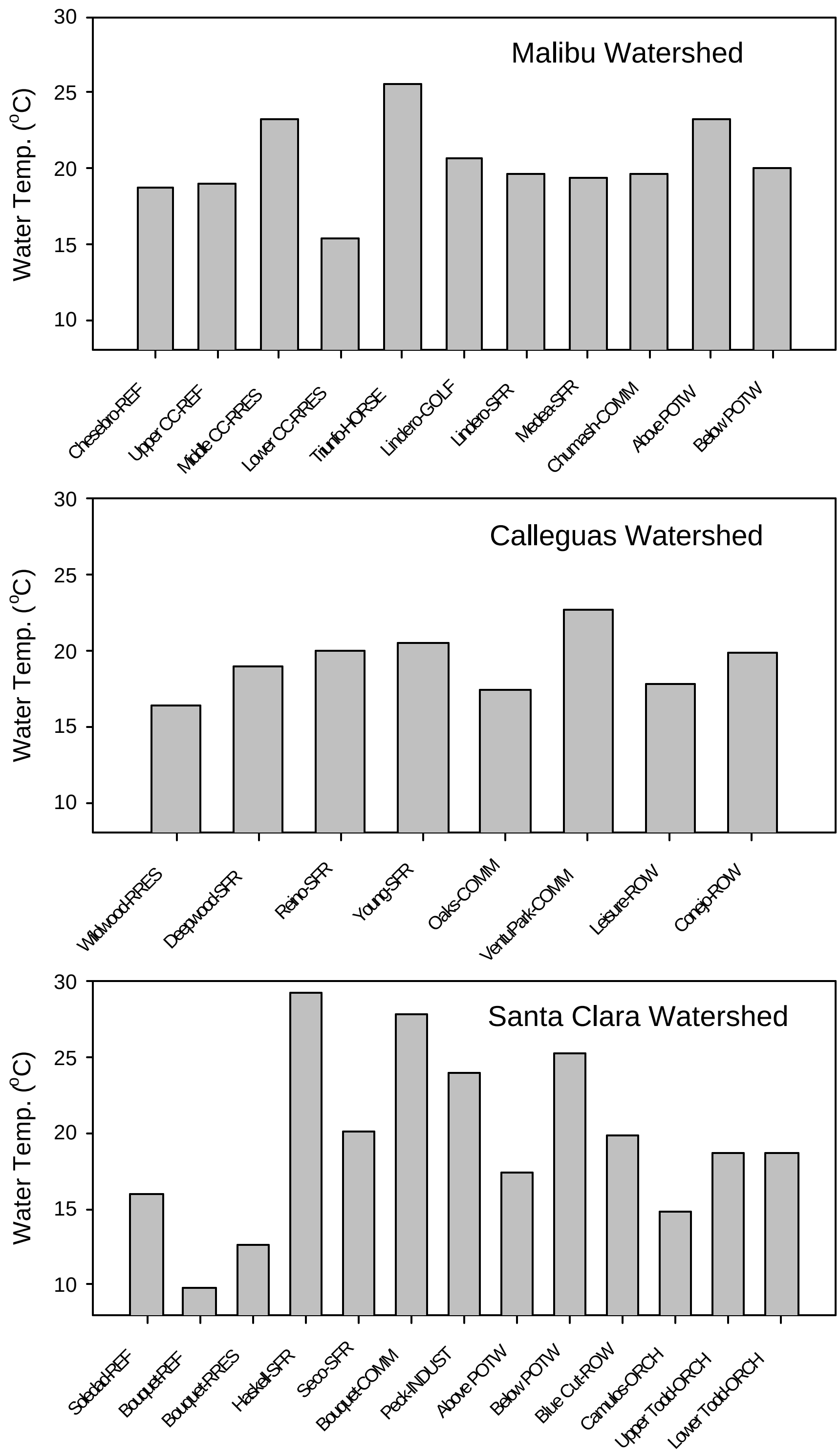


Figure 4. Water temperature measured *in situ* at all sites.

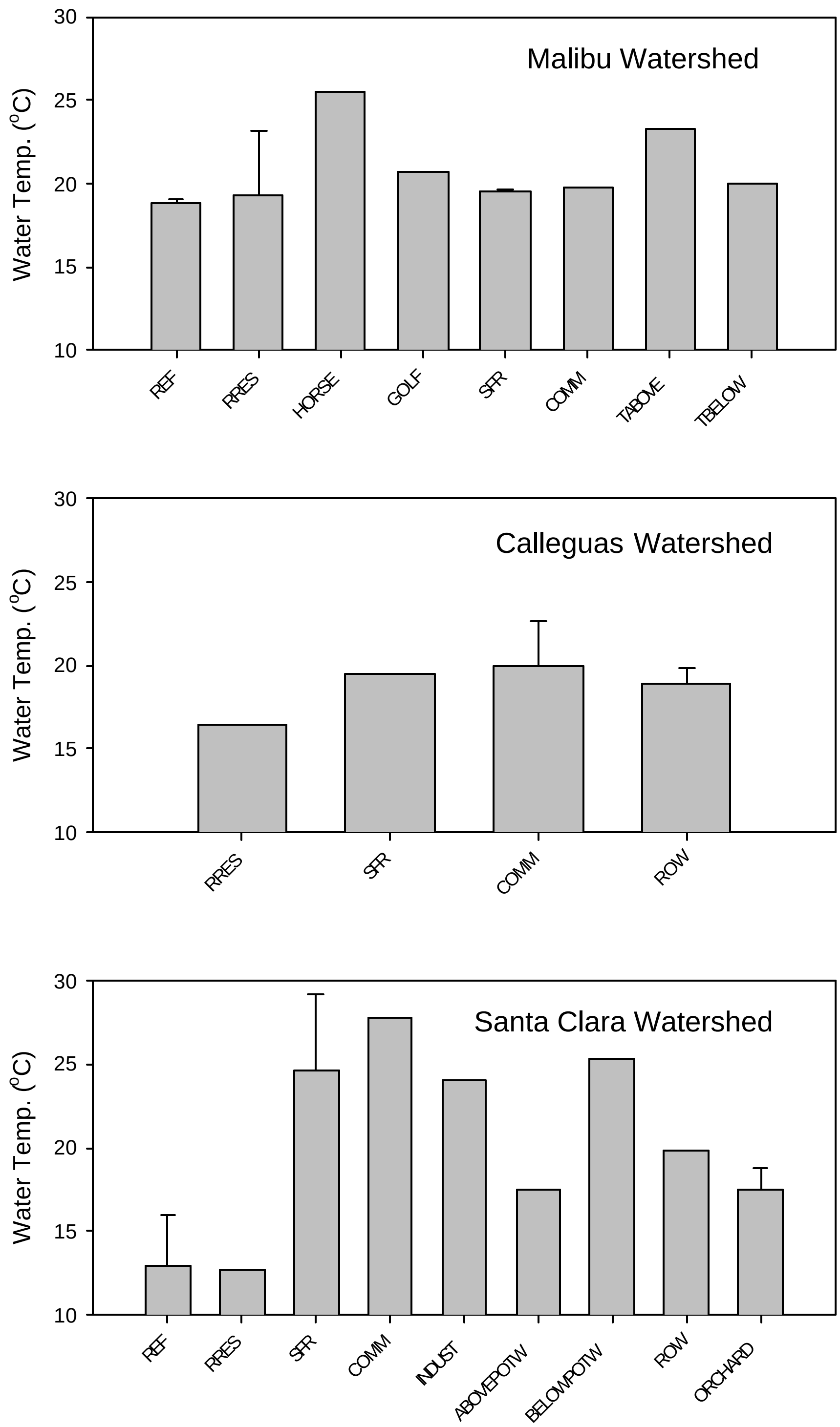


Figure 5. Water temperature by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

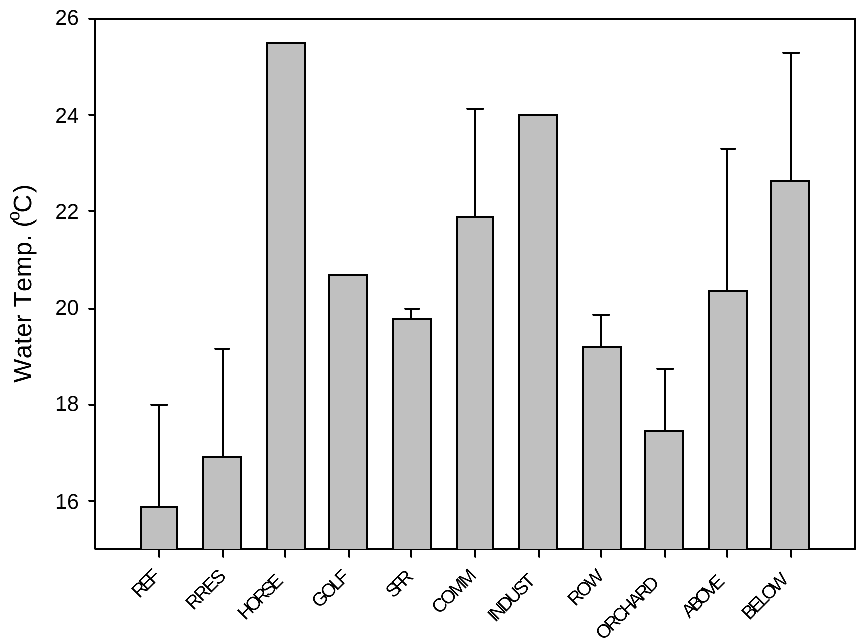


Figure 6. Water temperature by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

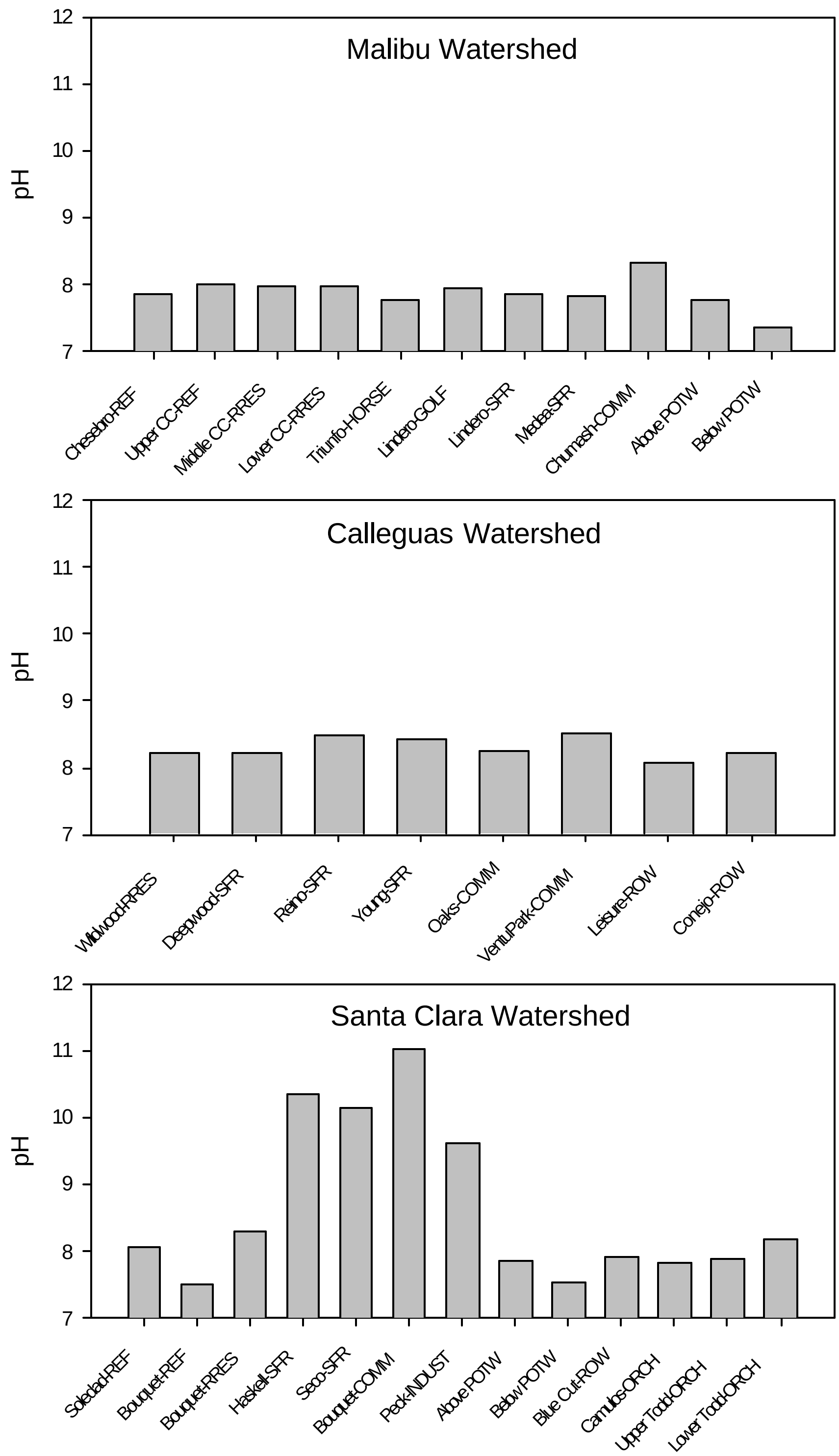


Figure 7. pH measured *in situ* at all sites.

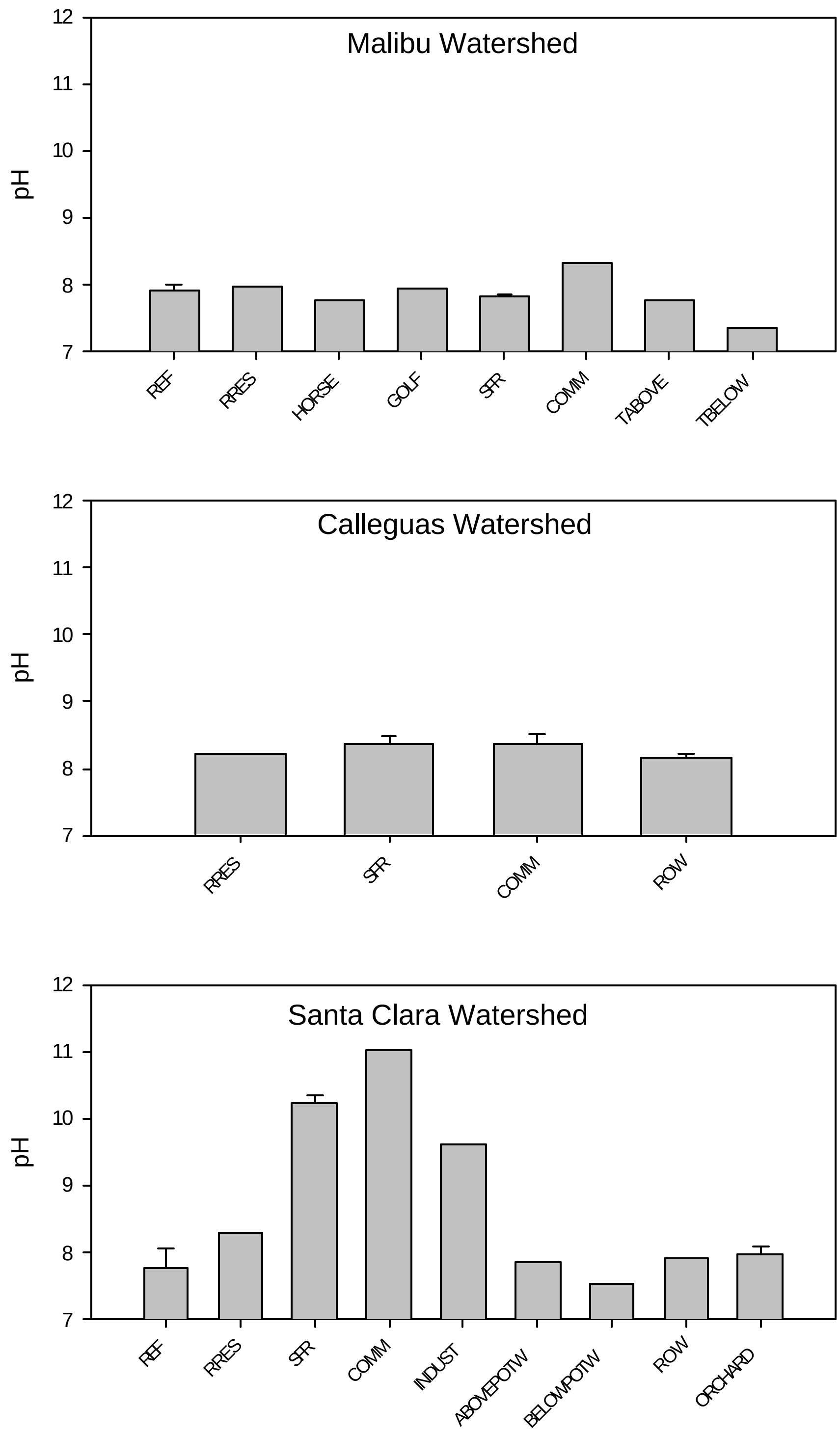


Figure 8. pH by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

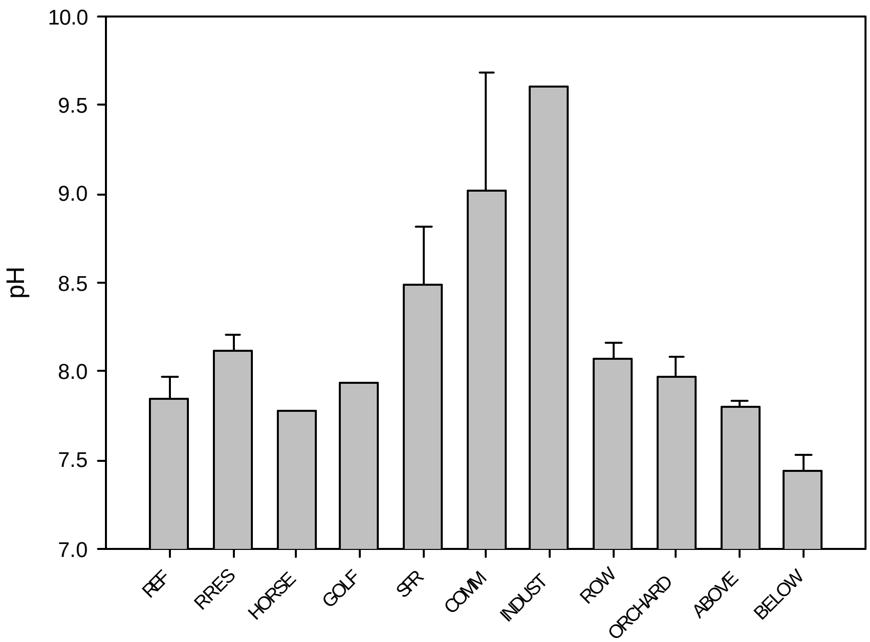


Figure 9. pH by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

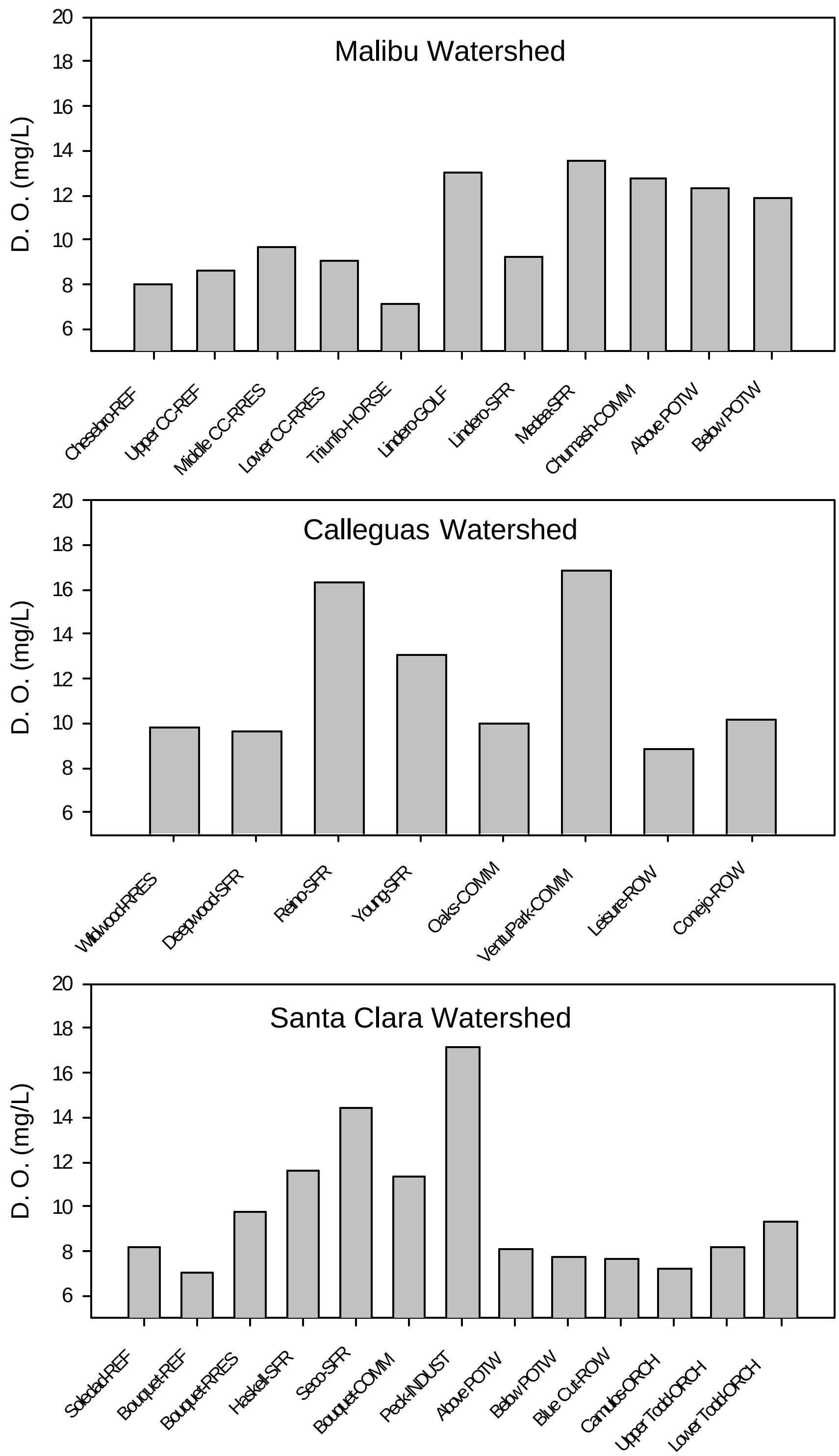


Figure 10. Dissolved oxygen measured *in situ* at all sites.

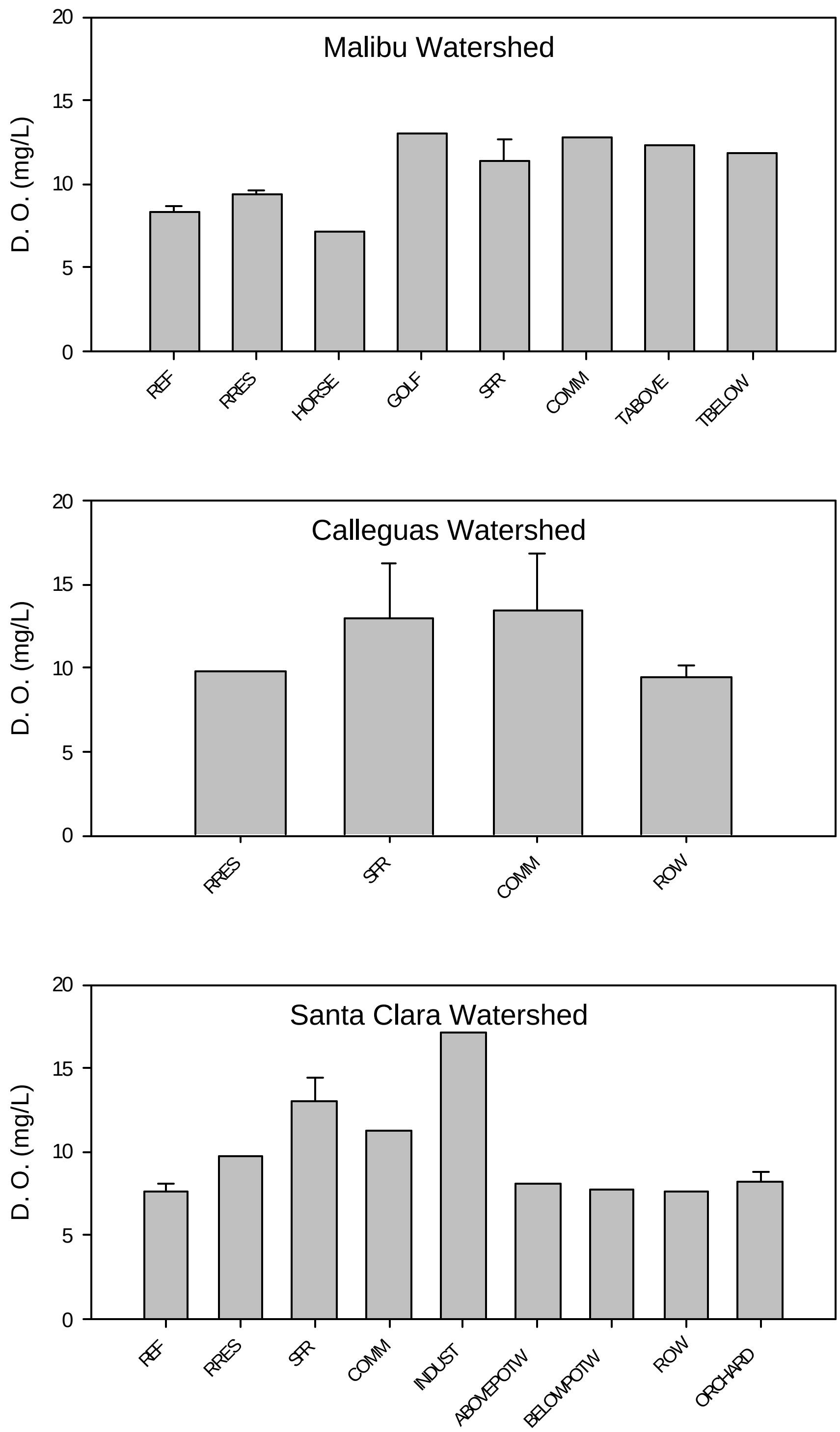


Figure 11. Dissolved oxygen by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

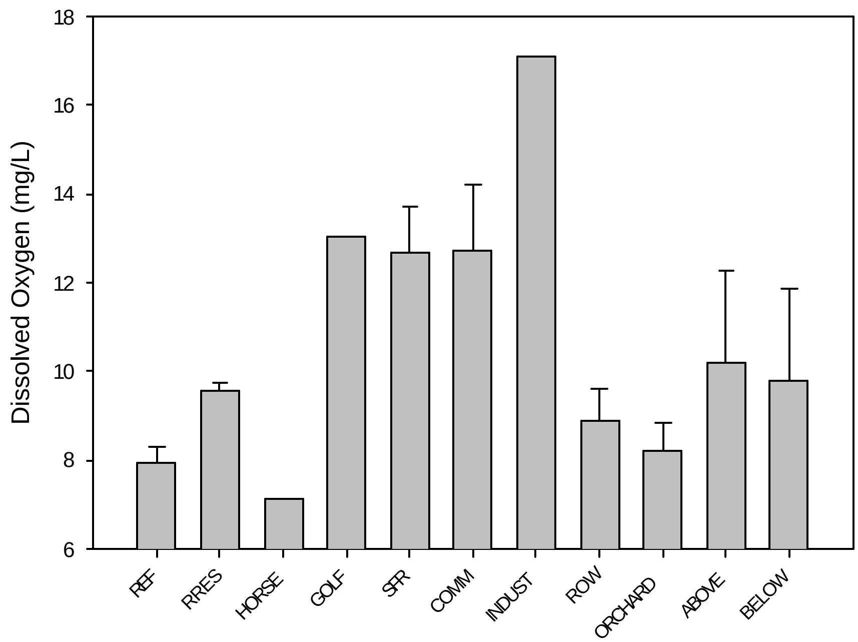


Figure 12. Dissolved oxygen by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

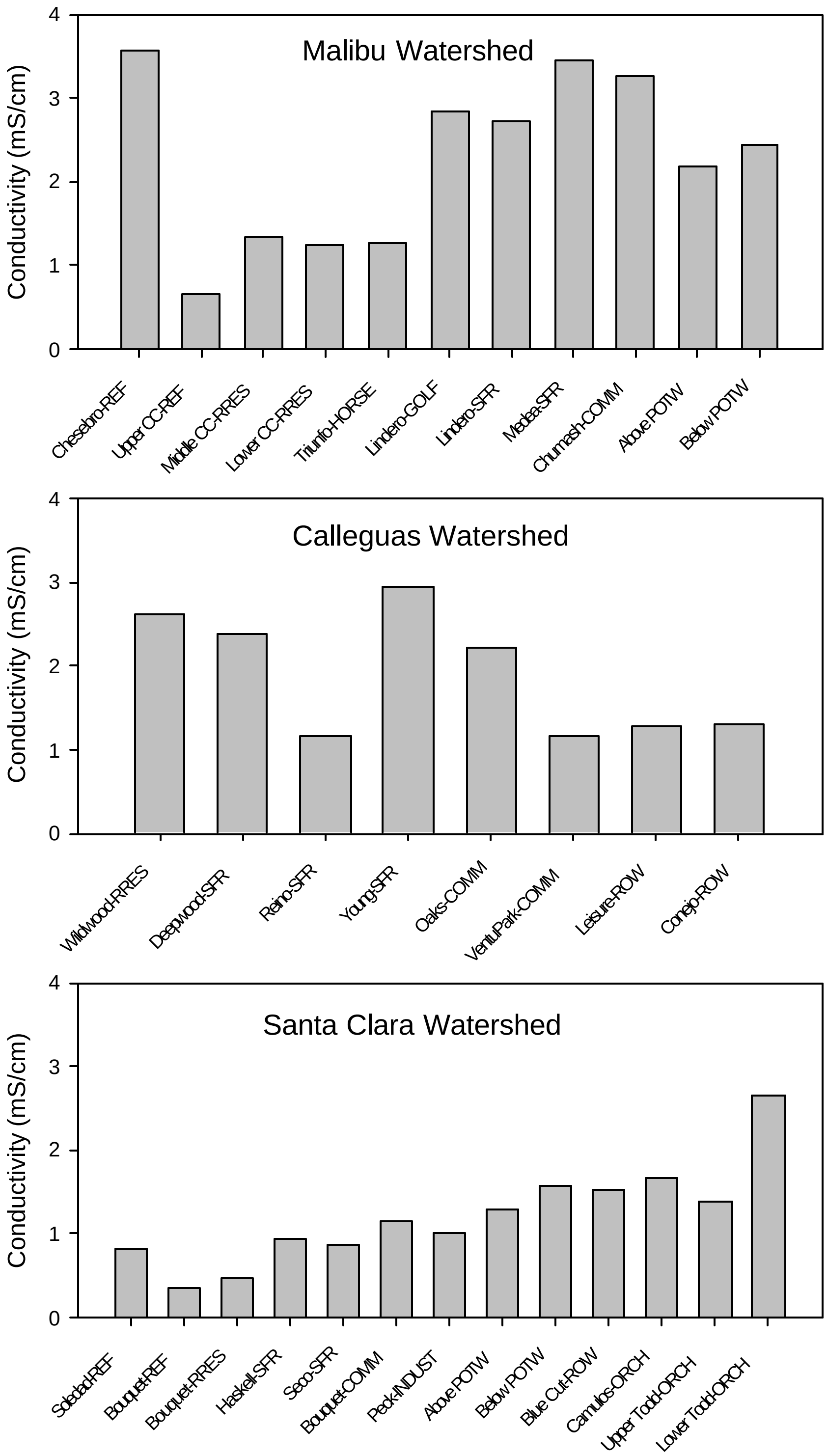


Figure 13. Conductivity measured *in situ* at all sites.

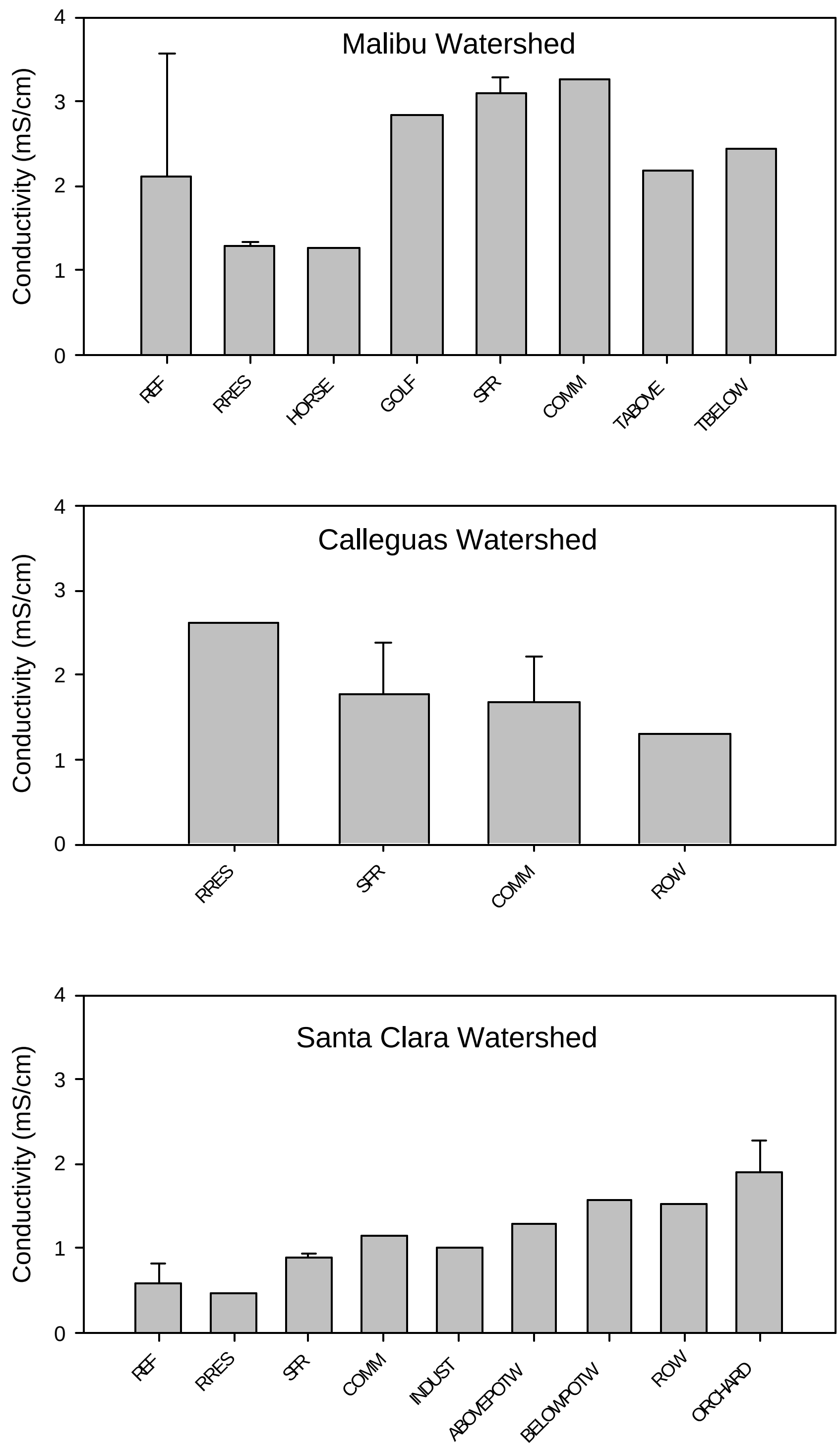


Figure 14. Conductivity by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

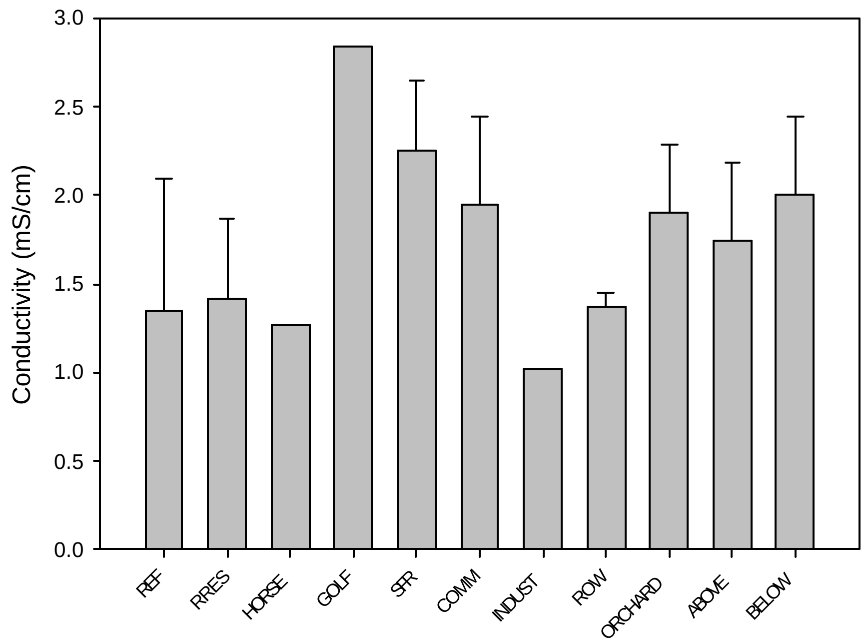


Figure 15. Conductivity by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

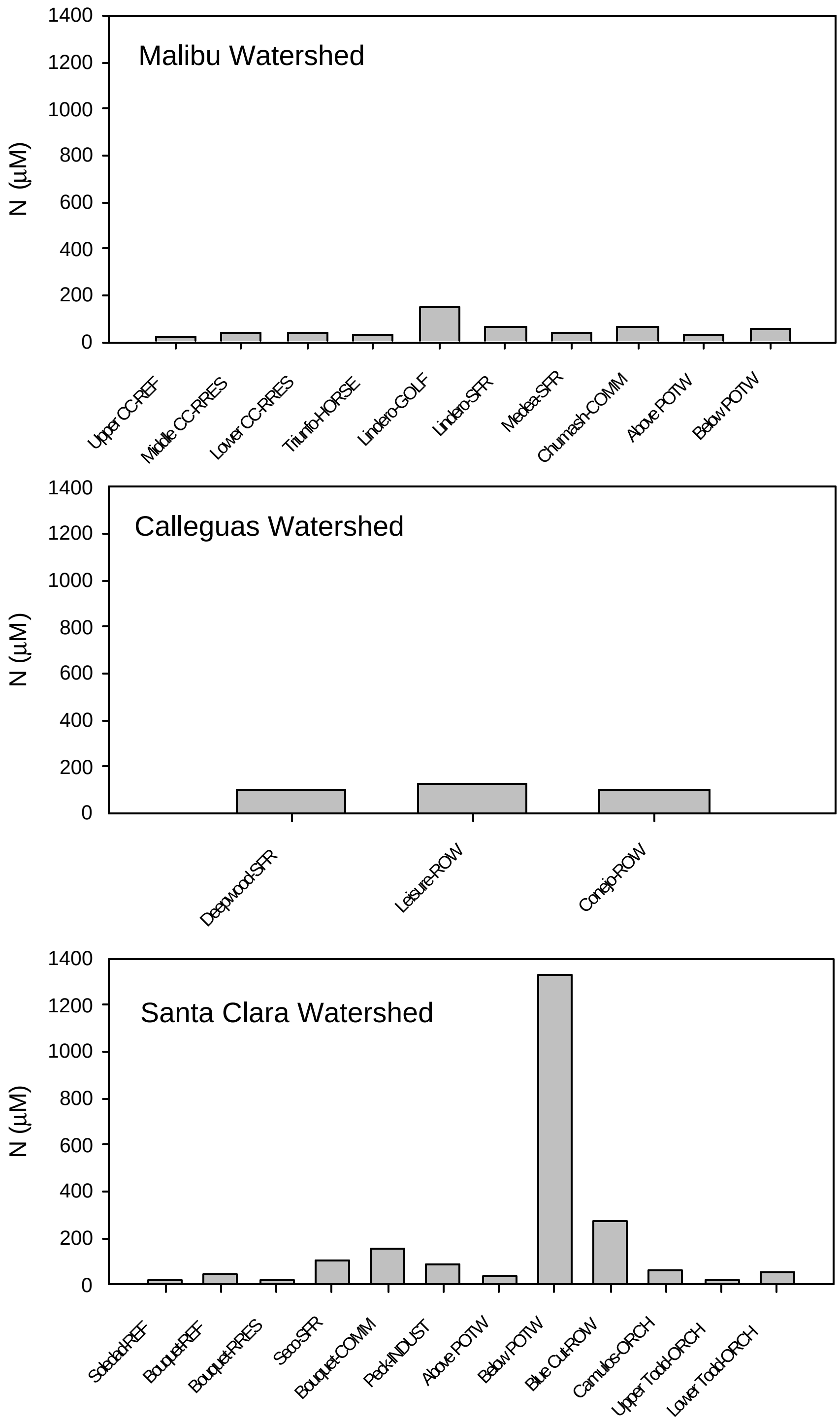


Figure 16. Nitrogen (Total Kjeldahl Nitrogen) at all sites.

Grab samples from CC and SCR sites were delivered to an analytical lab within 4 hours of collection. Samples from MC and Deepwood-SFR were supplied by UCSB research group and were subjected to variable holding times (3-60 hours).

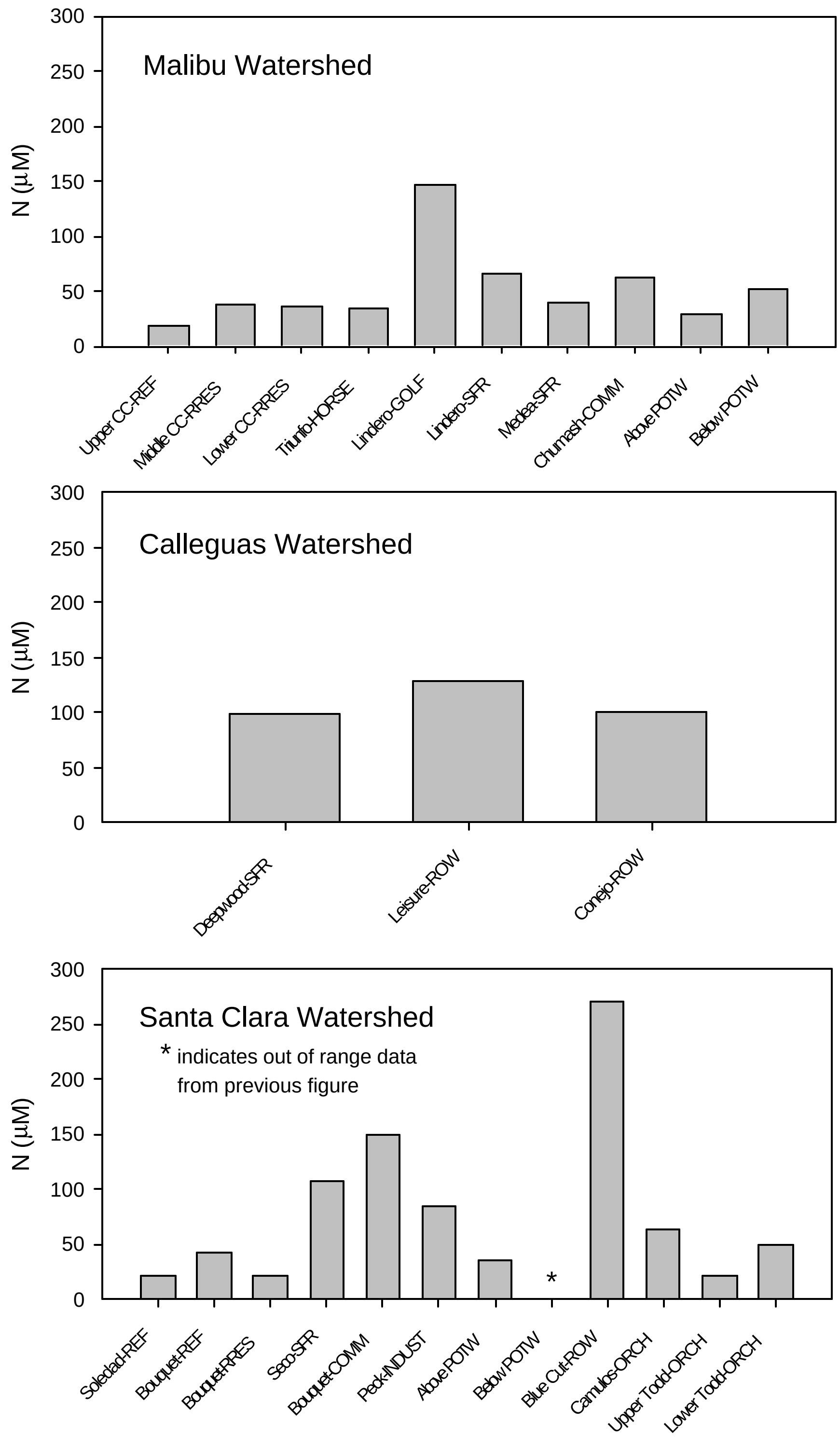


Figure 17. Nitrogen values from previous figure at appropriate scale after removing data from sites with off-scale readings.

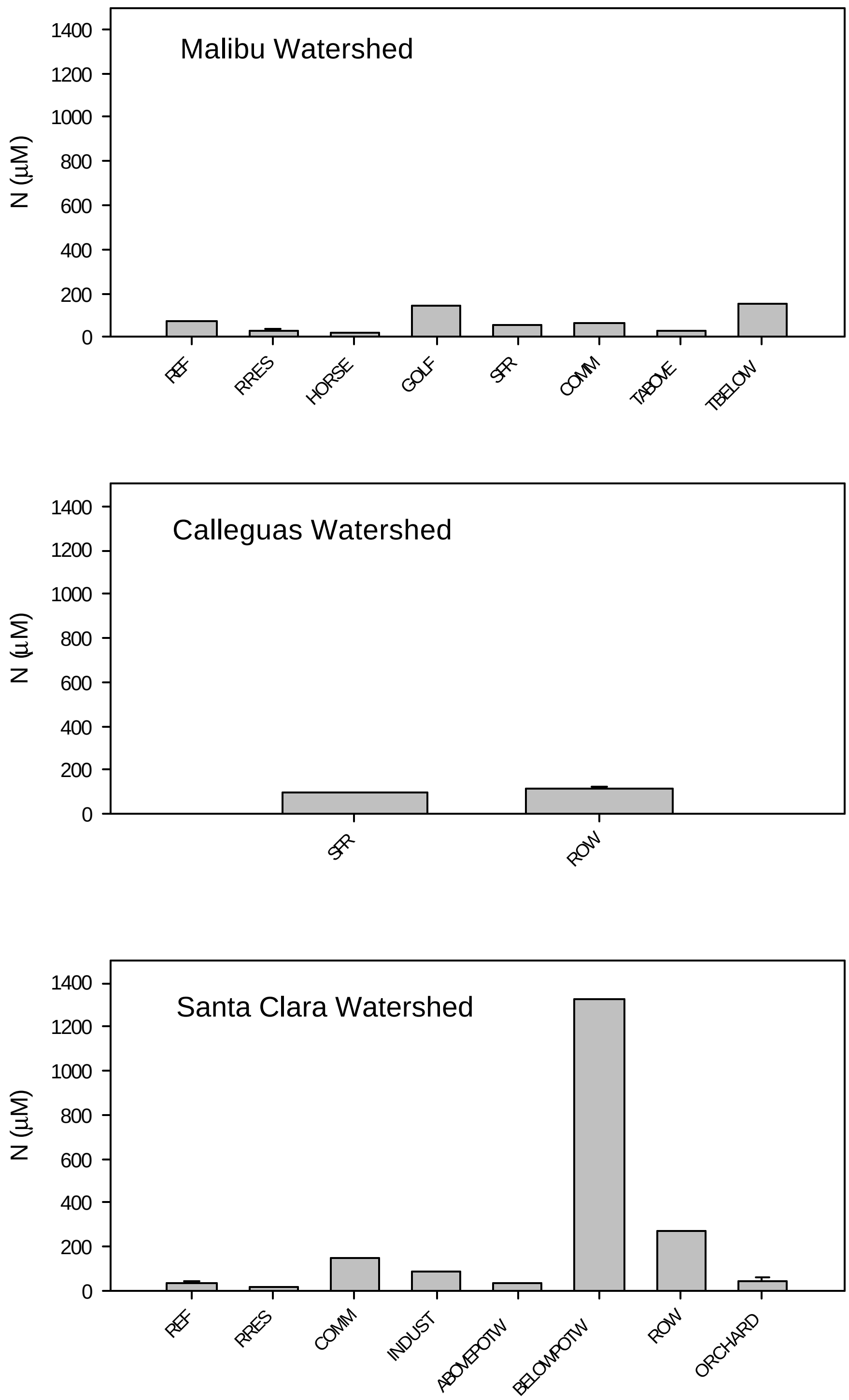


Figure 18. Nitrogen by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

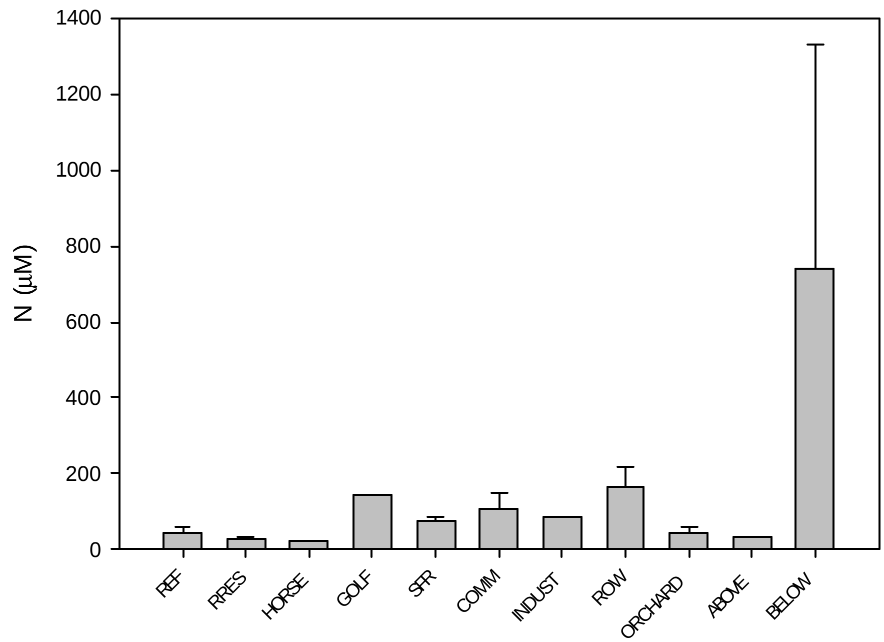


Figure 19. Nitrogen by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

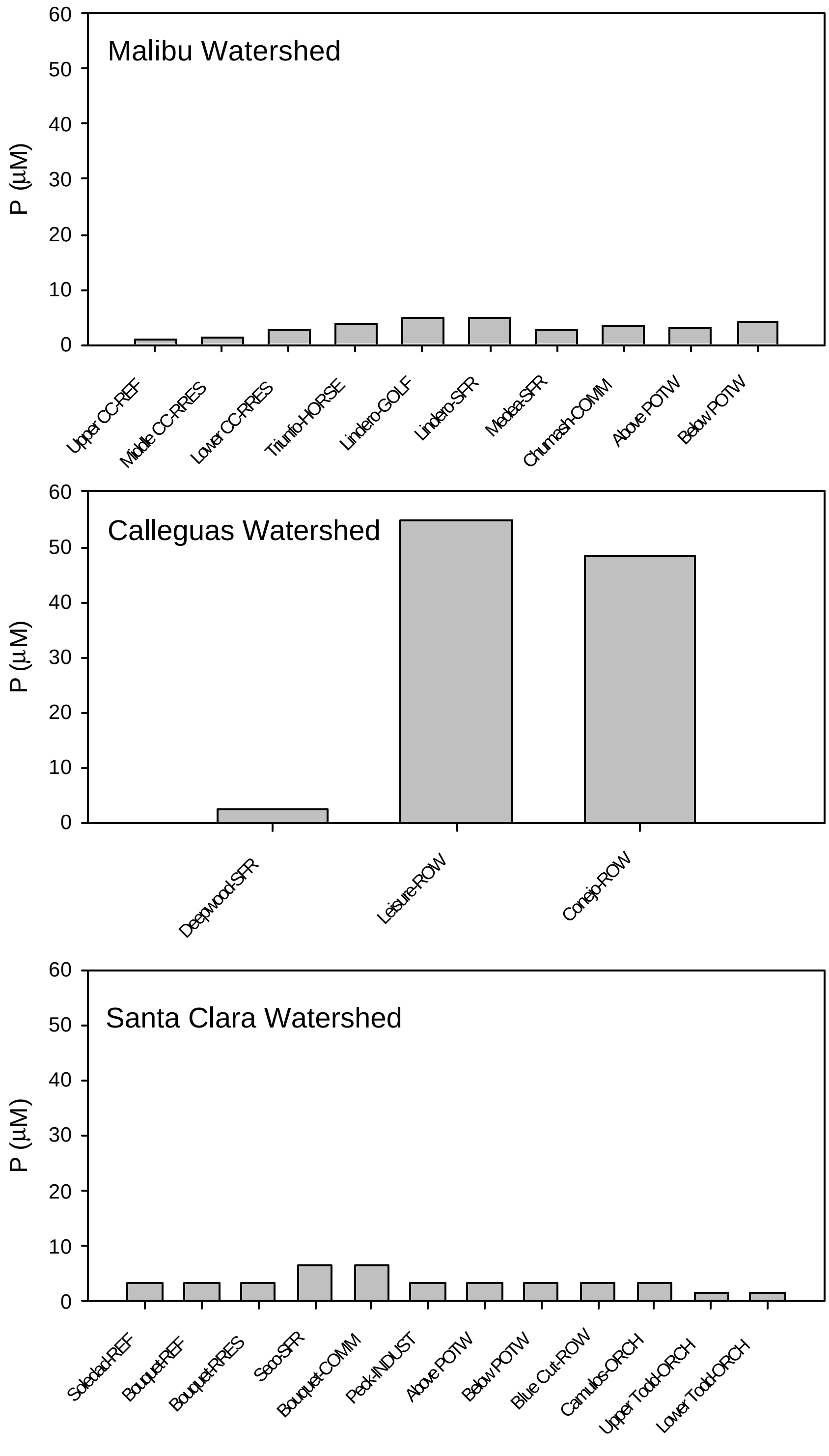


Figure 20. Phosphorous (Total P) at all sites.

Grab samples from CC and SCR sites were delivered to an analytical lab within 4 hours of collection. Samples from MC and Deepwood-SFR were supplied by UCSB research group and were subjected to variable holding times (3-60 hours).

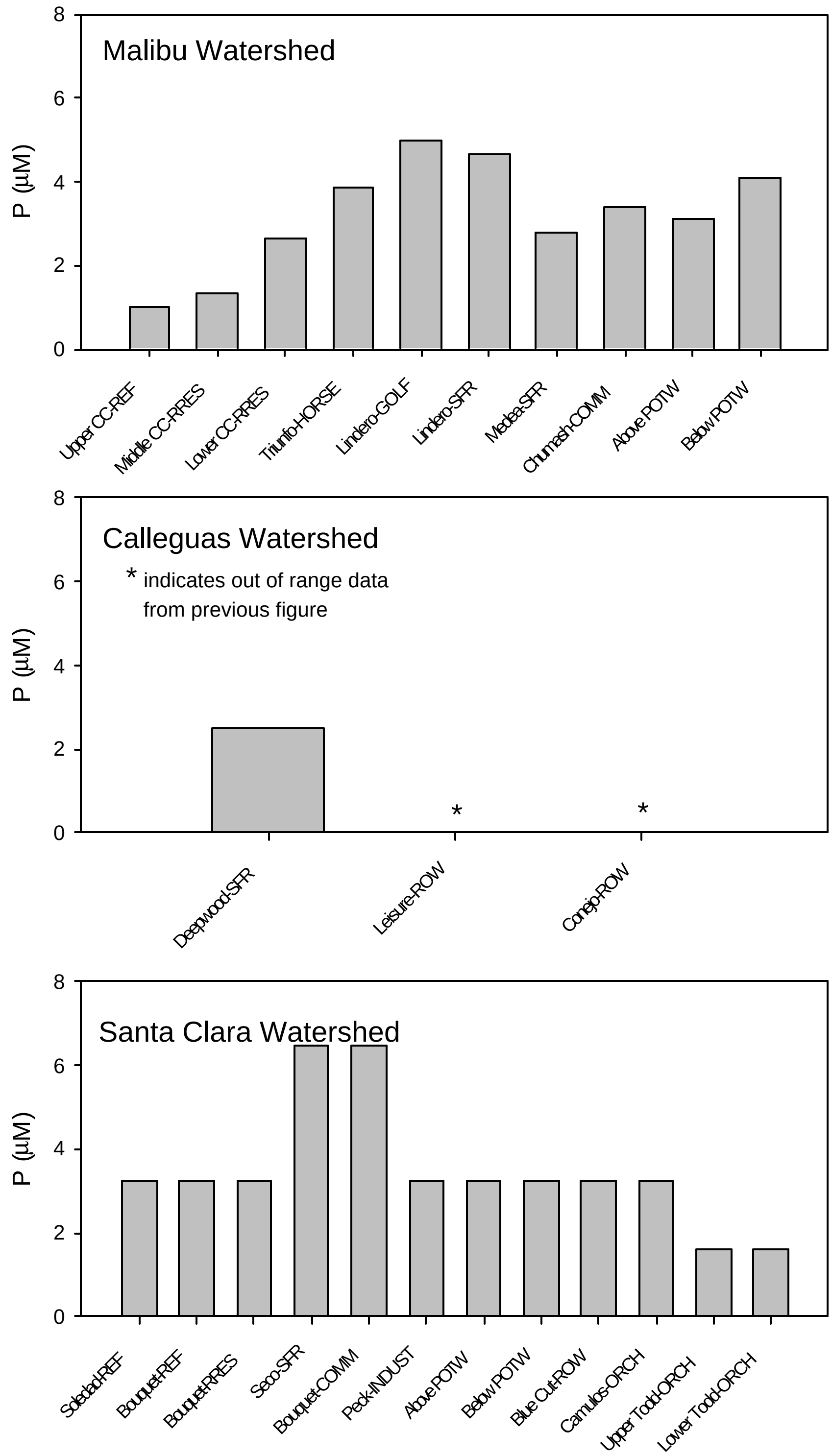


Figure 21. Phosphorous values from previous figure at appropriate scale after removing data from sites with off-scale readings.

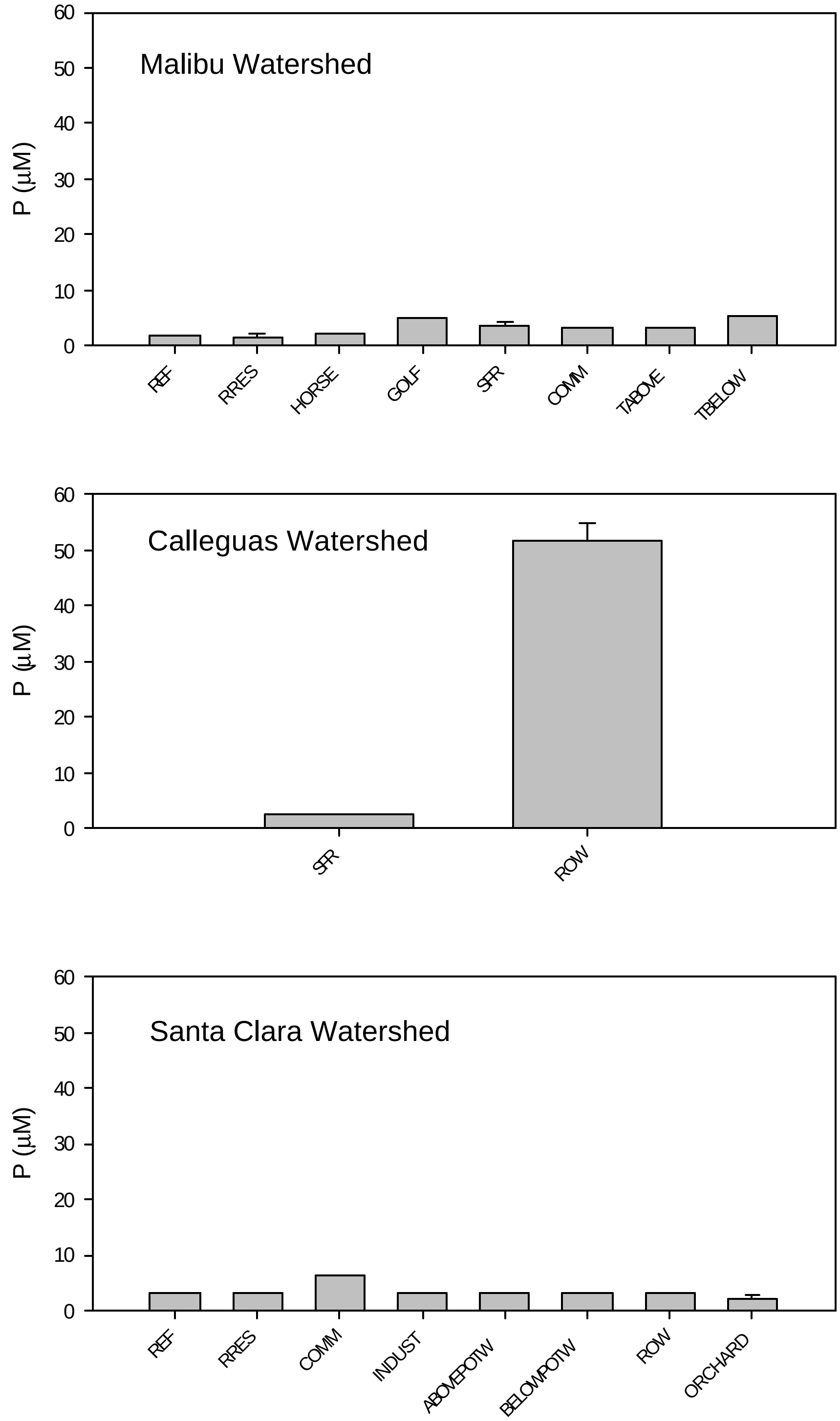


Figure 22. Phosphorous by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

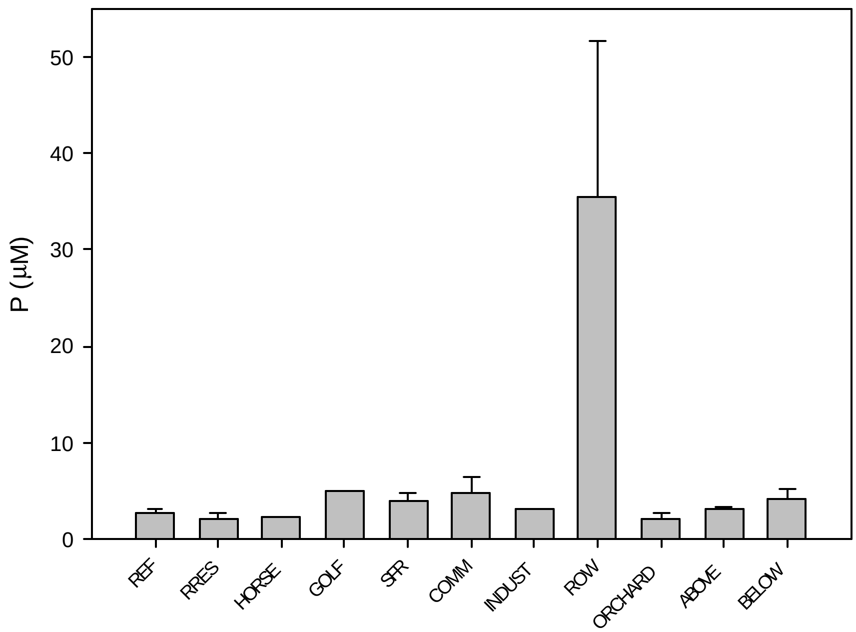


Figure 23. Phosphorous by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

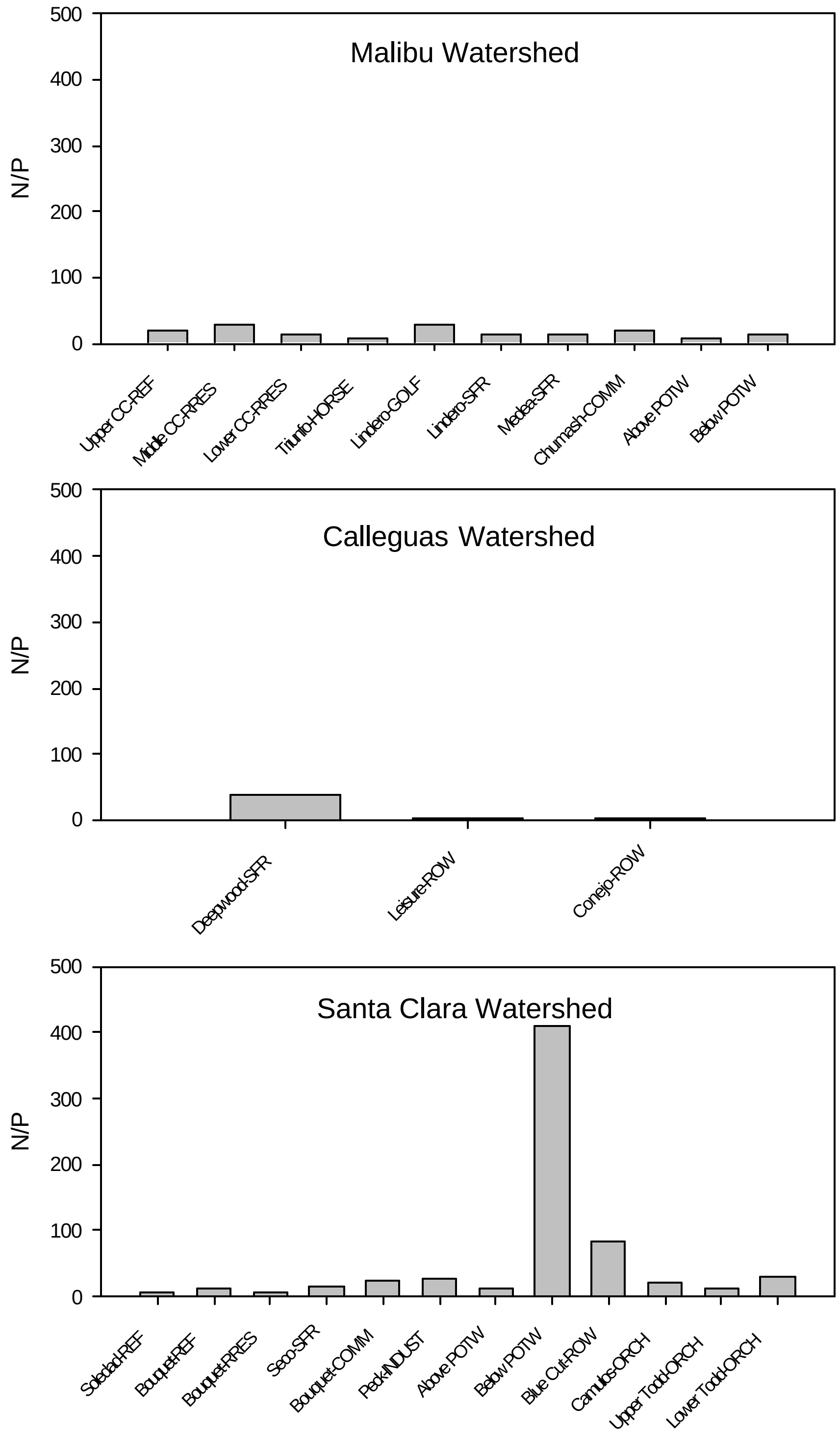


Figure 24. N:P ratios at all sites.

Grab samples from CC and SCR sites were delivered to an analytical lab within 4 hours of collection. Samples from MC and Deepwood-SFR were supplied by UCSB research group and were subjected to variable holding times (3-60 hours).

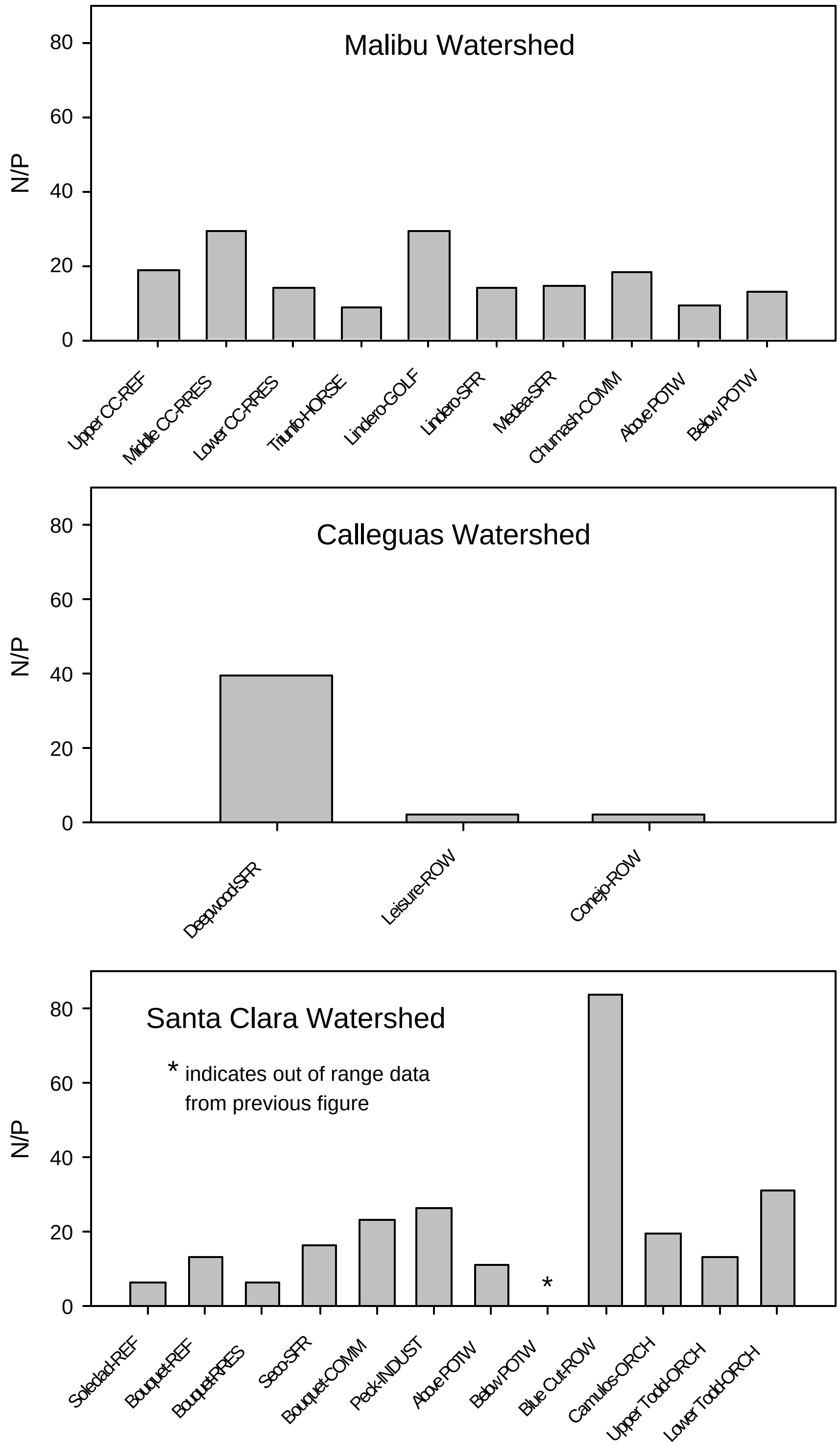


Figure 25. N:P ratios values from previous figure at appropriate scale after removing data from sites with off-scale readings.

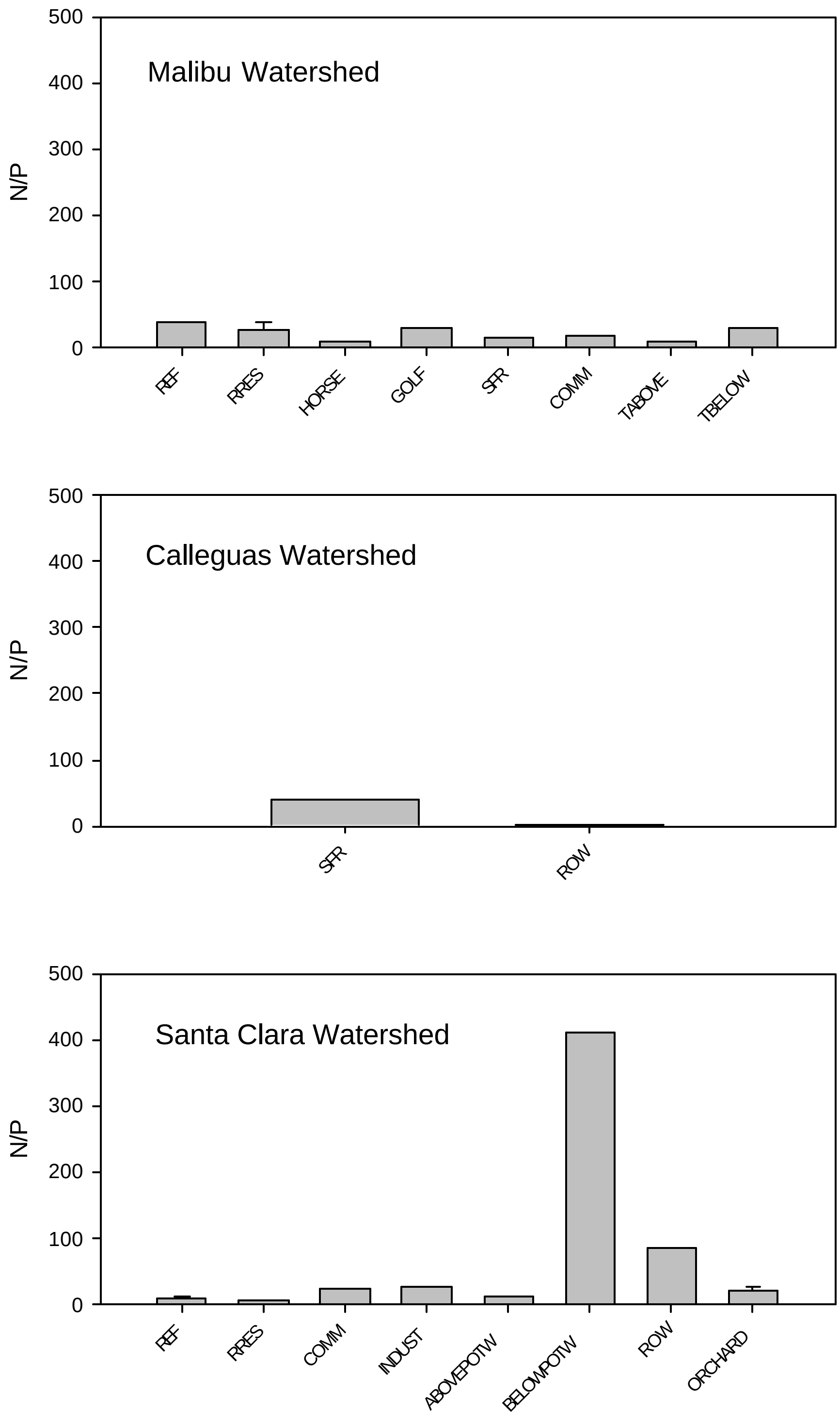


Figure 26. N:P ratios by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

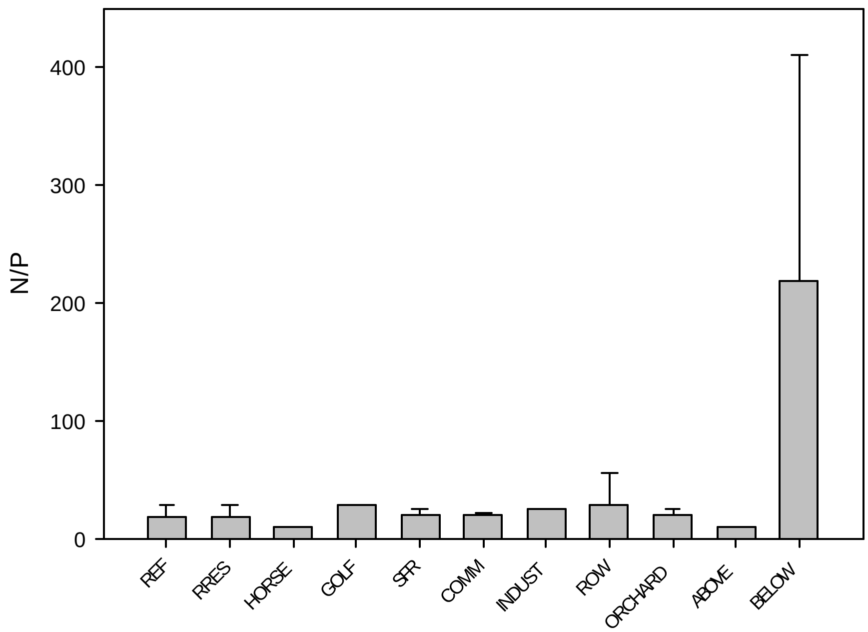


Figure 27. N:P ratios by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

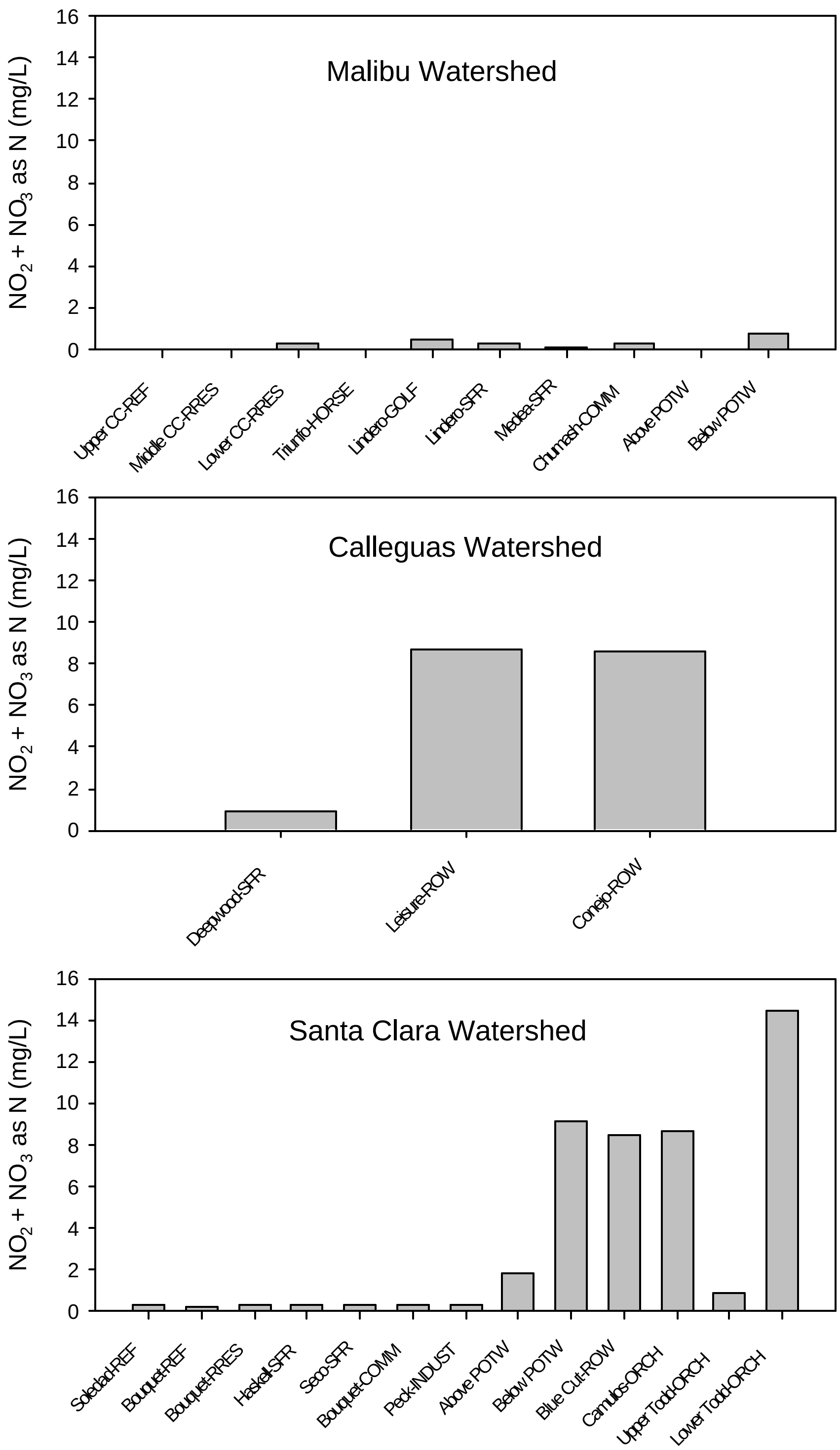


Figure 28. Combined nitrite and nitrate ($NO_2 + NO_3$) as N at all sites.

Grab samples from CC and SCR sites were delivered to an analytical lab within 4 hours of collection. Samples from MC and Deepwood-SFR were supplied by UCSB research group and were subjected to variable holding times (3-60 hours).

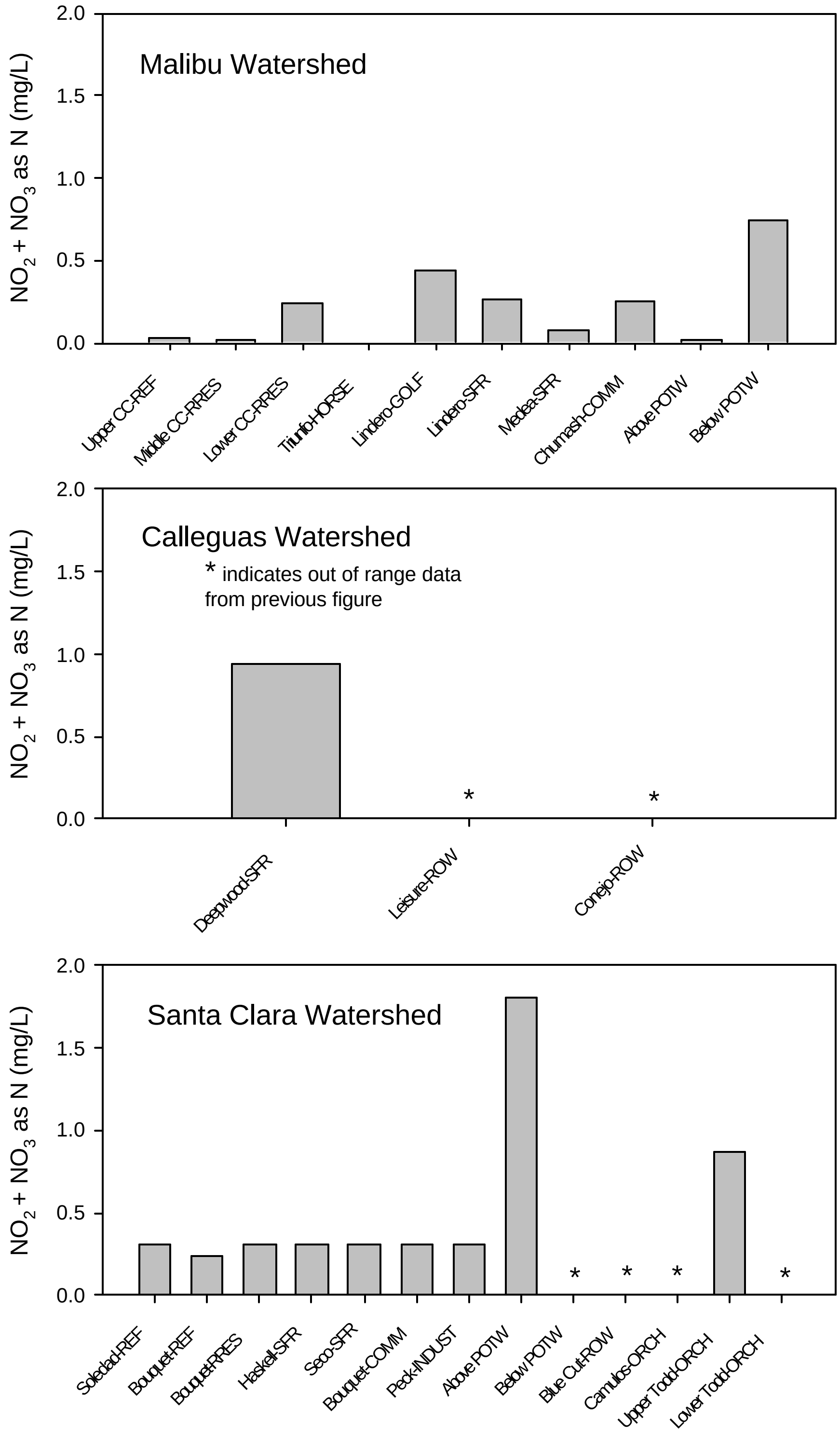


Figure 29. Combined nitrite and nitrate ($NO_2 + NO_3$) as N values from previous figure at appropriate scale after removing data from sites with off-scale readings.

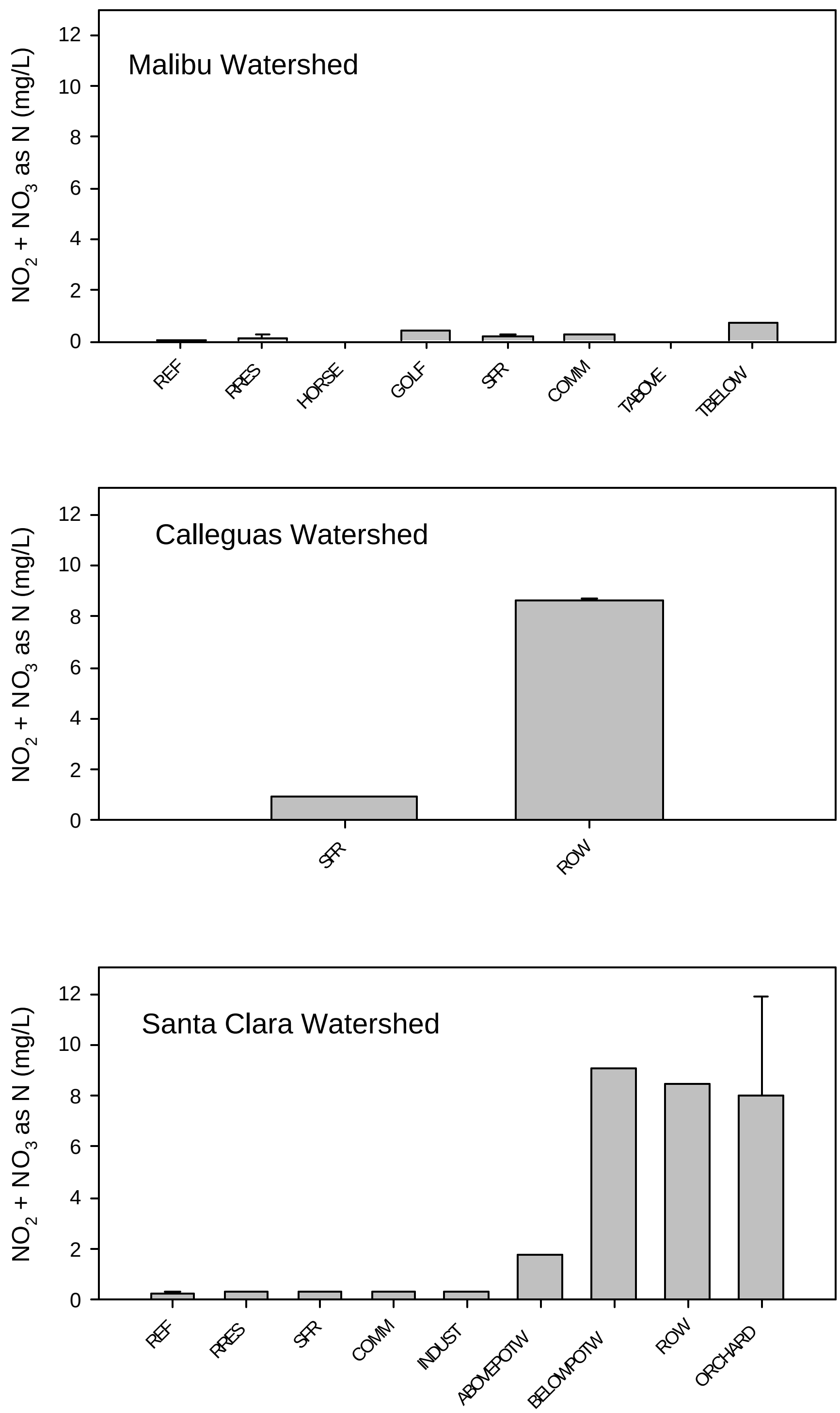


Figure 30. Combined nitrite and nitrate ($NO_2 + NO_3$) as N by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

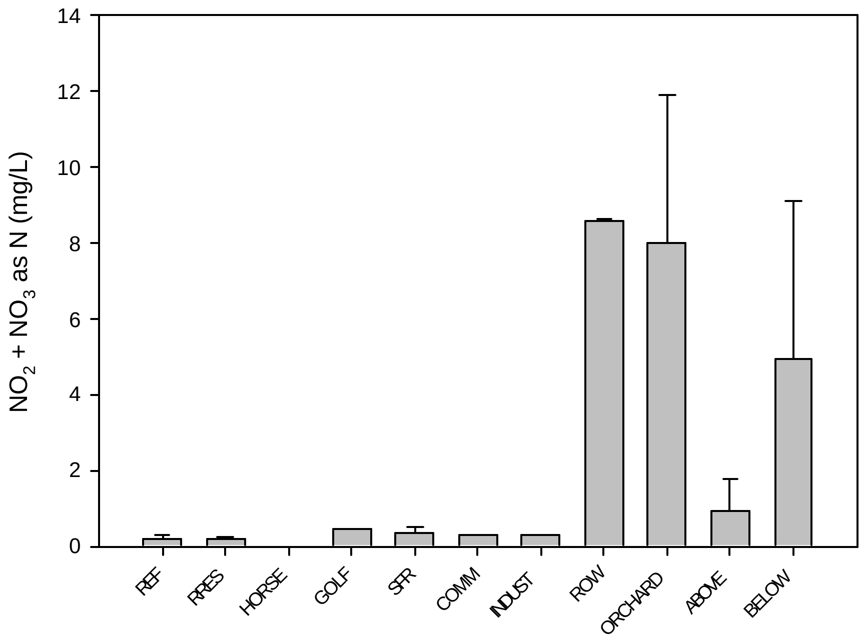


Figure 31. Combined nitrite and nitrate ($NO_2 + NO_3$) as N by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

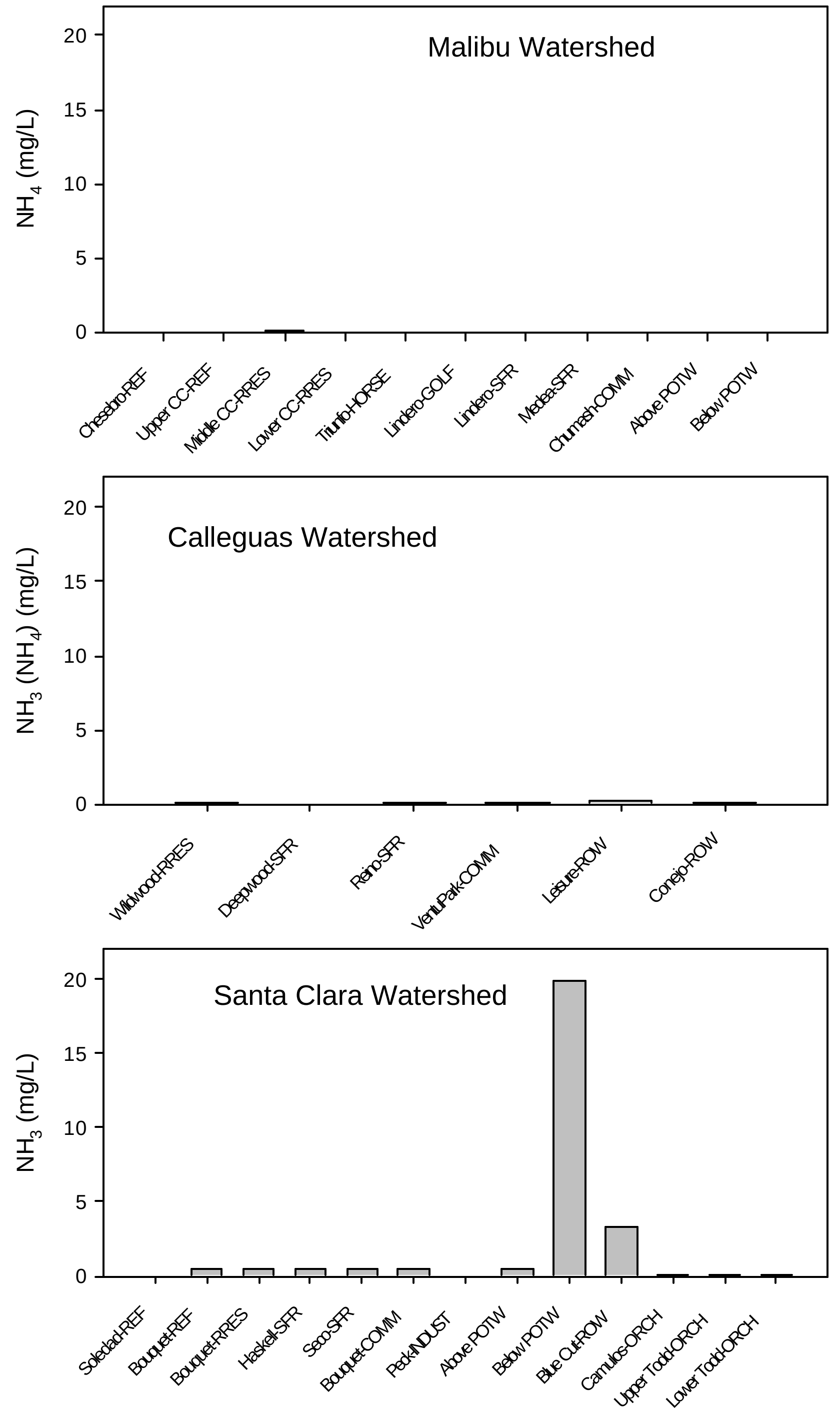


Figure 32. Ammonia as NH_3 or Ammonium as NH_4^+ at all sites.

Grab samples from CC and SCR sites were delivered to an analytical lab within 4 hours of collection or were analyzed in the field for NH_3. Samples from MC and Deepwood-SFR were supplied by UCSB research group and were subjected to variable holding times (3-60 hours) before being analyzed for NH_4^+.

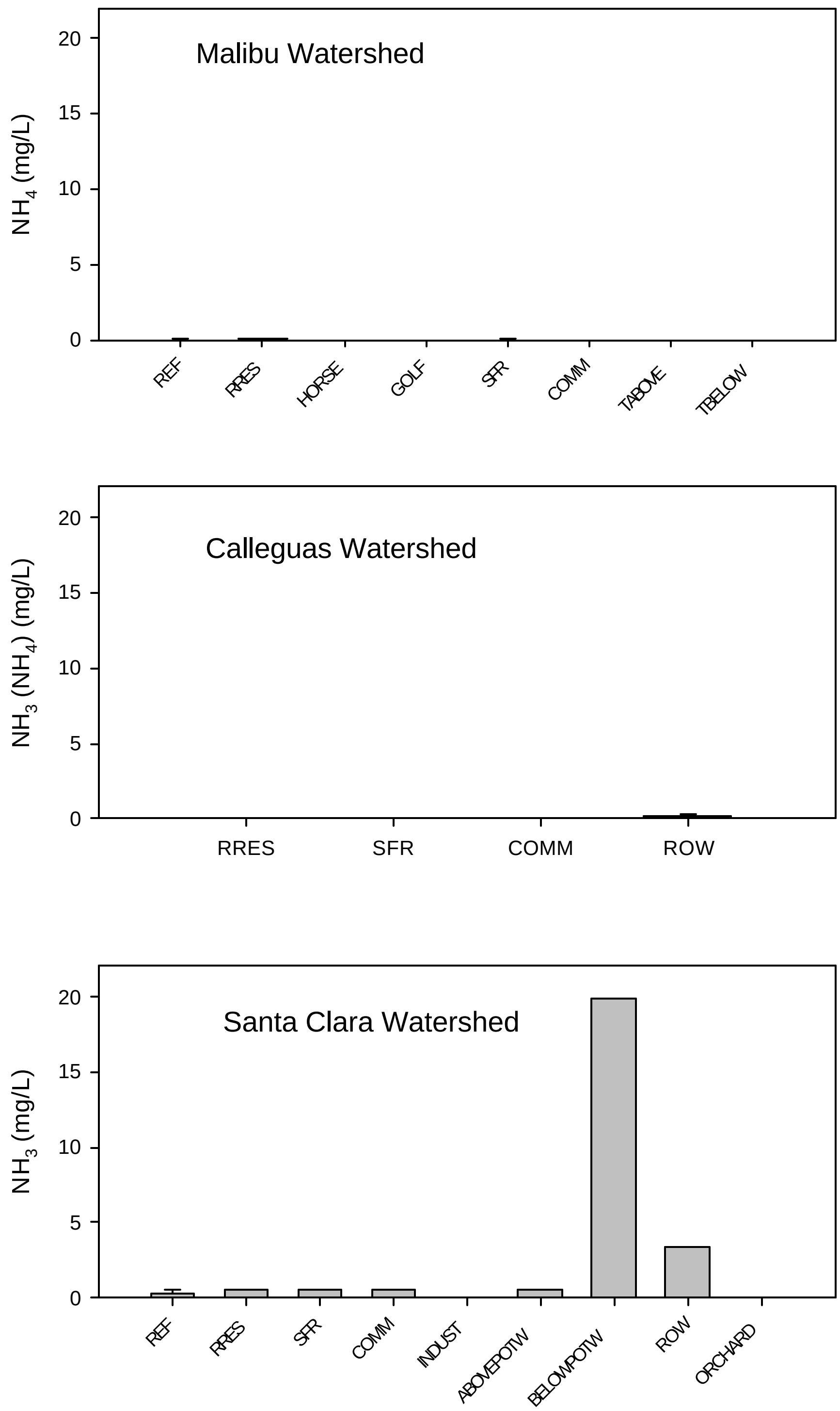


Figure 33. Ammonia (NH_3) or Ammonium (NH_4^+) by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

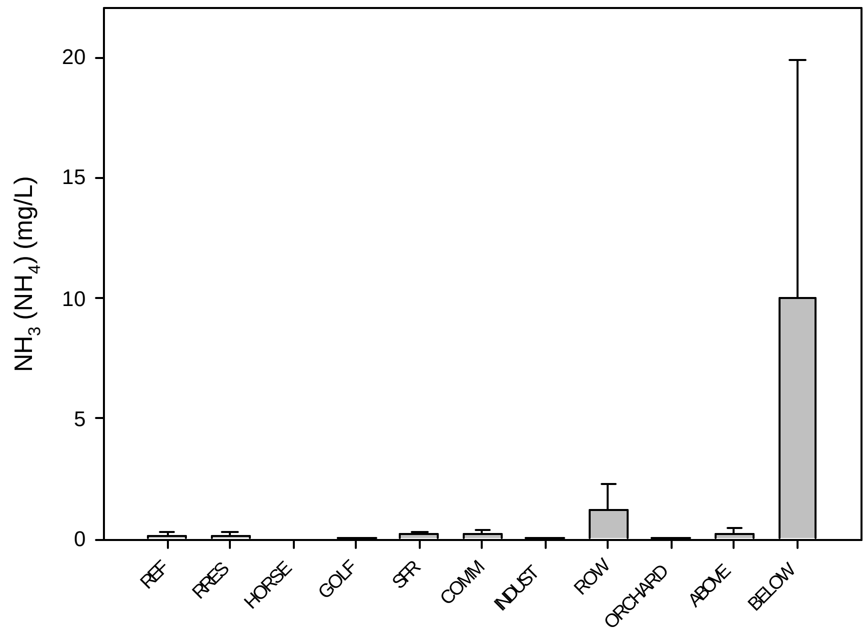


Figure 34. Ammonia (NH_3) or Ammonium (NH_4^+) by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

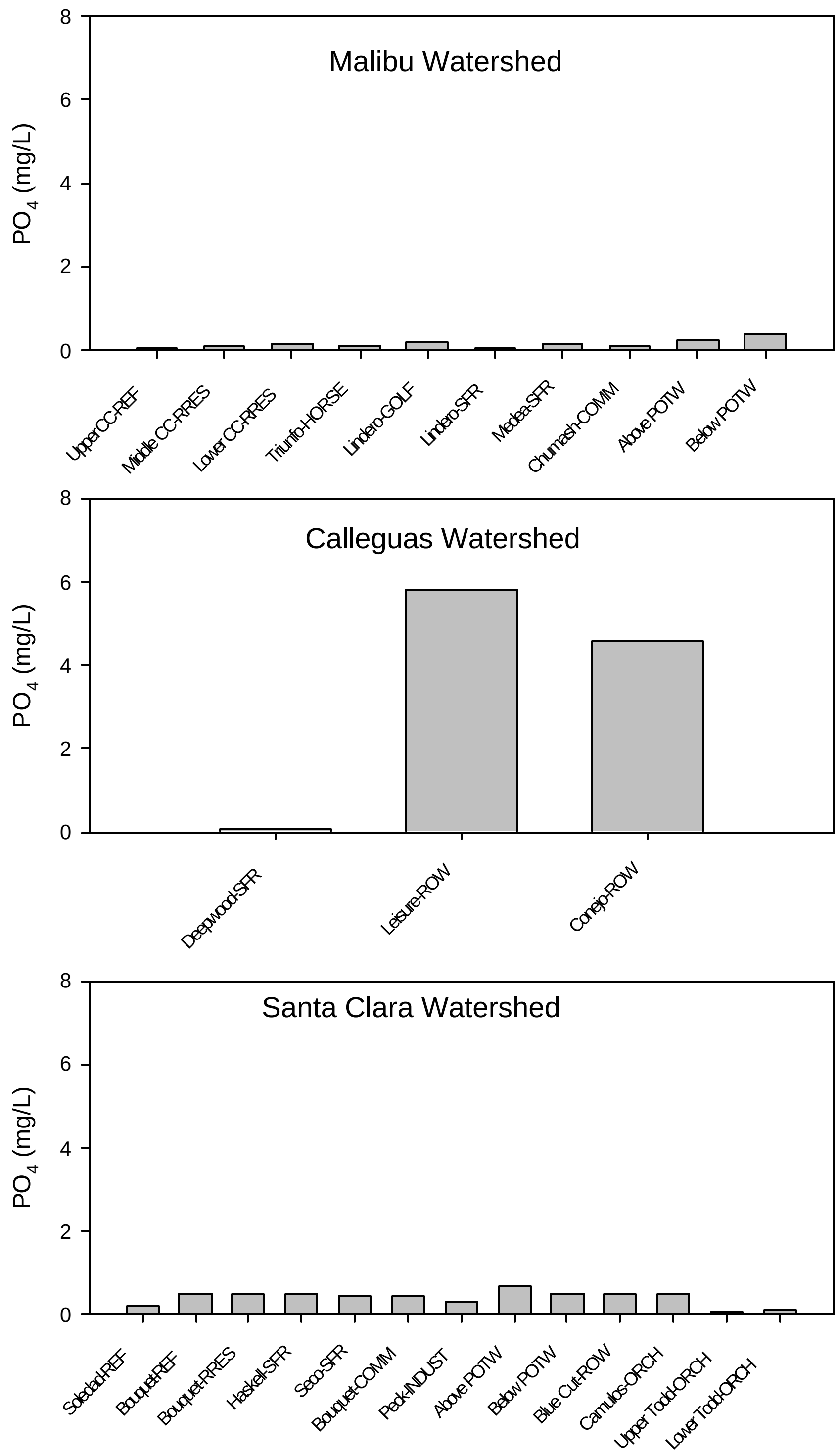


Figure 35. Phosphate (PO_4^{3-}) at all sites.

Grab samples from CC and SCR sites were delivered to an analytical lab within 4 hours of collection. Samples from MC and Deepwood-SFR were supplied by UCSB research group and were subjected to variable holding times (3-60 hours).

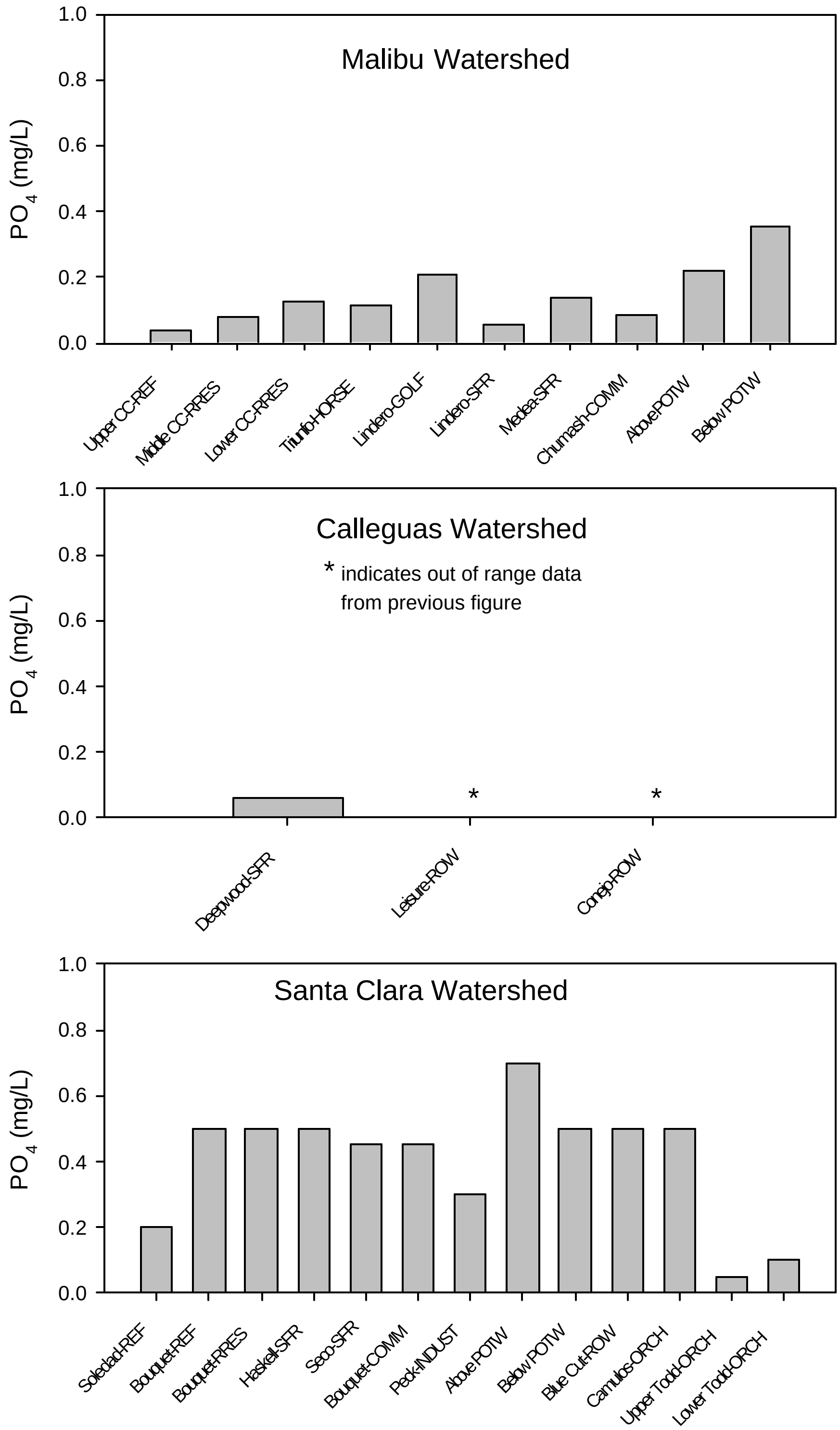


Figure 36. Phosphate (PO_4^{3-}) values from previous figure at appropriate scale after removing data from sites with off-scale readings.

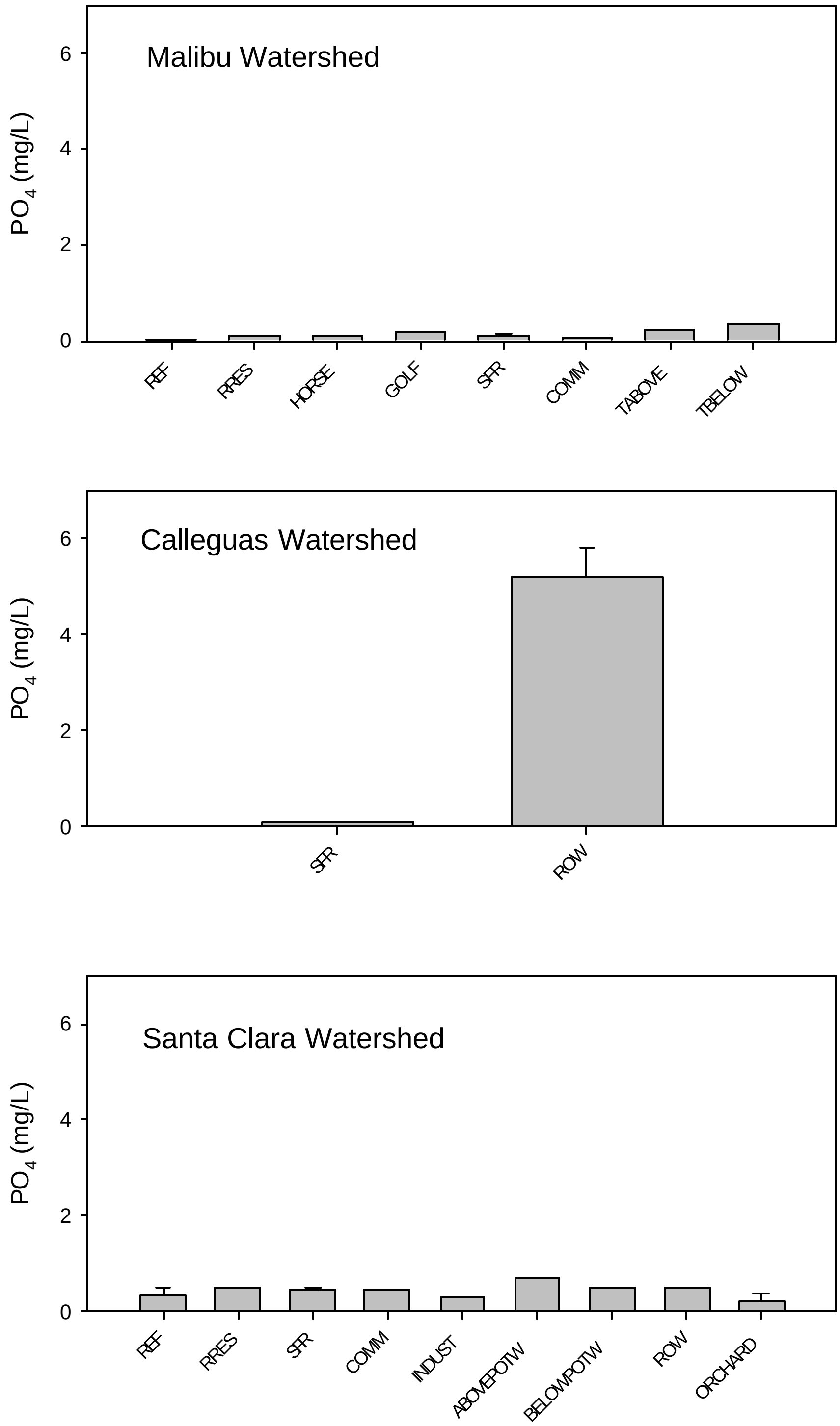


Figure 37. Phosphate (PO_4^{3-}) by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

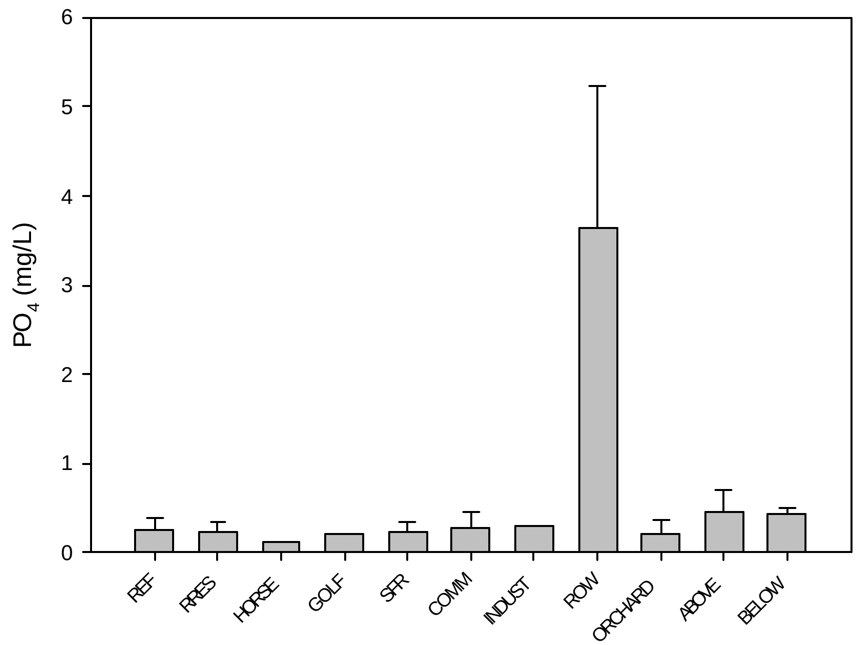


Figure 38. Phosphate (PO_4^{3-}) by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

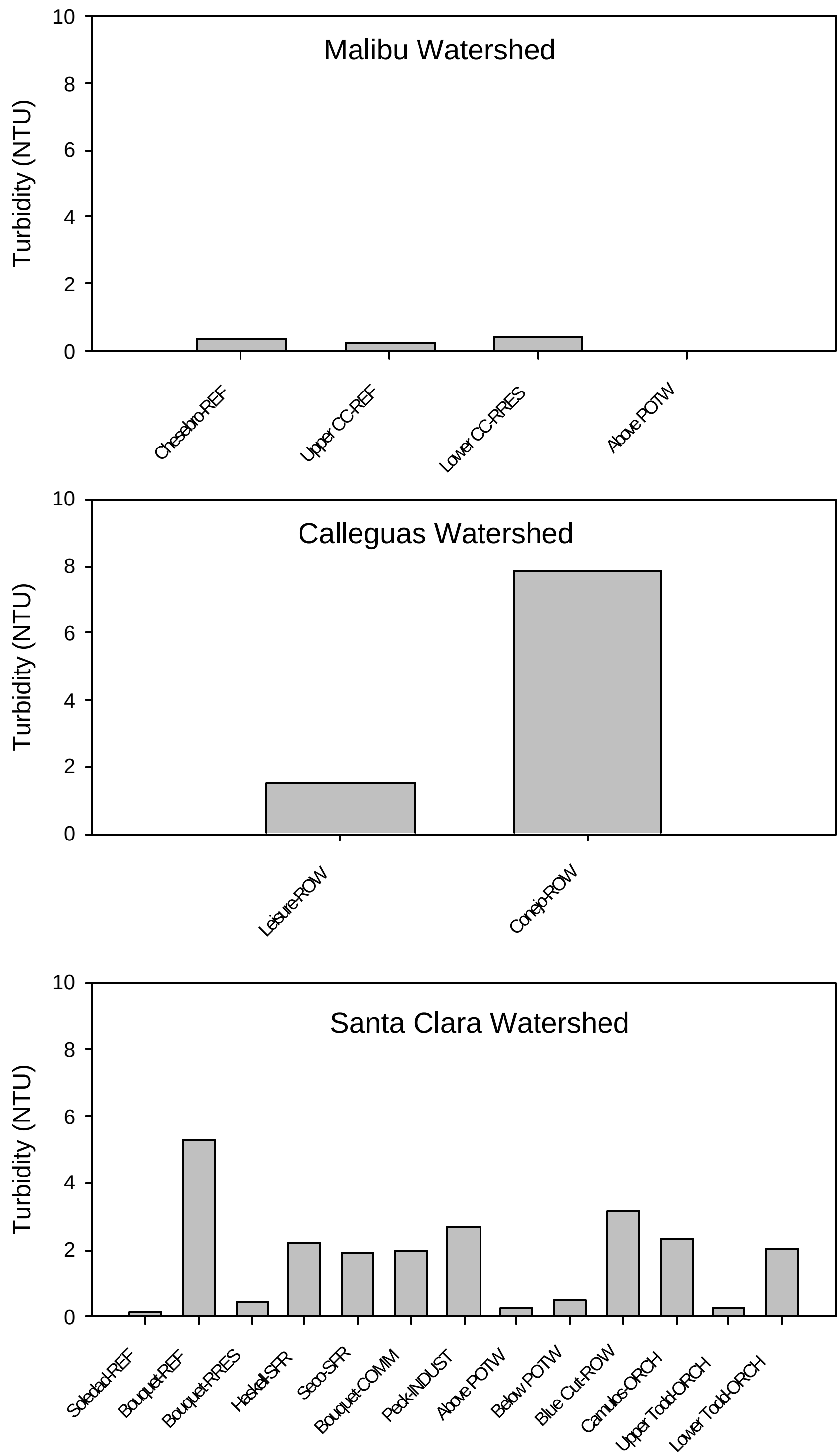


Figure 39. Turbidity at all sites.

Grab samples from CC and SCR sites were delivered to an analytical lab within 4 hours of collection. Samples from MC and Deepwood-SFR were supplied by UCSB research group.

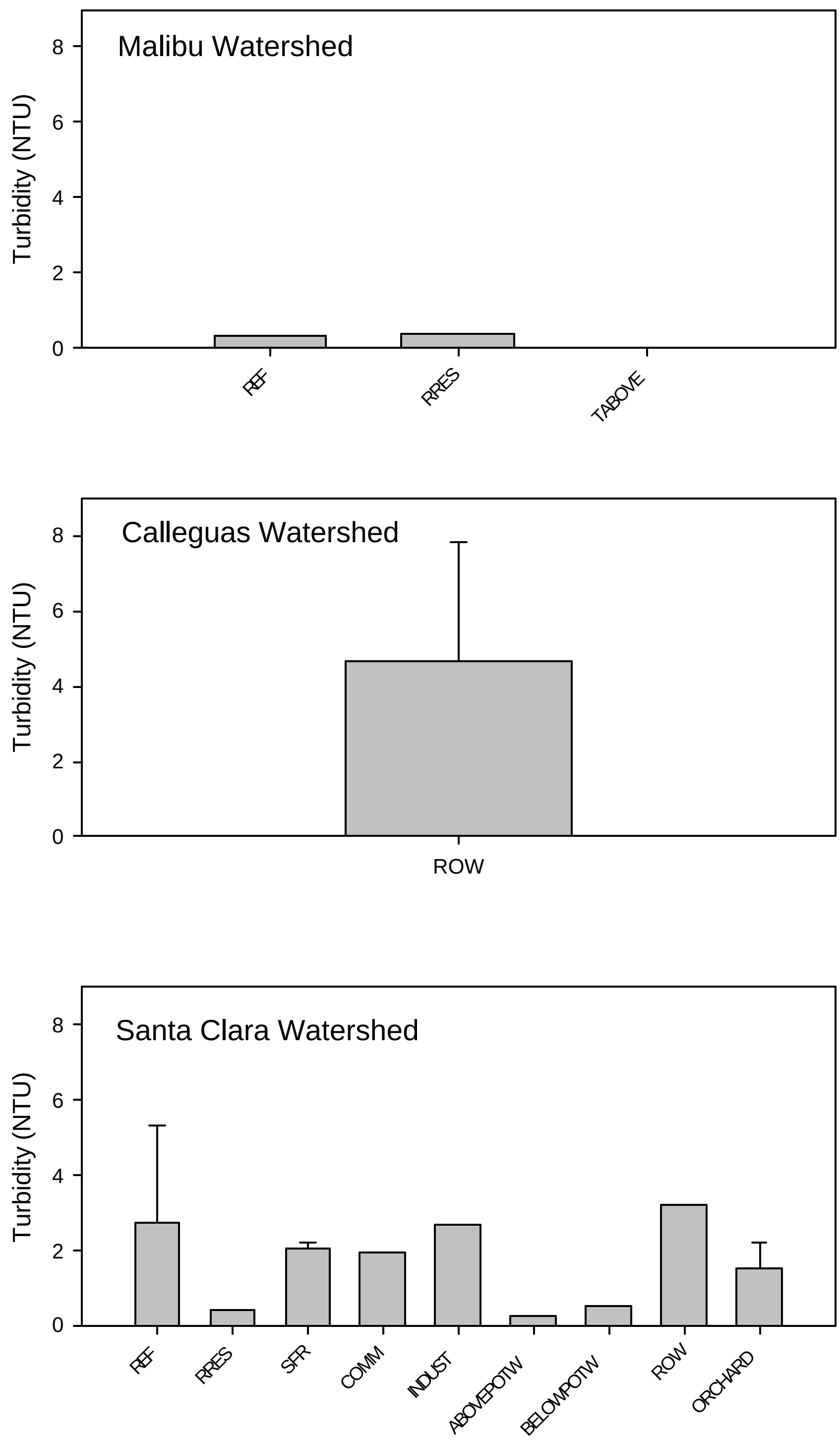


Figure 40. Turbidity by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

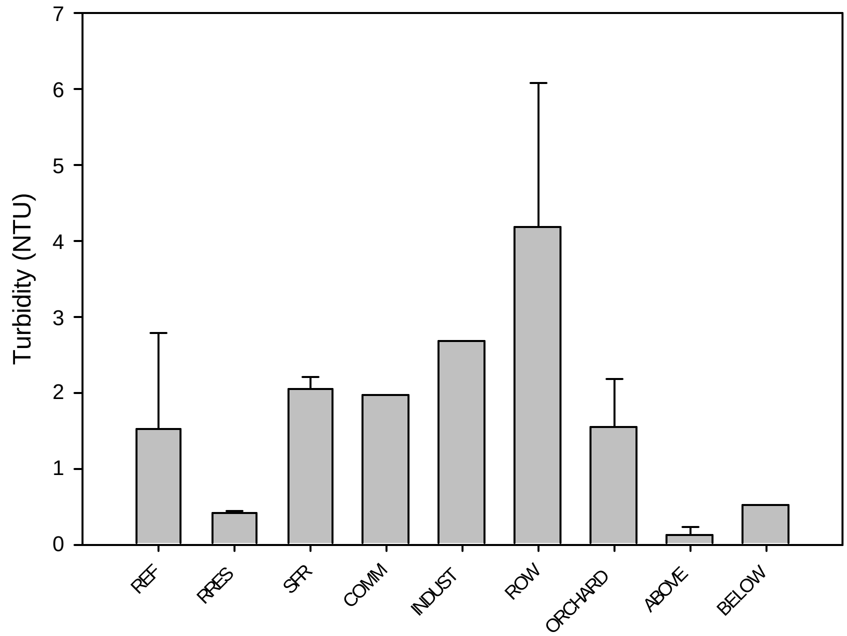


Figure 41. Turbidity by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

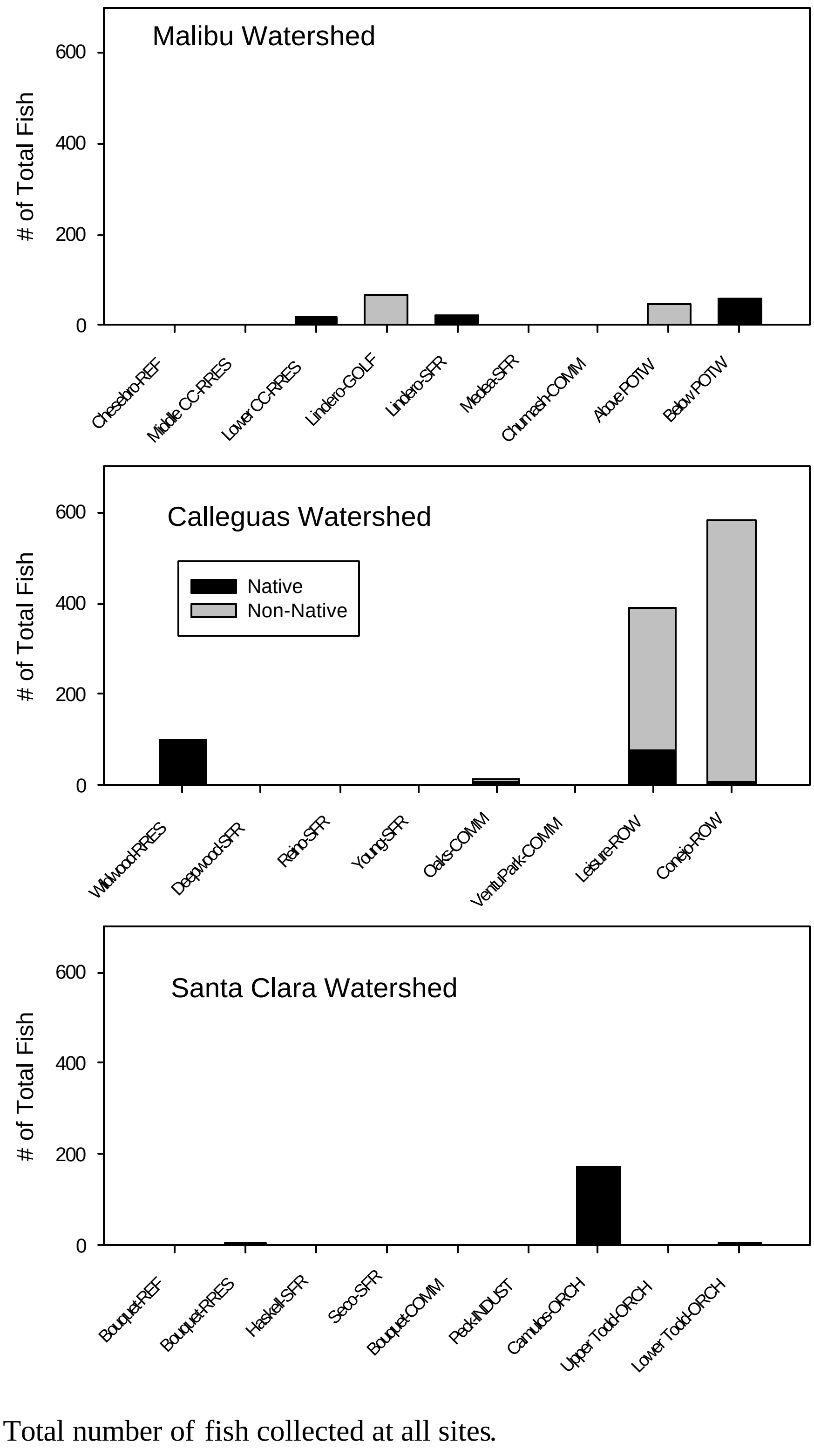


Figure 42. Total number of fish collected at all sites.

Not all sites were fished. Sites with an obvious lack of habitat (i.e. concrete channels), or with known threatened or endangered species were not fished.

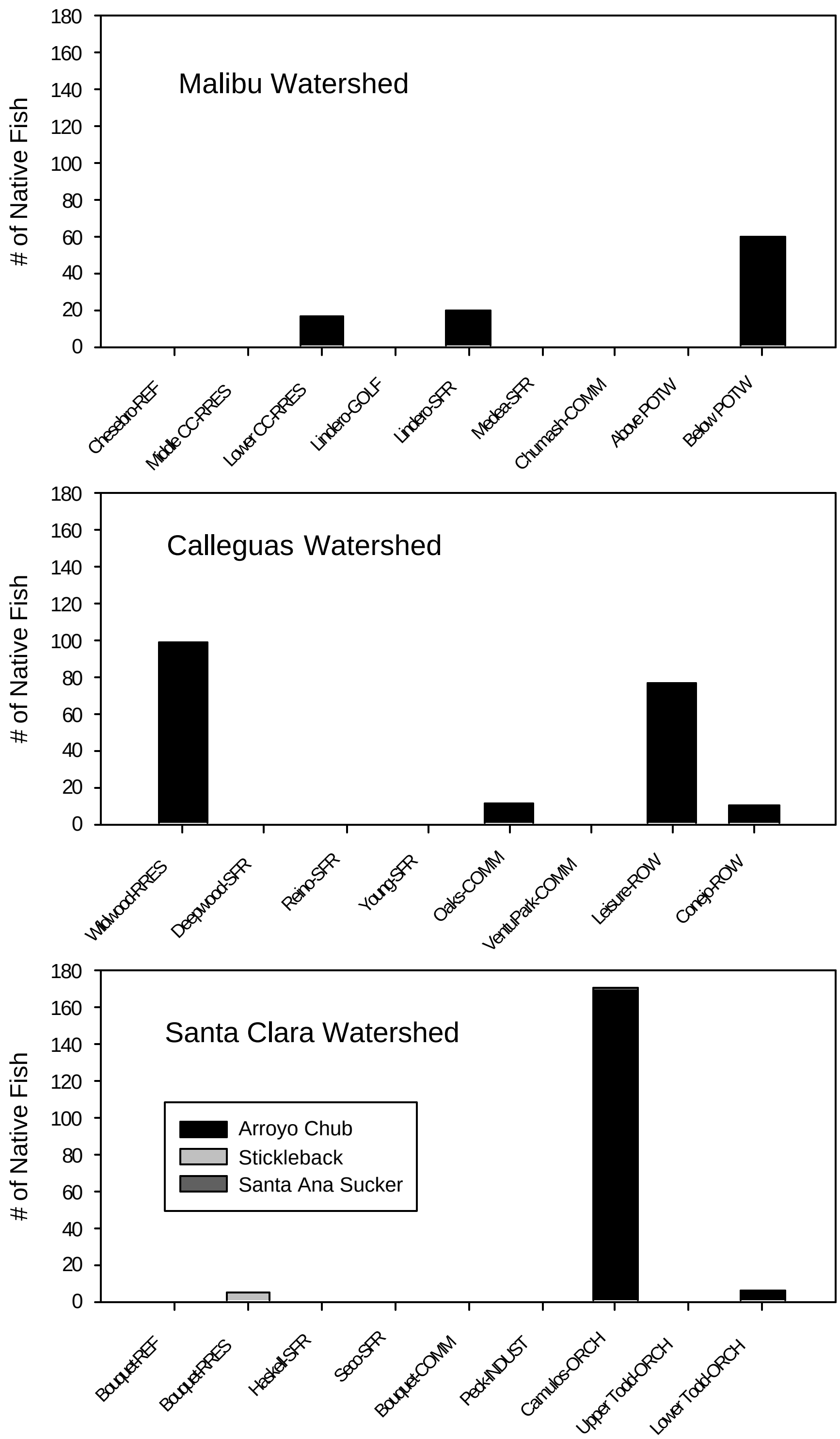


Figure 43. Total number of native fish collected at all sites.

Not all sites were fished. Sites with an obvious lack of habitat (i.e. concrete channels), or with known threatened or endangered species were not fished.

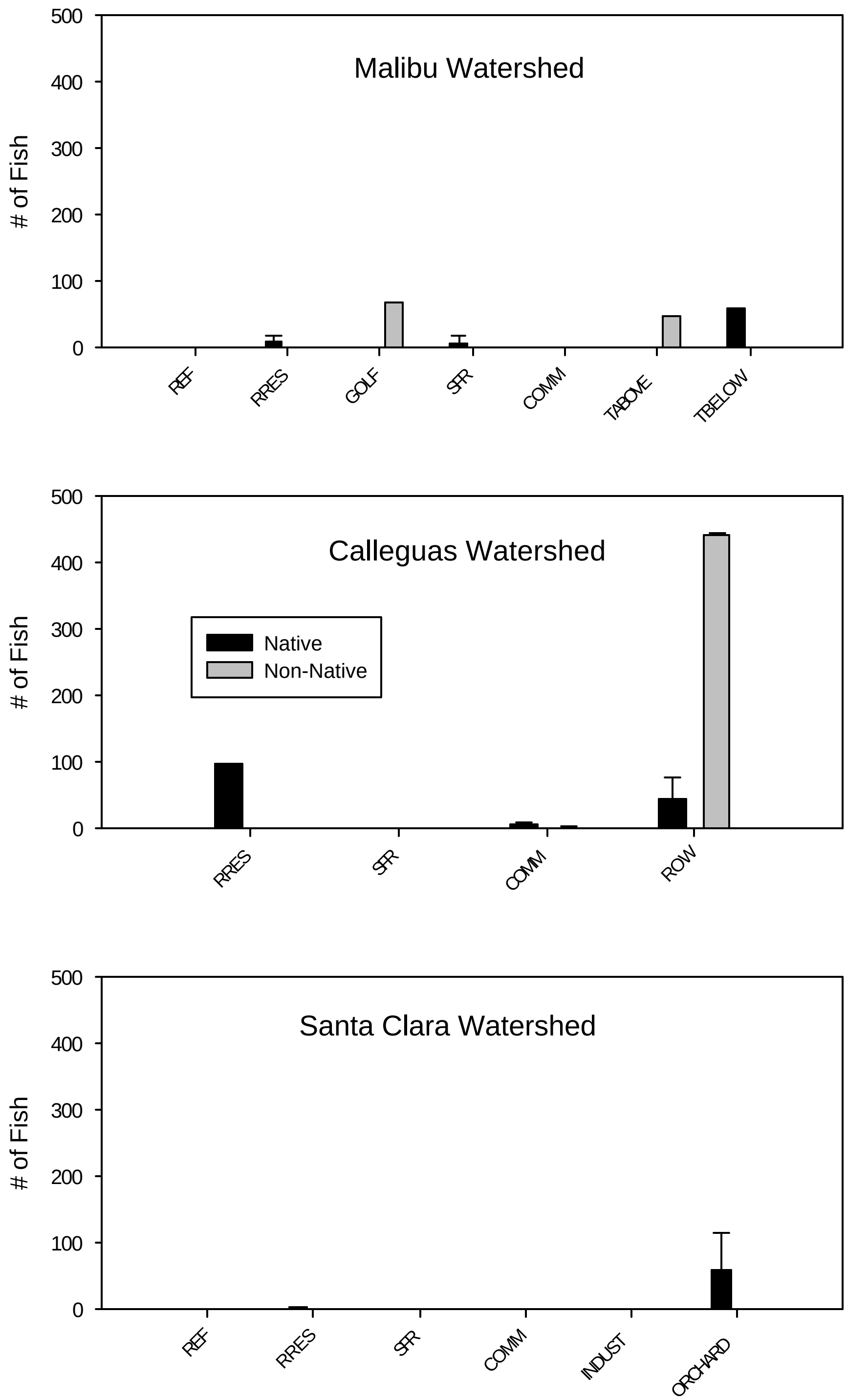
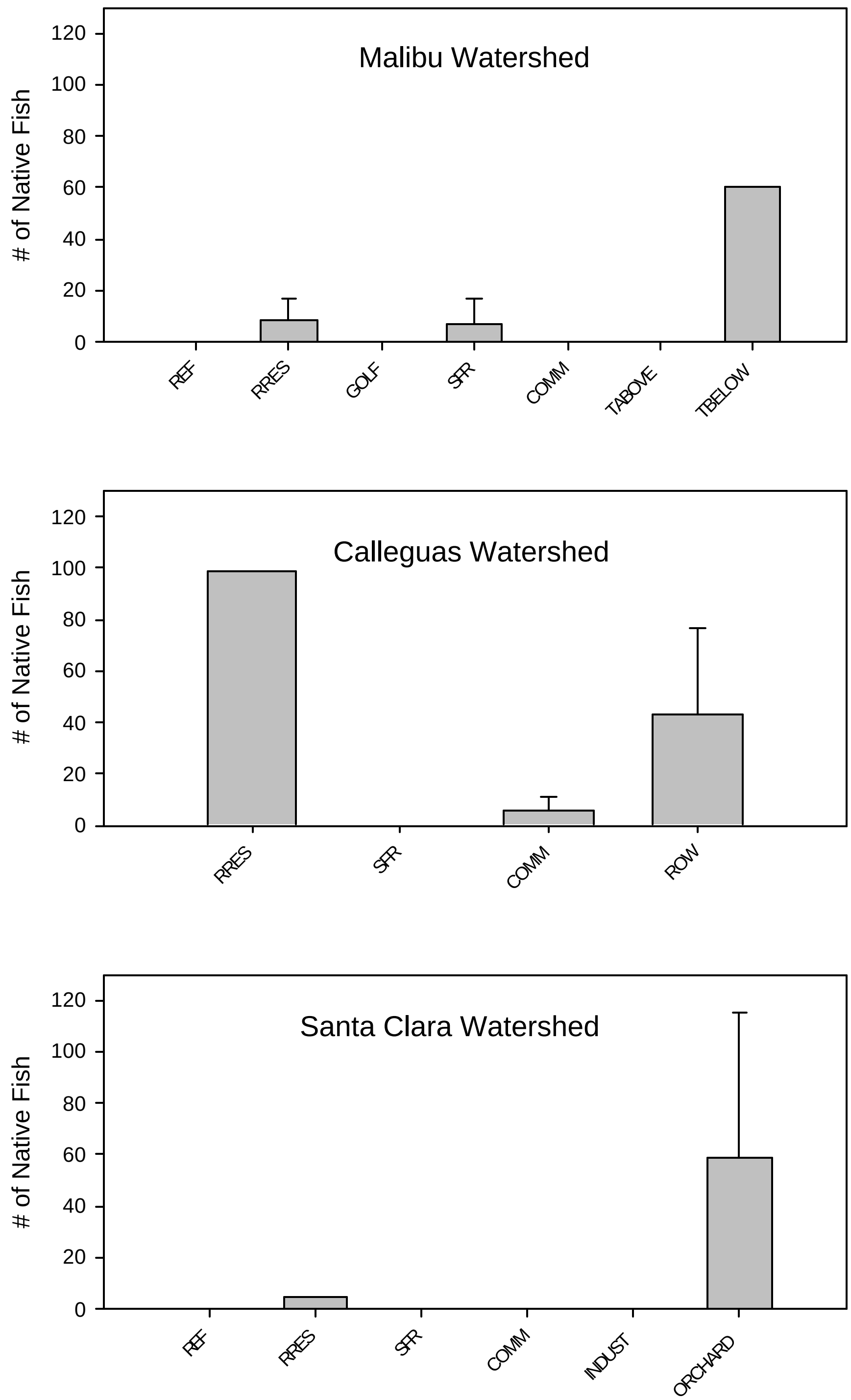


Figure 44. Total number of fish by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.



*all arroyo chubs, except five stickleback at SC-RRES and one S.A. sucker at SC-ORCHARD

Figure 45. Total number of native fish by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

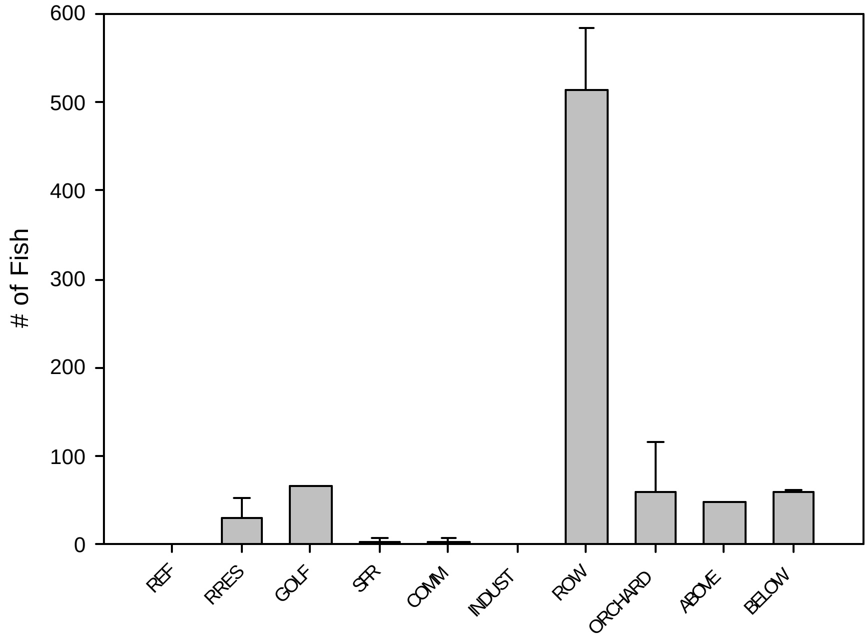


Figure 46. Total number of fish by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

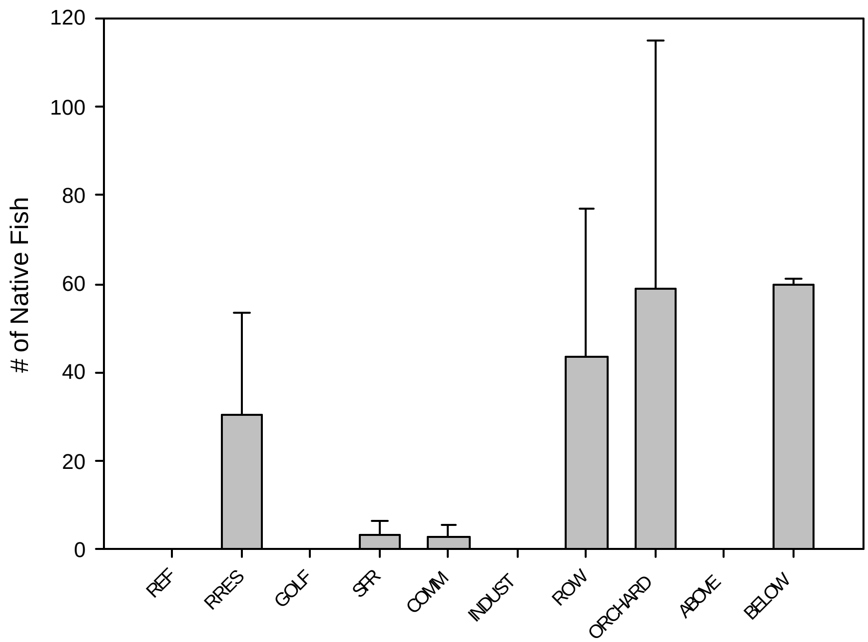


Figure 47. Total number of native fish by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

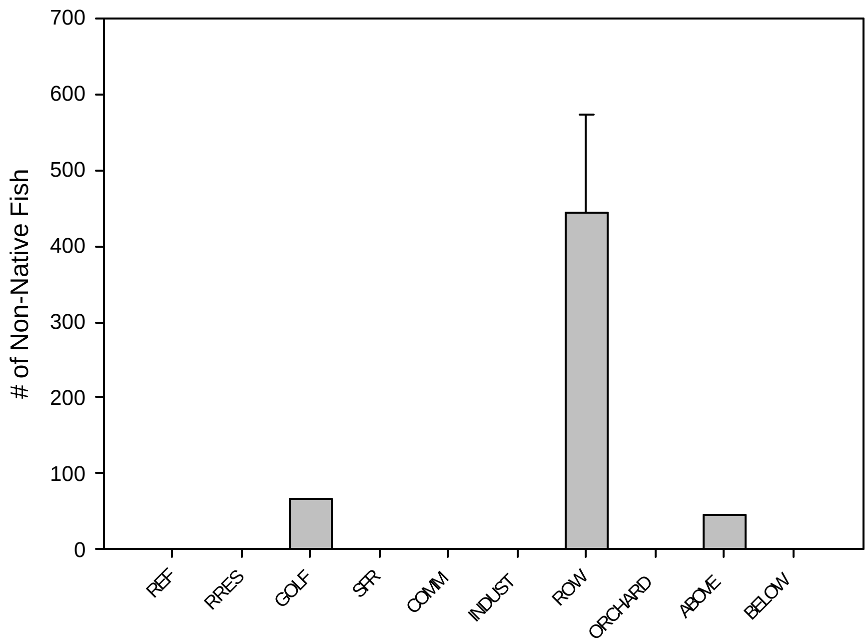


Figure 48. Total number of non-native fish by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

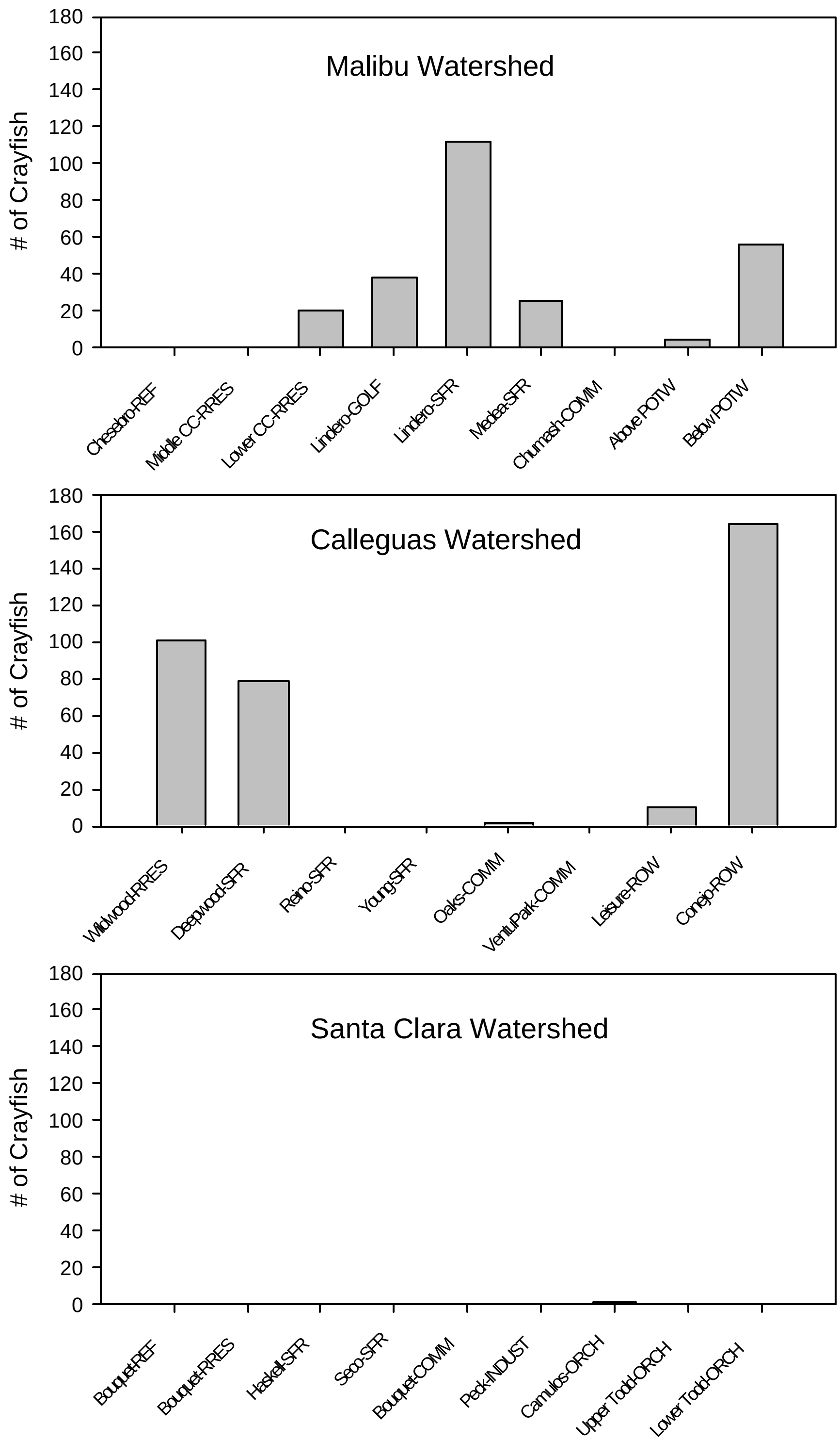


Figure 49. Total number of crayfish collected at all sites.

Not all sites were fished. Sites with an obvious lack of habitat (i.e. concrete channels), or with known threatened or endangered species were not fished.

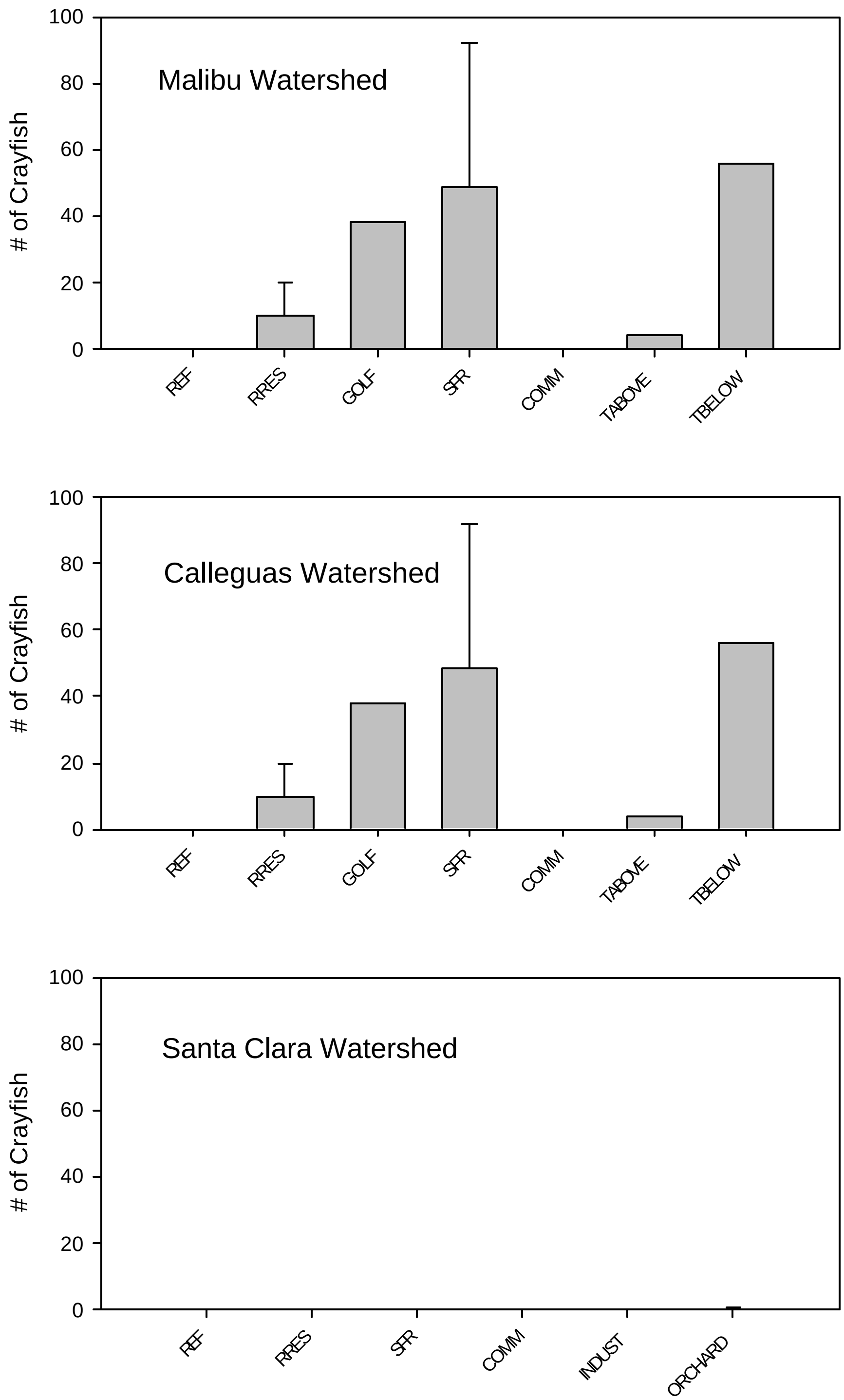


Figure 50. Total number of crayfish by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds. Error bars are only present on bars reflecting averaged values.

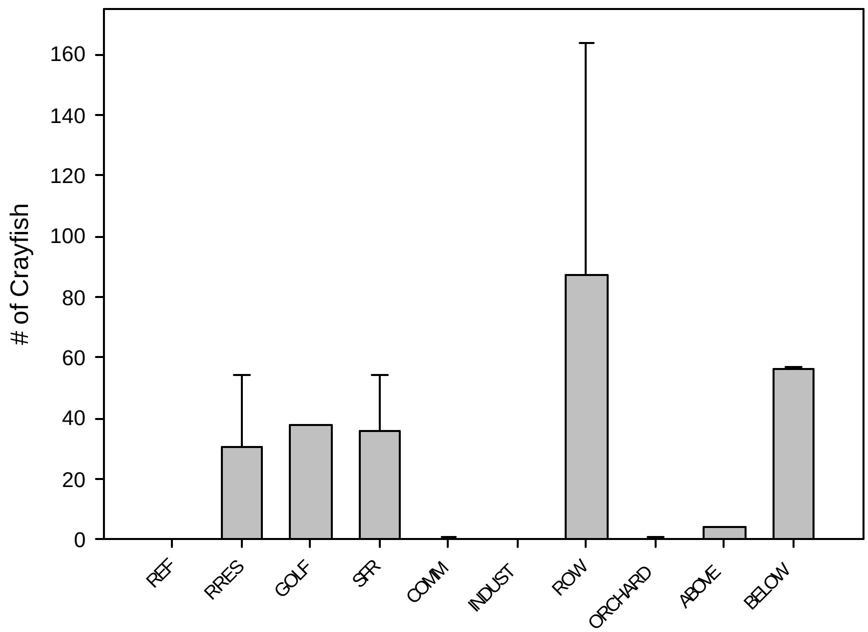


Figure 51. Total number of crayfish by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds, as appropriate. Error bars are only present on bars reflecting averaged values.

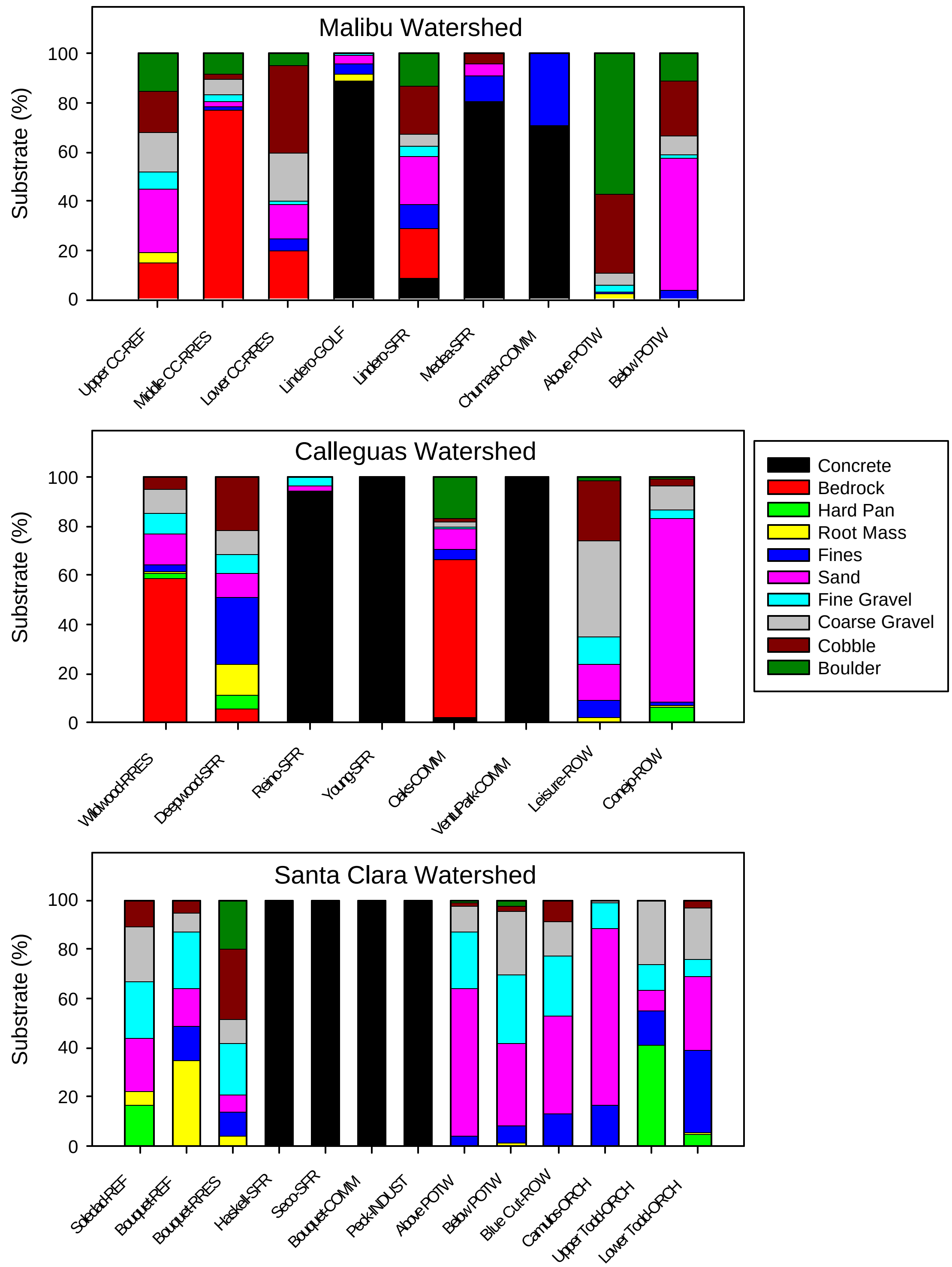


Figure 52. Substrate at all sites.

Substrate types were recorded at twenty (ten, if wetted width < 1m) positions across the wetted width at each transect.

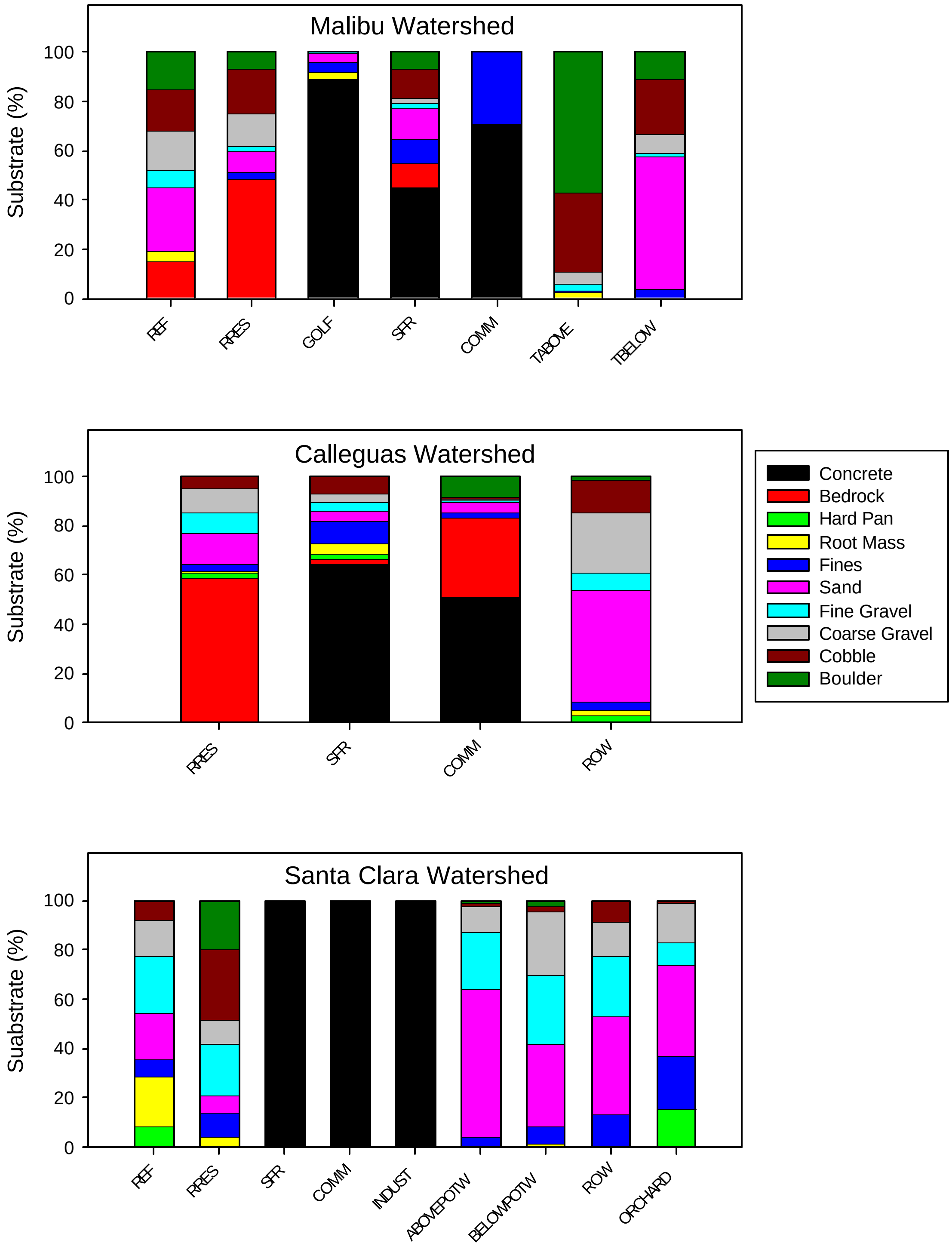


Figure 53. Substrate by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

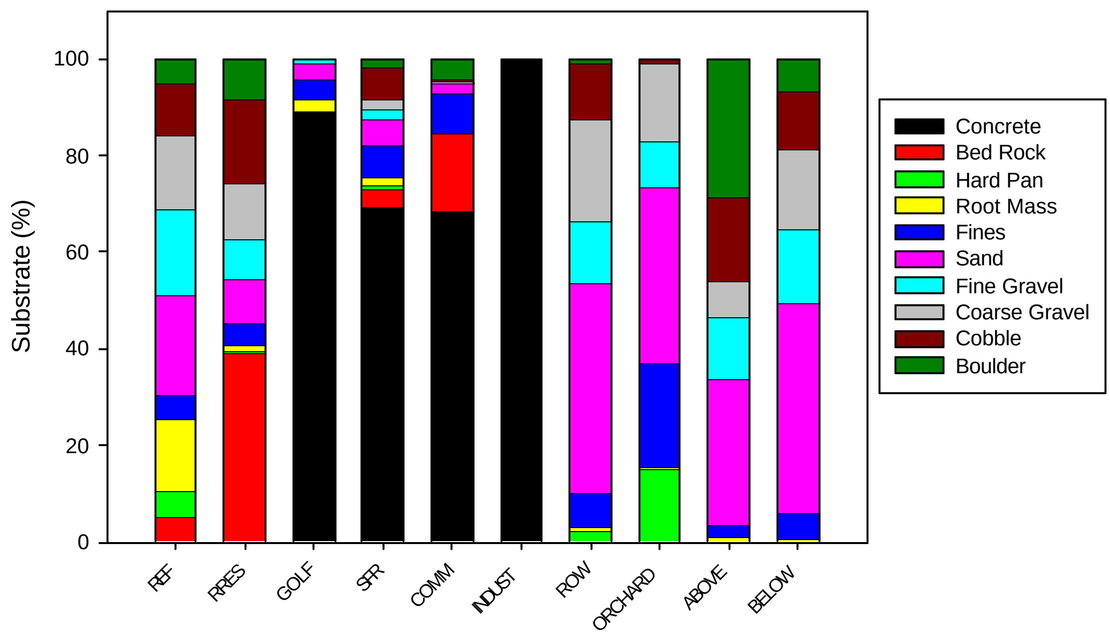


Figure 54. Substrate by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

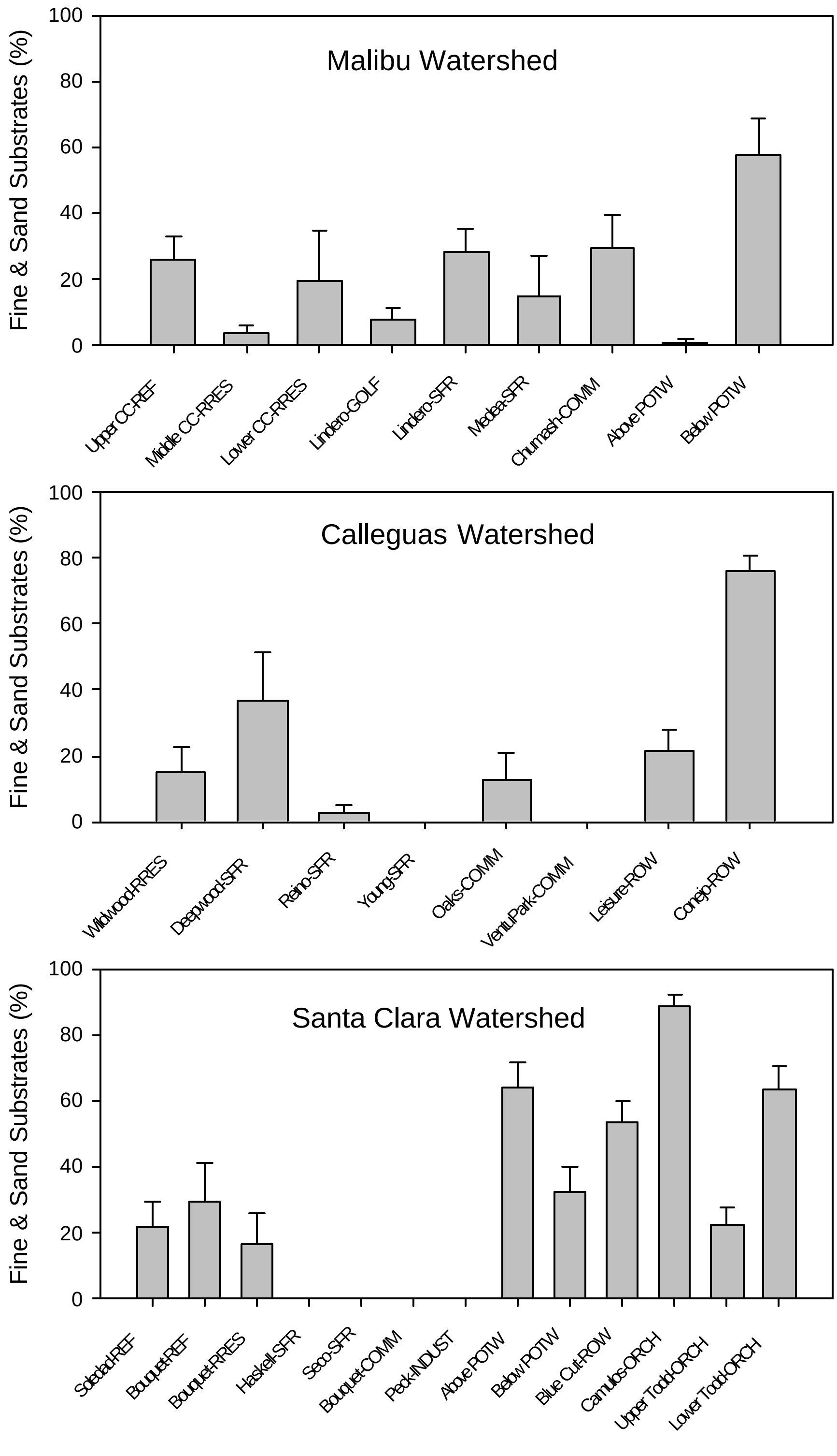


Figure 55. Fine and sand substrate at all sites.

Substrate types were recorded at twenty (ten, if wetted width < 1m) positions across the wetted width at each transect.

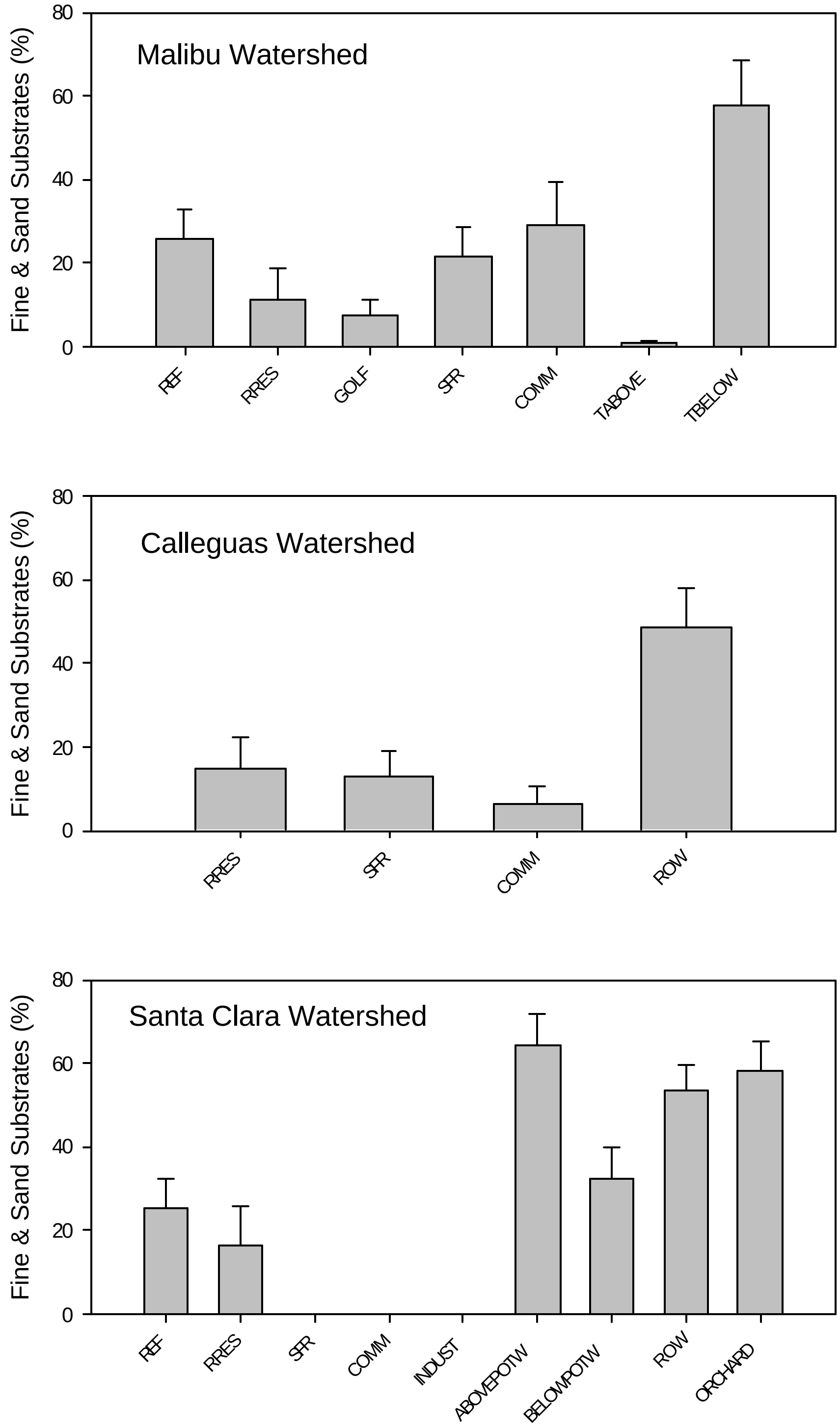


Figure 56. Fine and sand substrate by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

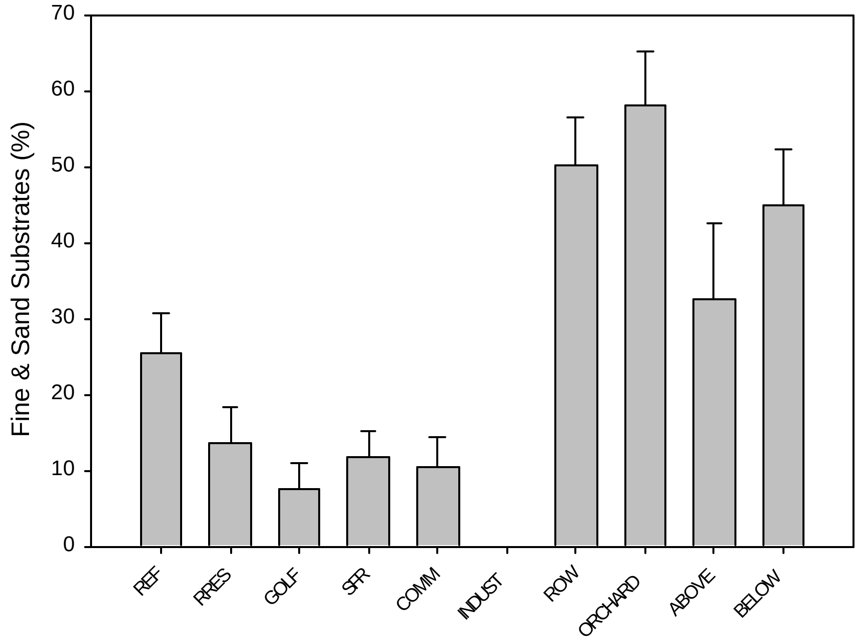


Figure 57. Fine and sand substrate by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

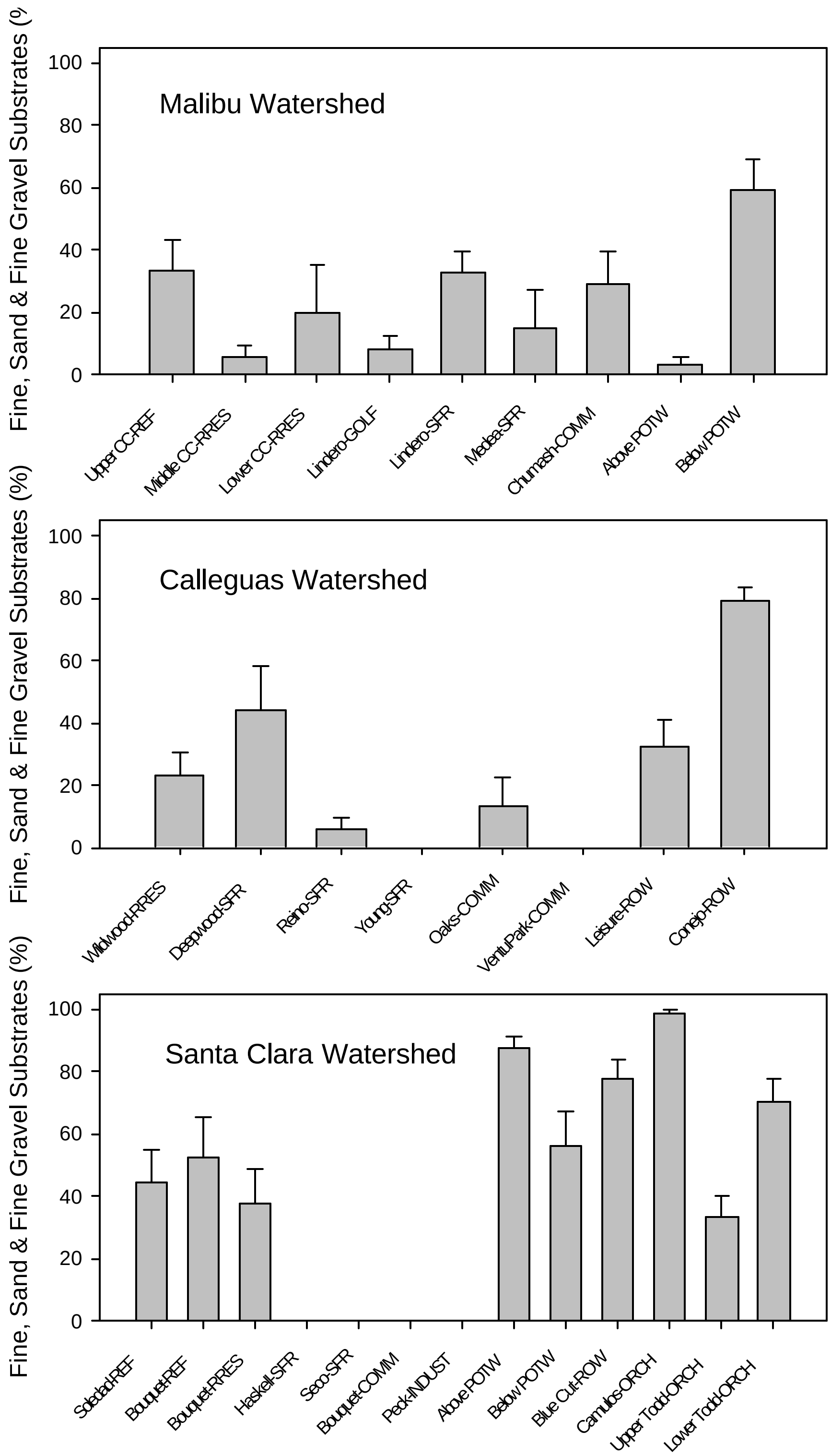


Figure 58. Fine, sand and fine gravel substrate at all sites. Fine, Sand & Fine Gravel Substrates (%)

Substrate types were recorded at twenty (ten, if wetted width < 1m) positions across the wetted width at each transect.

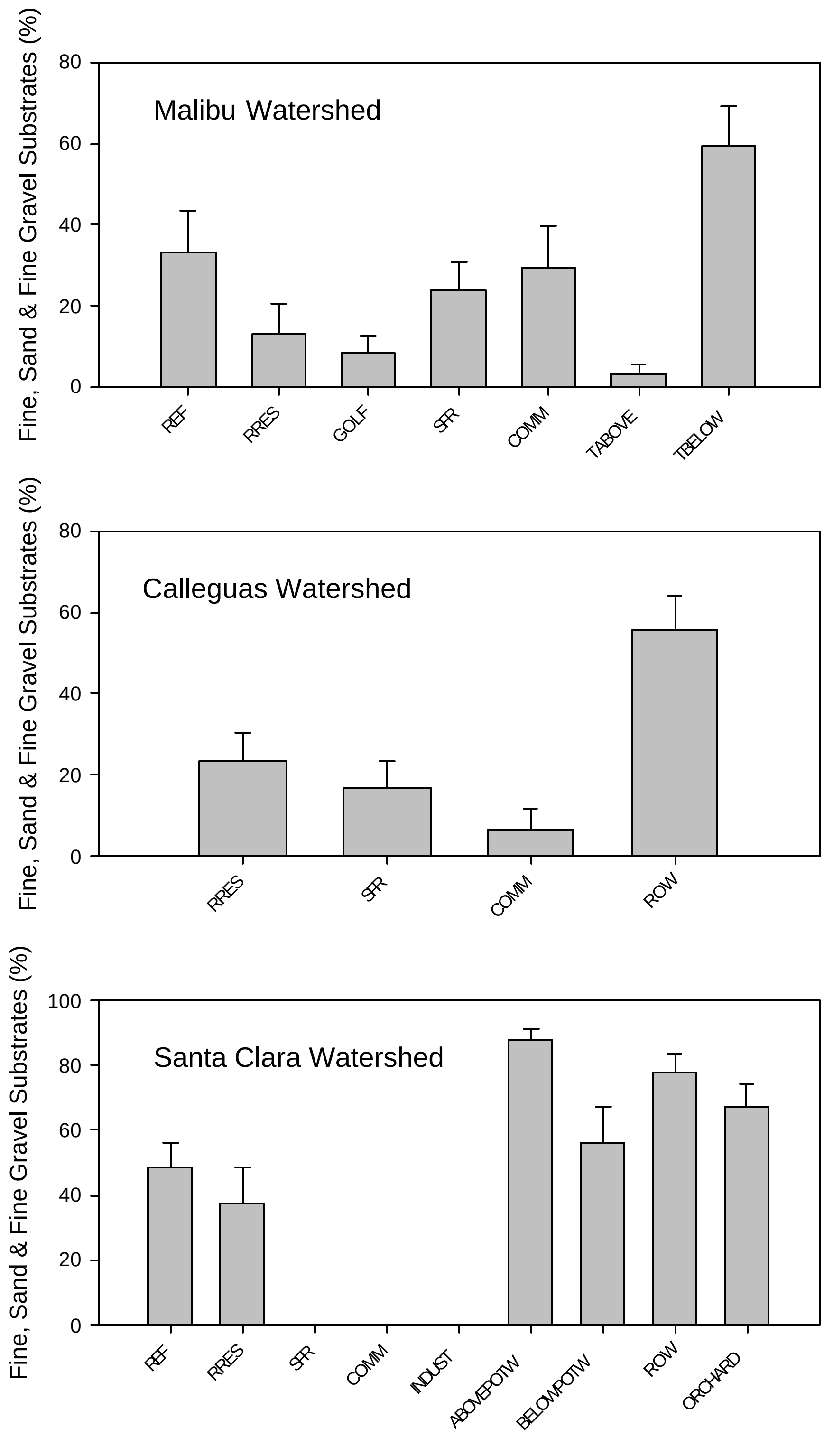


Figure 59. Fine, sand and fine gravel substrate by land use within each watershed. Sites of similar land use were combined within each of the three watersheds.

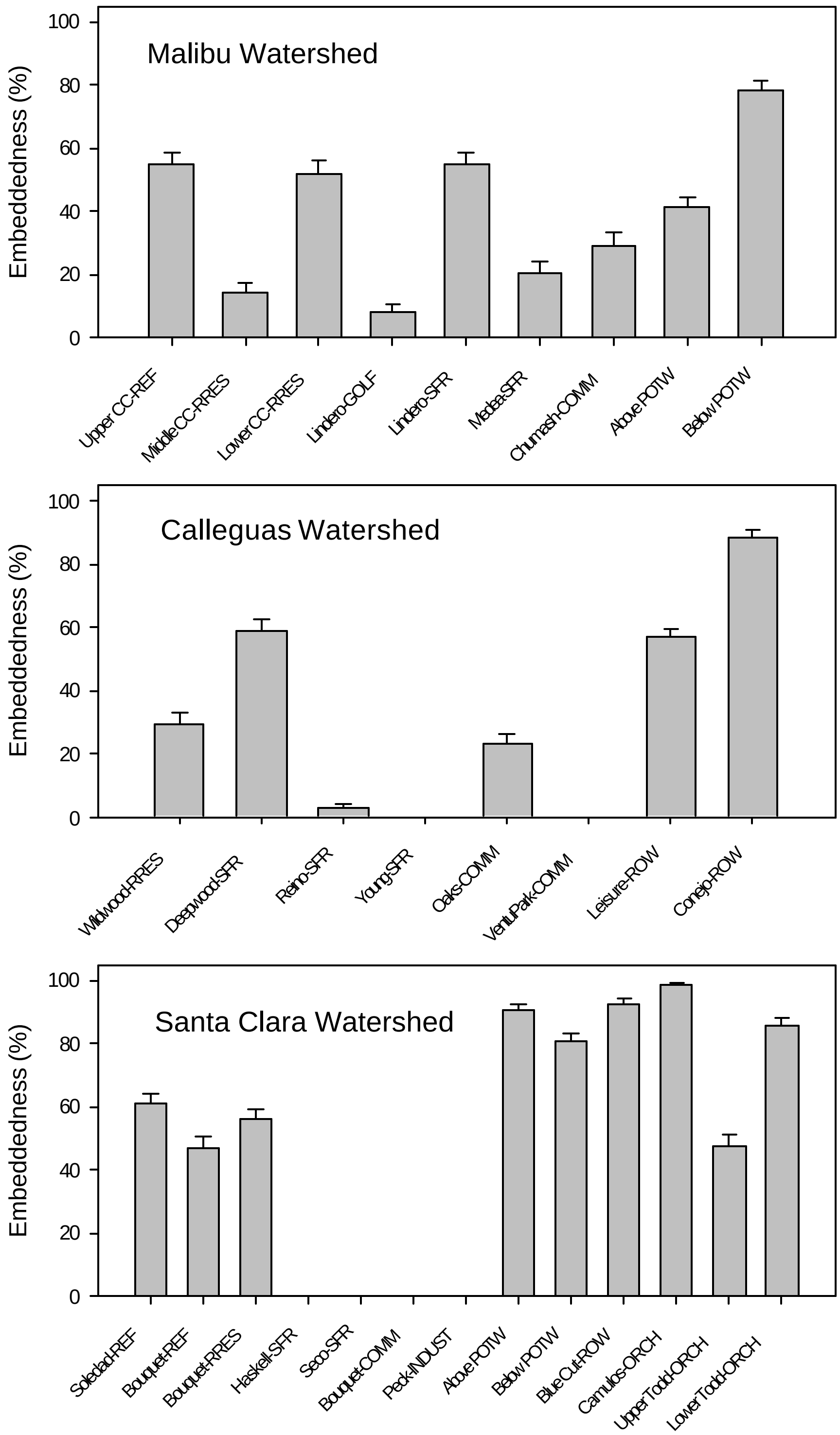


Figure 60. Embeddedness at all sites.

Substrate embeddedness was recorded at twenty (ten, if wetted width < 1m) positions across the wetted width at each transect.

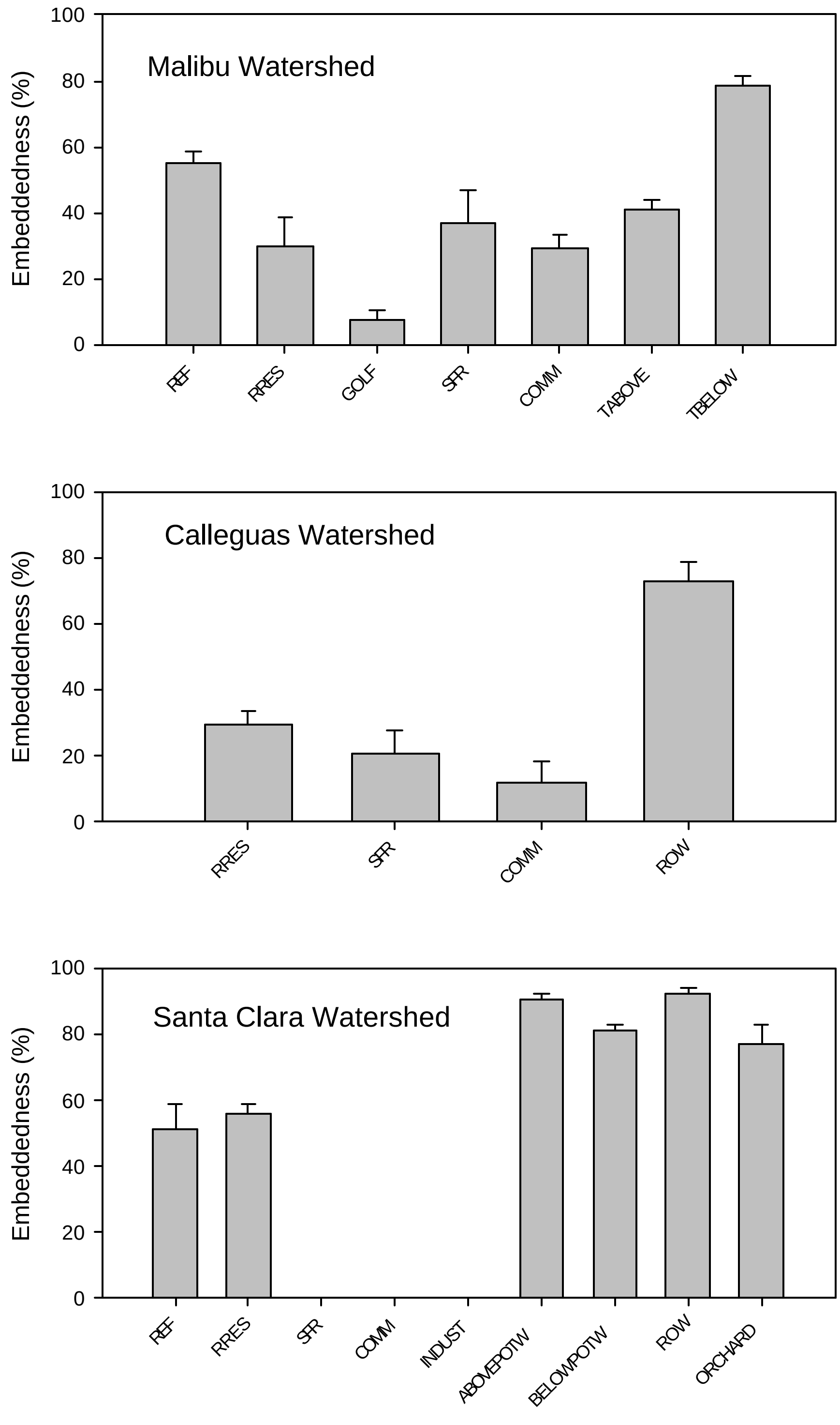


Figure 61. Embeddedness by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

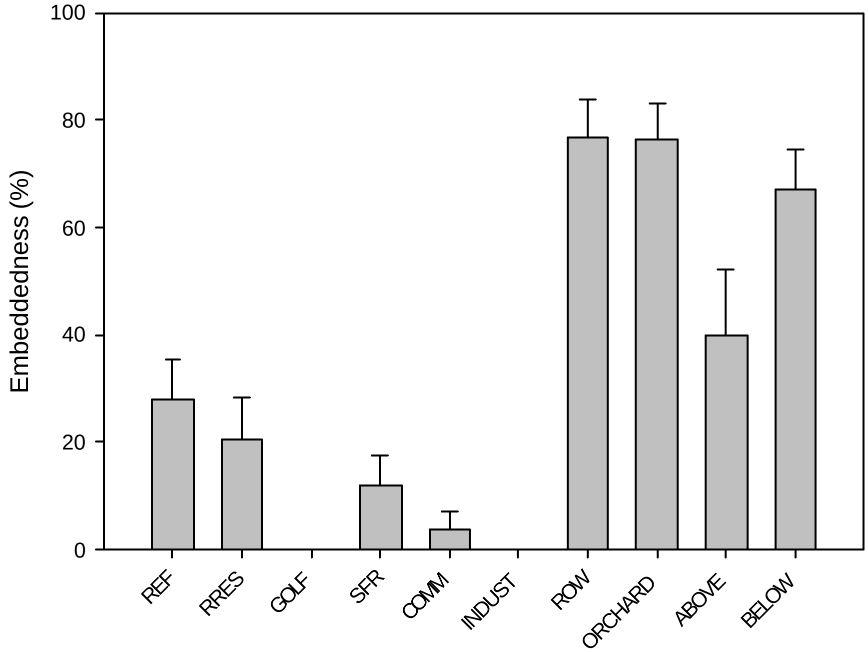


Figure 62. Embeddedness by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

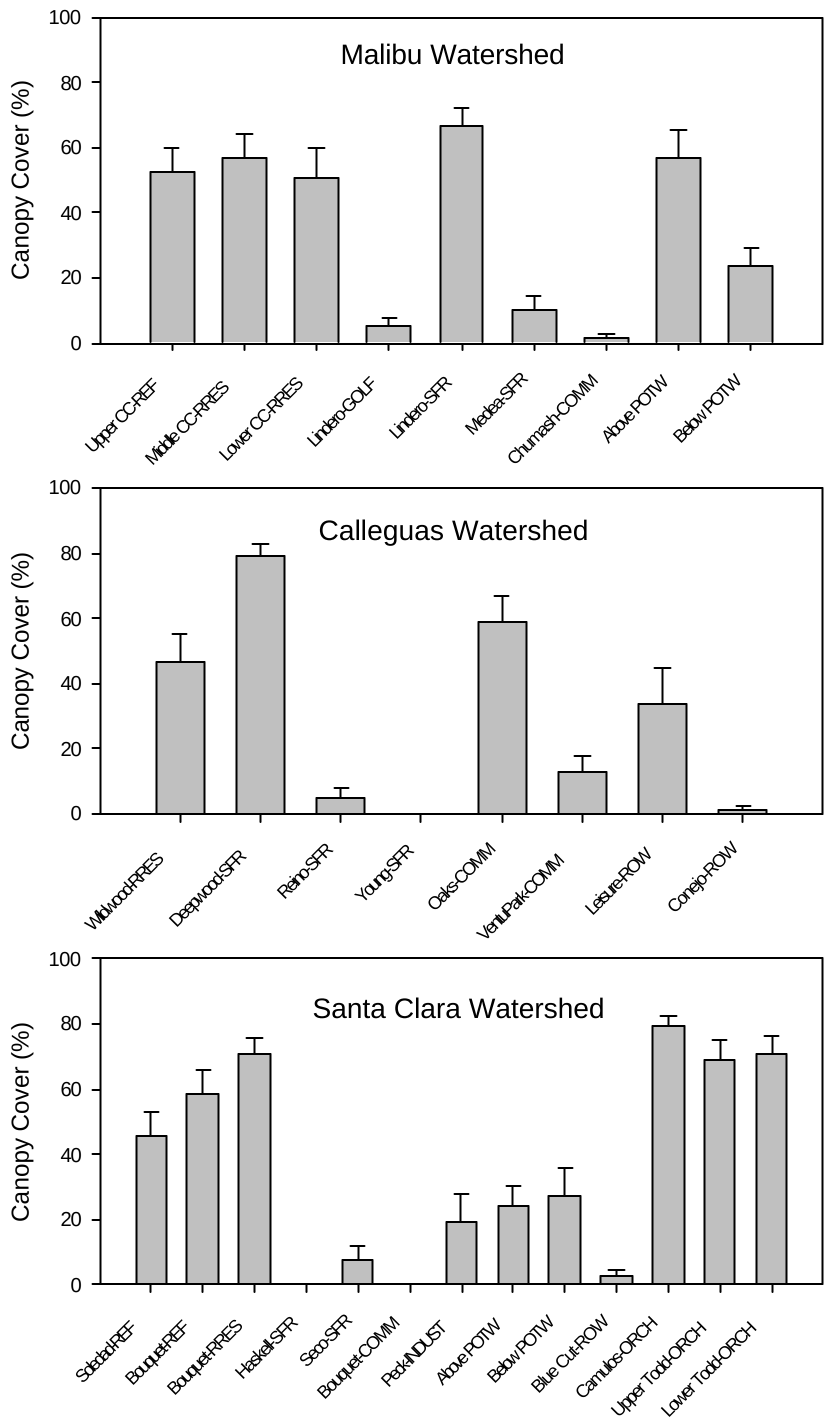


Figure 63. Total canopy cover at all sites.

Canopy estimates were made within a 10mX10m plot along each bank at each transect using EMAP methods. One departure from EMAP was that the plot started at the wetted width margin rather than from bankfull. All vegetation above 5m was included in this canopy estimate.

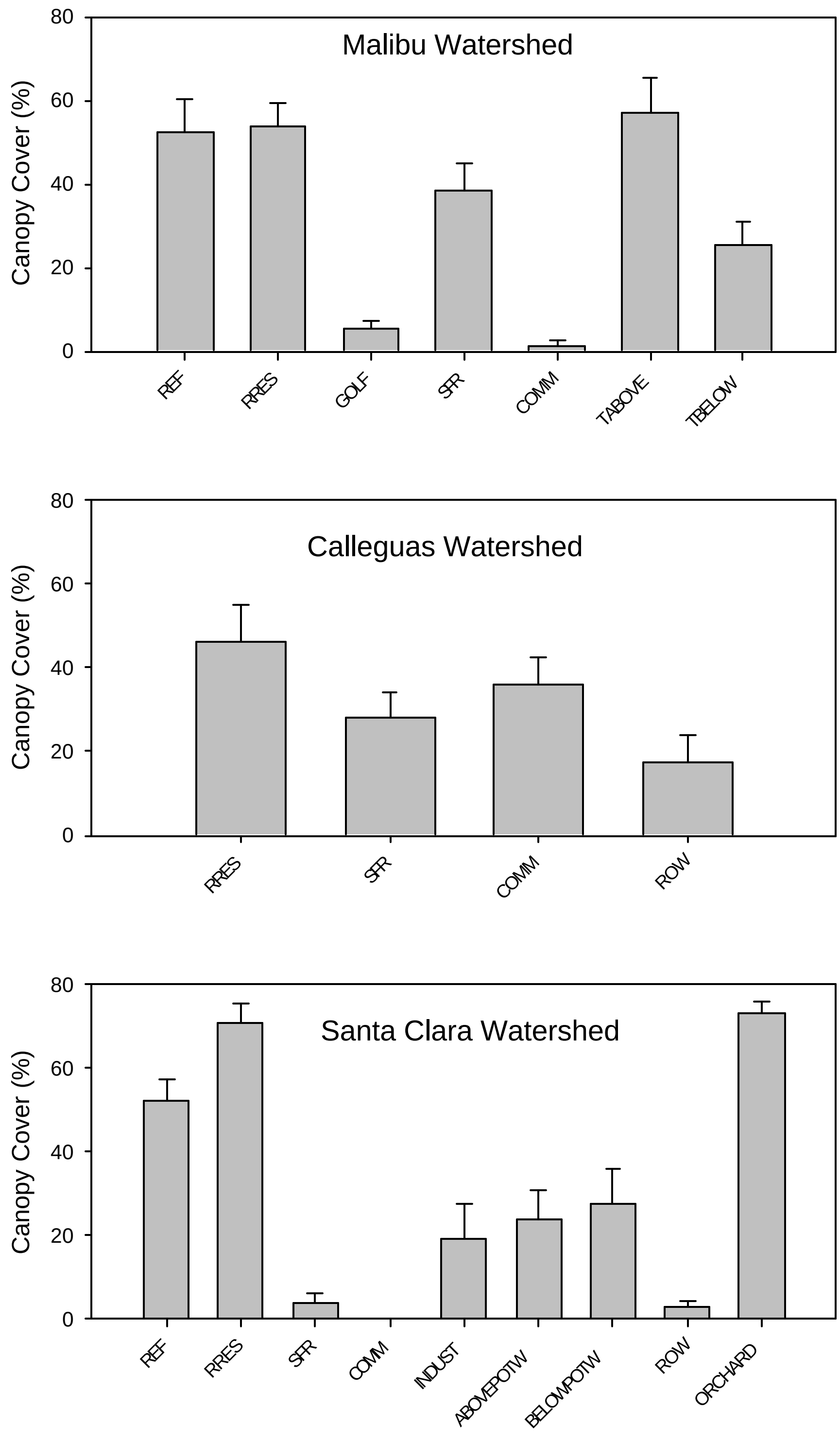


Figure 64. Total canopy cover by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

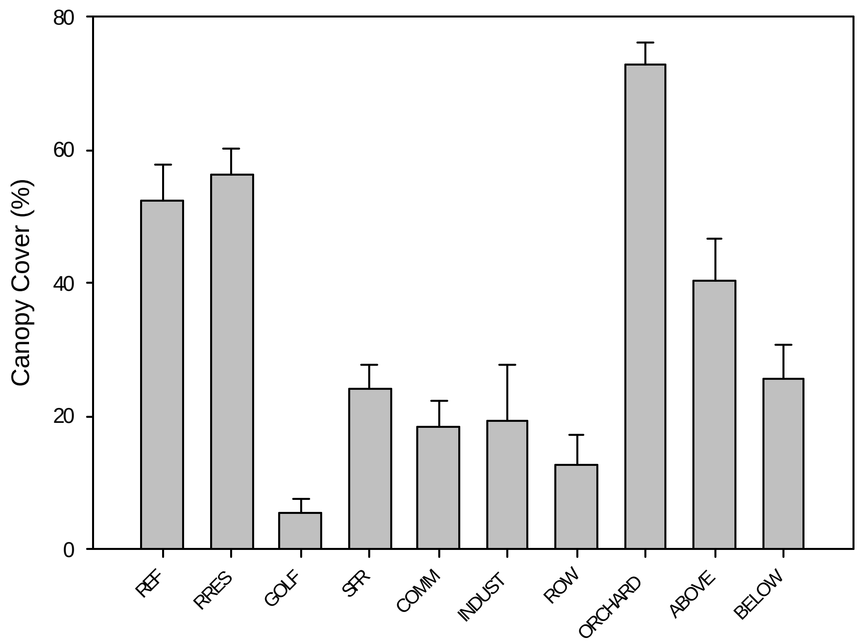


Figure 65. Total canopy cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

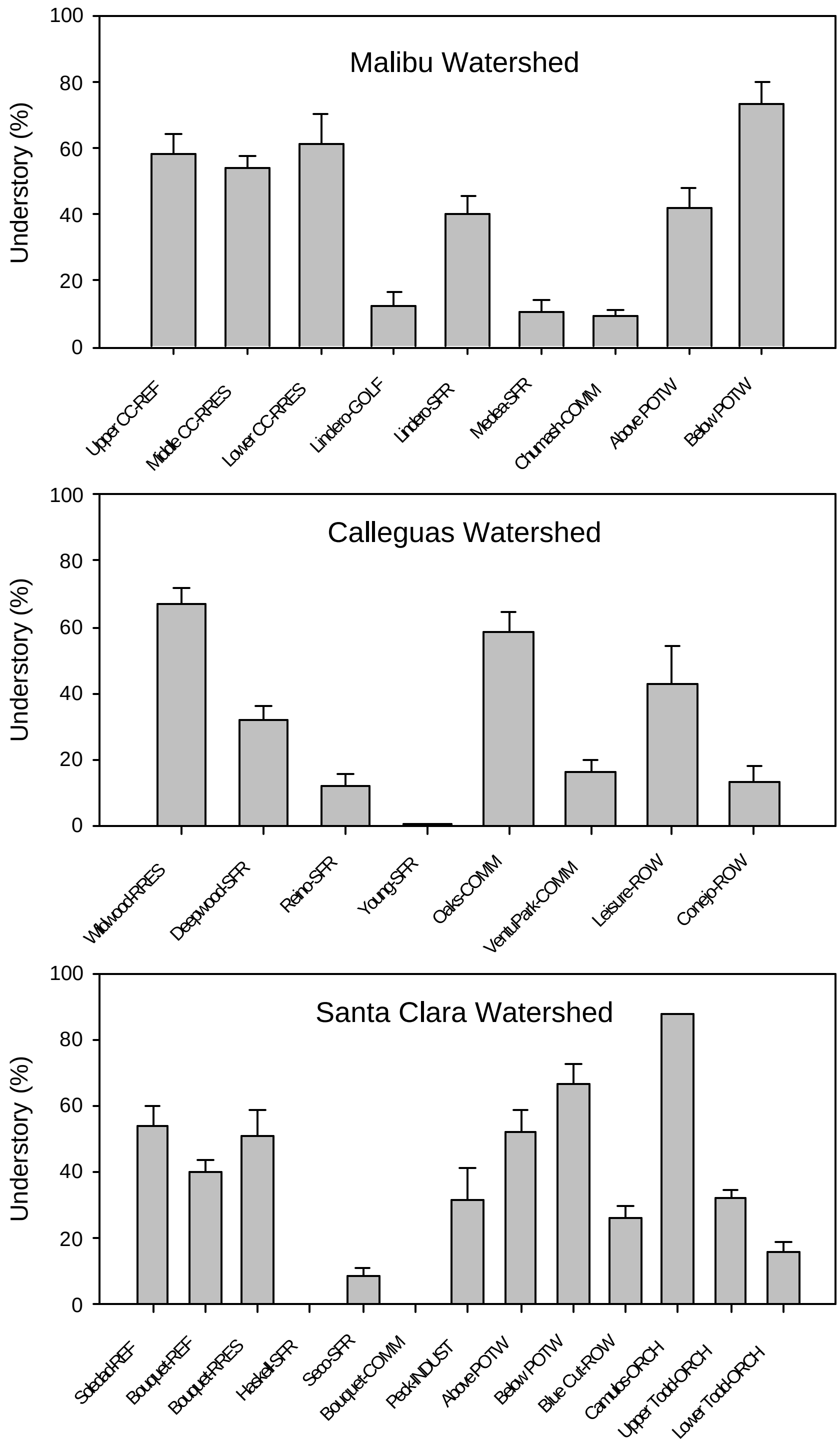


Figure 66. Total cover of understory vegetation at all sites.

Understory estimates were made within a 10mX10m plot along each bank at each transect using EMAP methods. One departure from EMAP was that the plot started at the wetted width margin rather than from bankfull. All vegetation between 0.5m and 5m was included in this understory estimate.

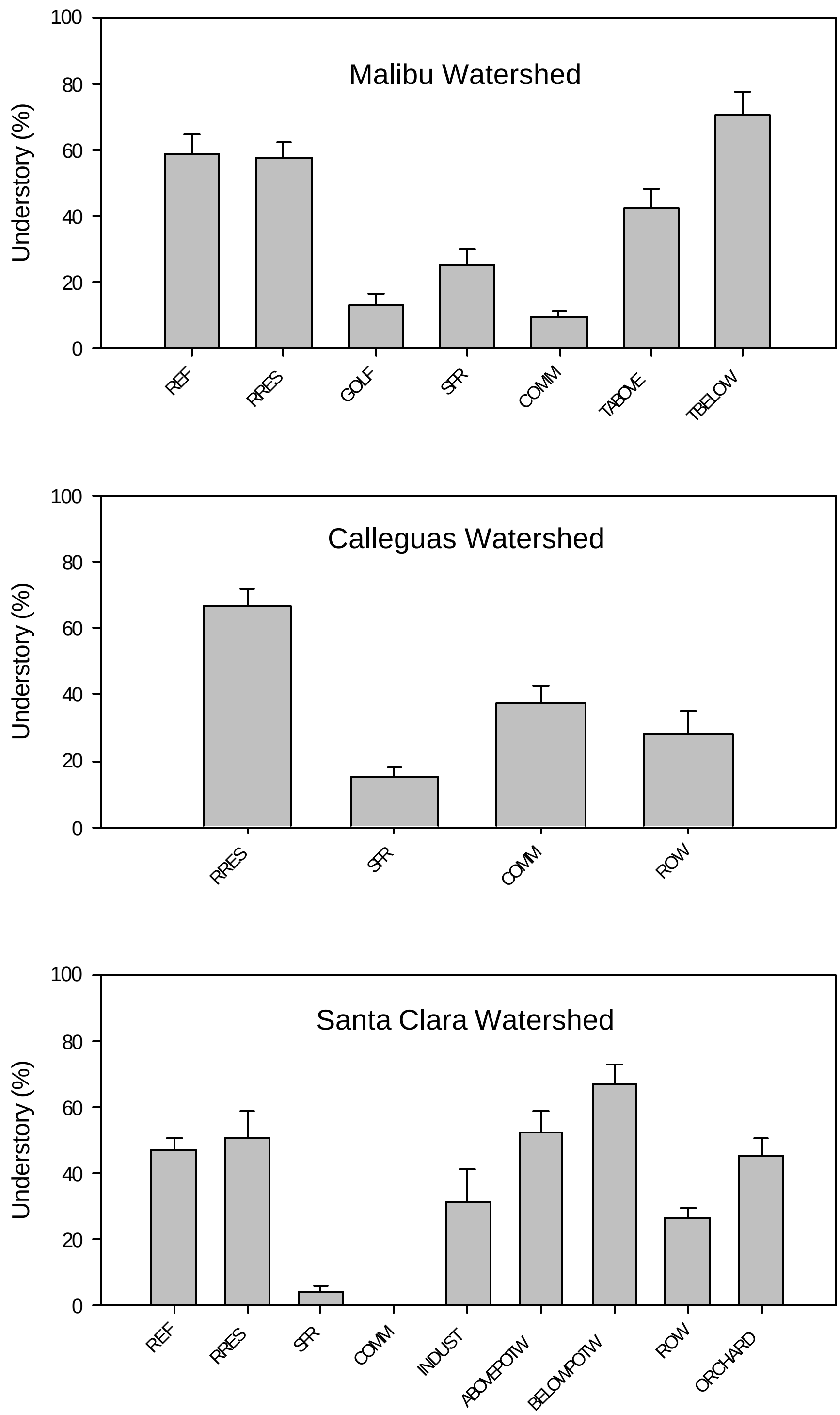


Figure 67. Total cover of understory vegetation by land use within each watershed. Sites of similar land use were combined within each of the three watersheds.

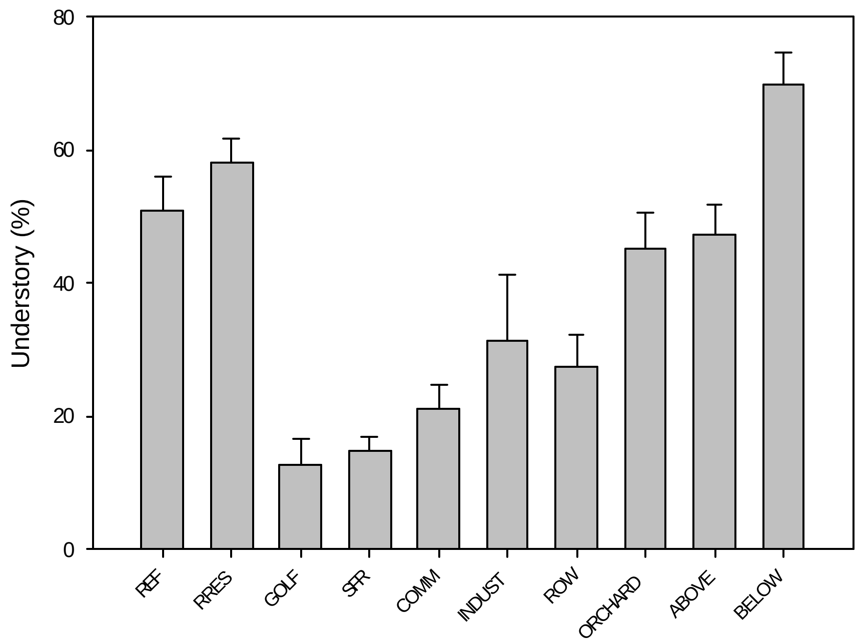


Figure 68. Total cover of understory vegetation by land use among watersheds. Sites of similar land use were combined or averaged across all three watersheds.

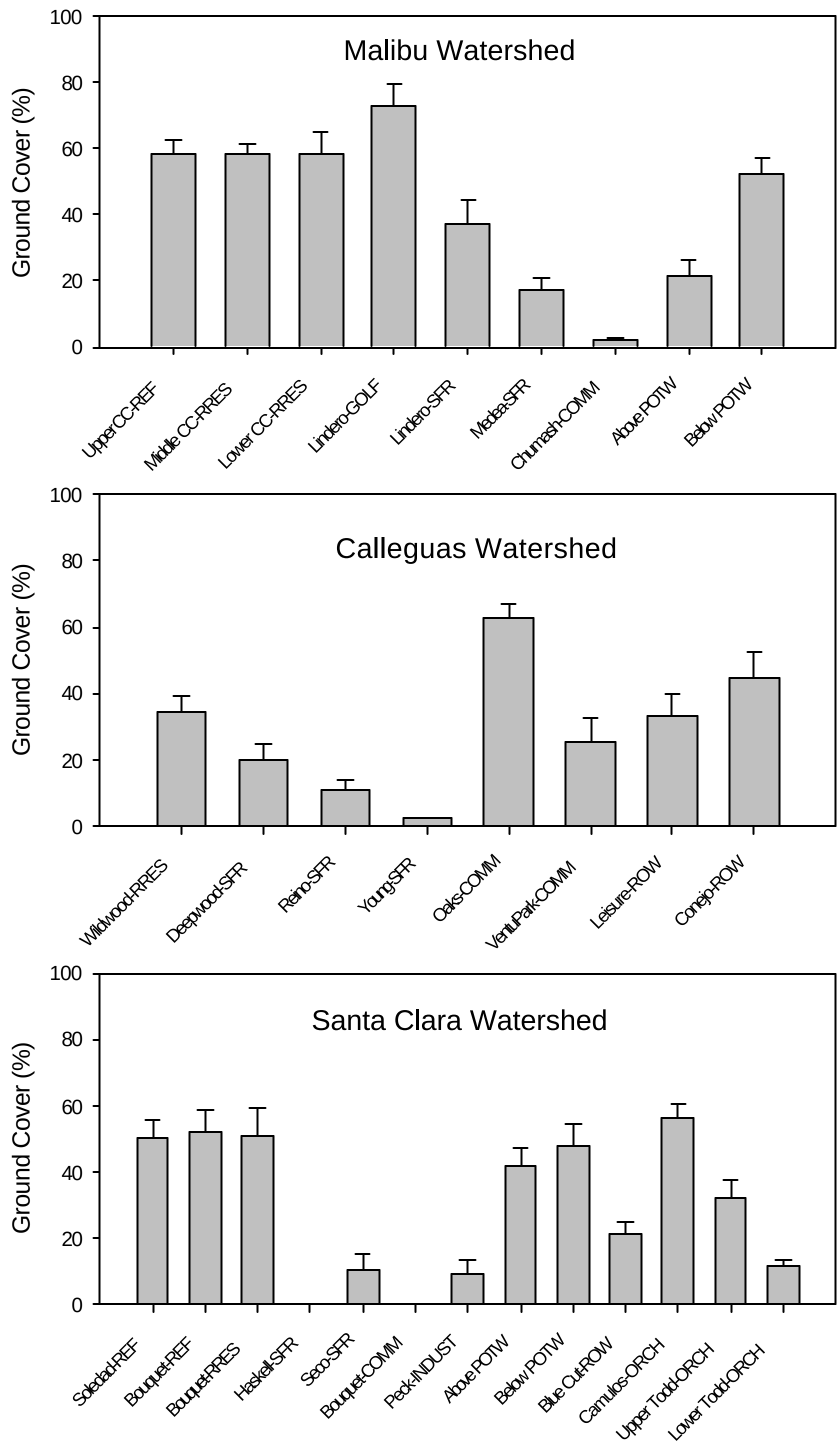


Figure 69. Total ground cover vegetation at all sites.

Ground cover estimates were made within a 10mX10m plot along each bank at each transect using EMAP methods. One departure from EMAP was that the plot started at the wetted width margin rather than from bankfull. All vegetation below 0.5m was included in this ground cover estimate.

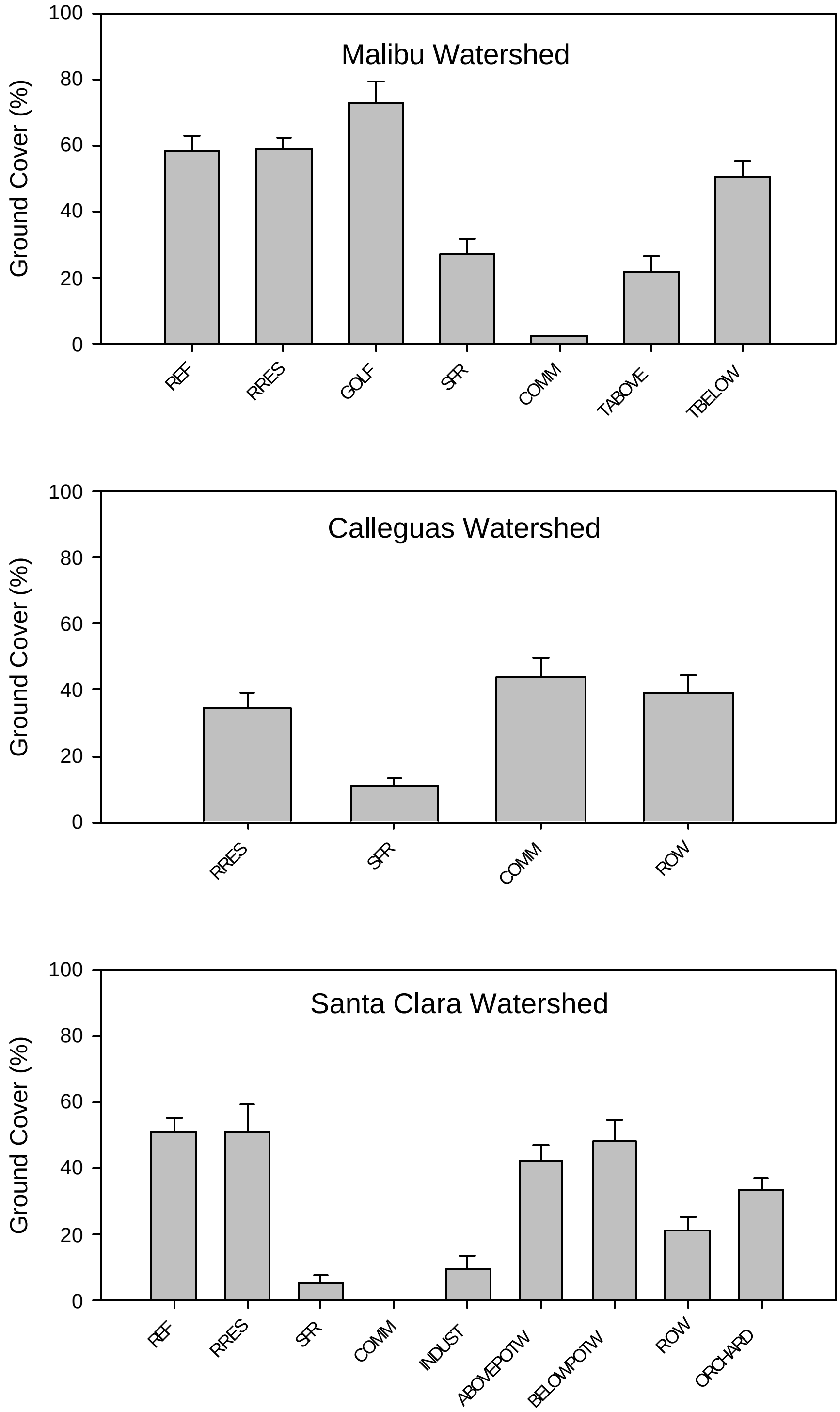


Figure 70. Total ground cover vegetation by land use within each watershed. Sites of similar land use were combined within each of the three watersheds.

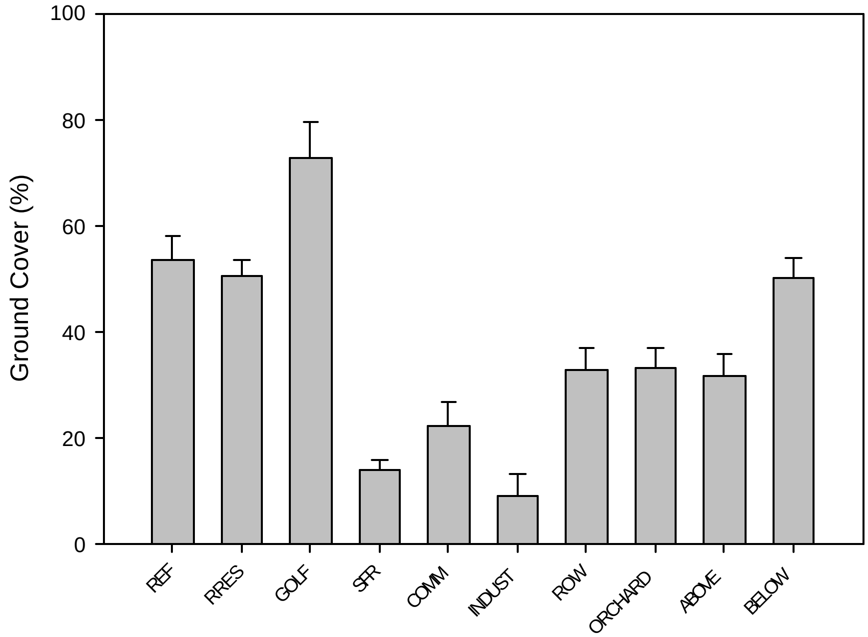


Figure 71. Total ground cover vegetation by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

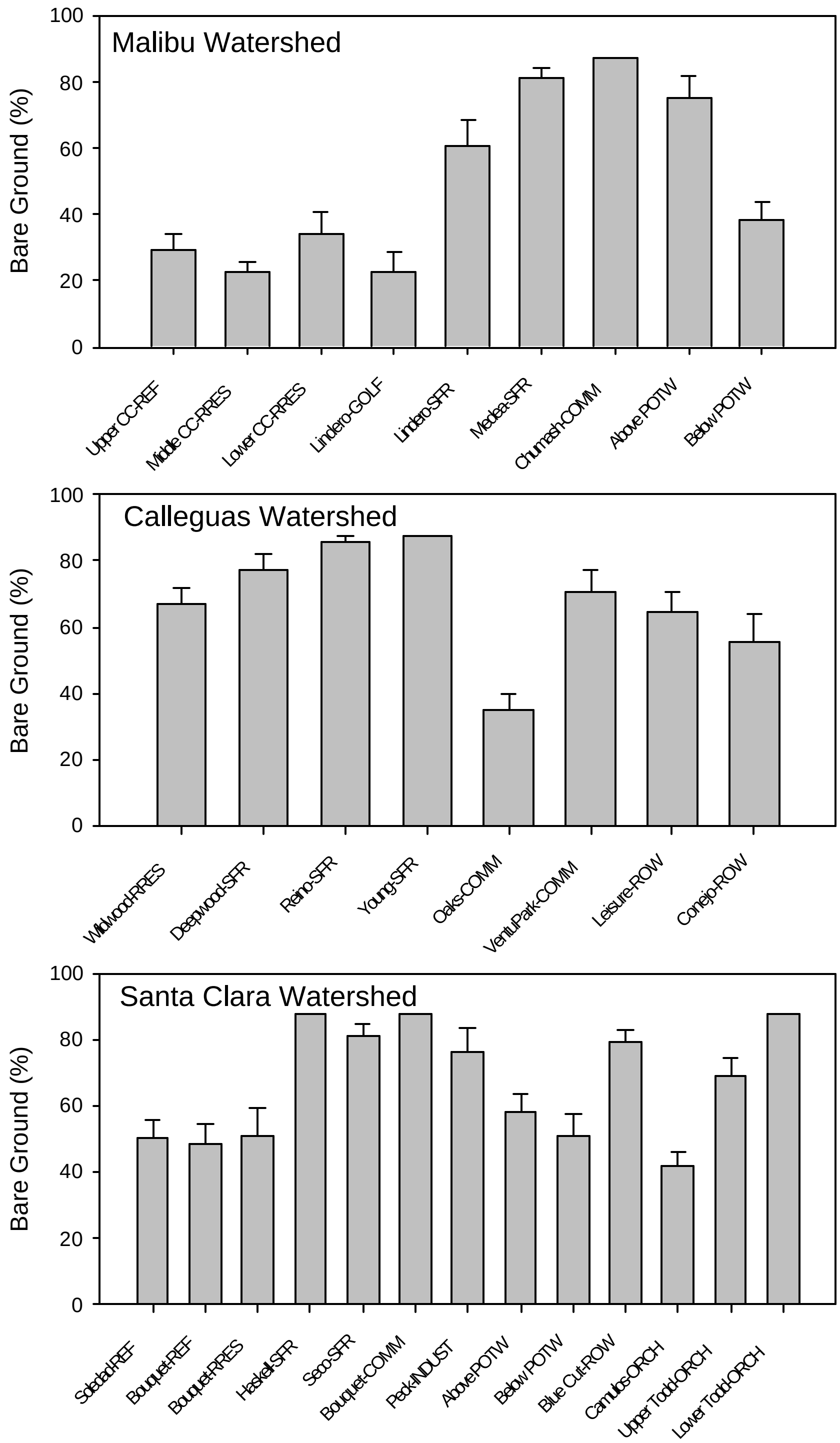


Figure 72. Total bare ground at all sites.

Bare ground estimates were made within a 10mX10m plot along each bank at each transect using EMAP methods. One departure from EMAP was that the plot started at the wetted width margin rather than from bankfull. All area lacking vegetation was included in this bare ground estimate.

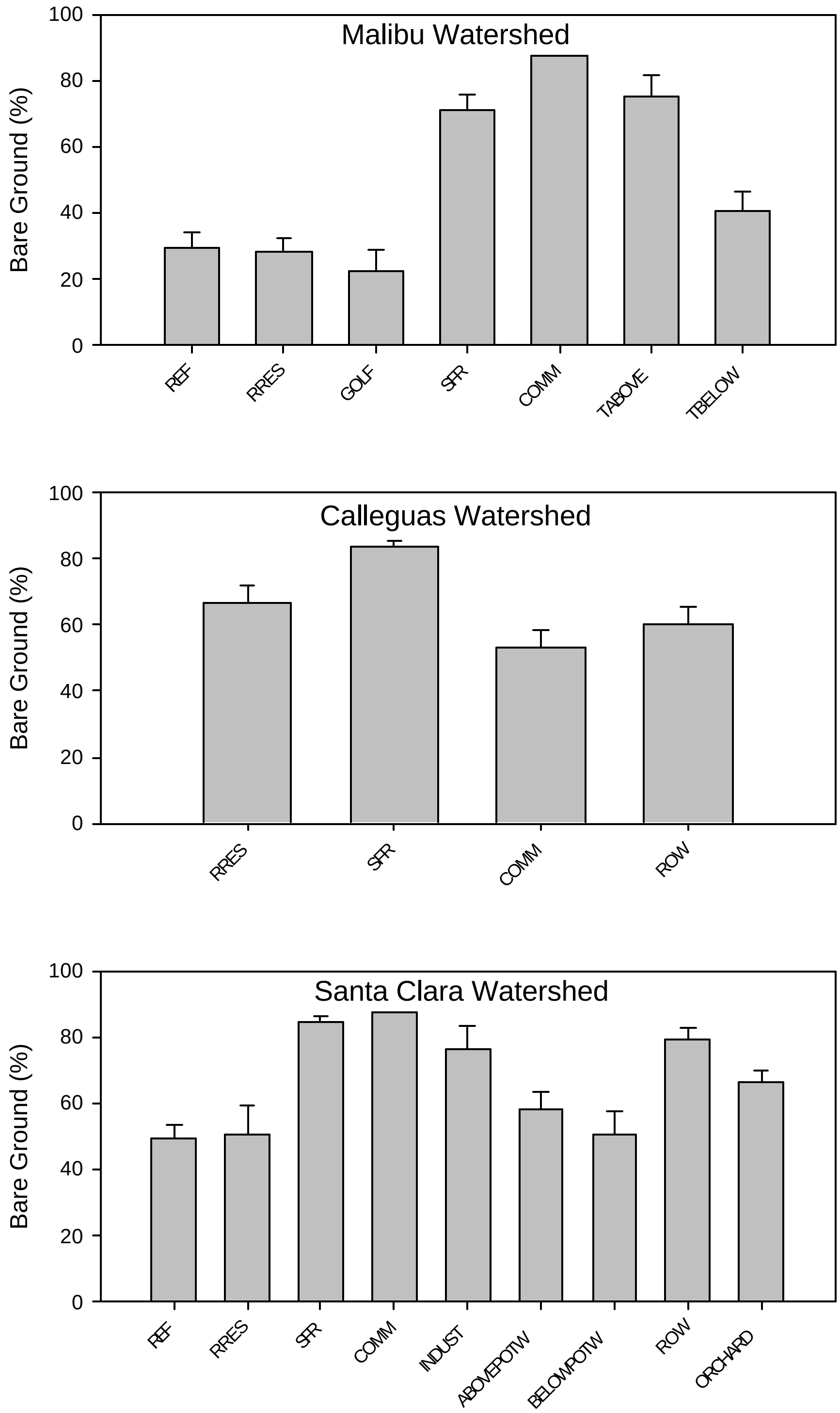


Figure 73. Total bare ground by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

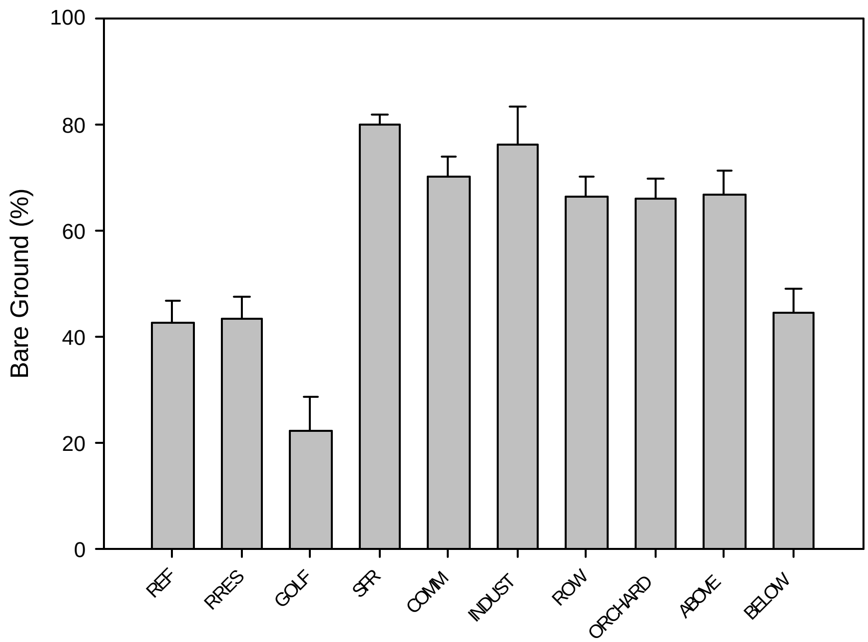


Figure 74. Total bare ground by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

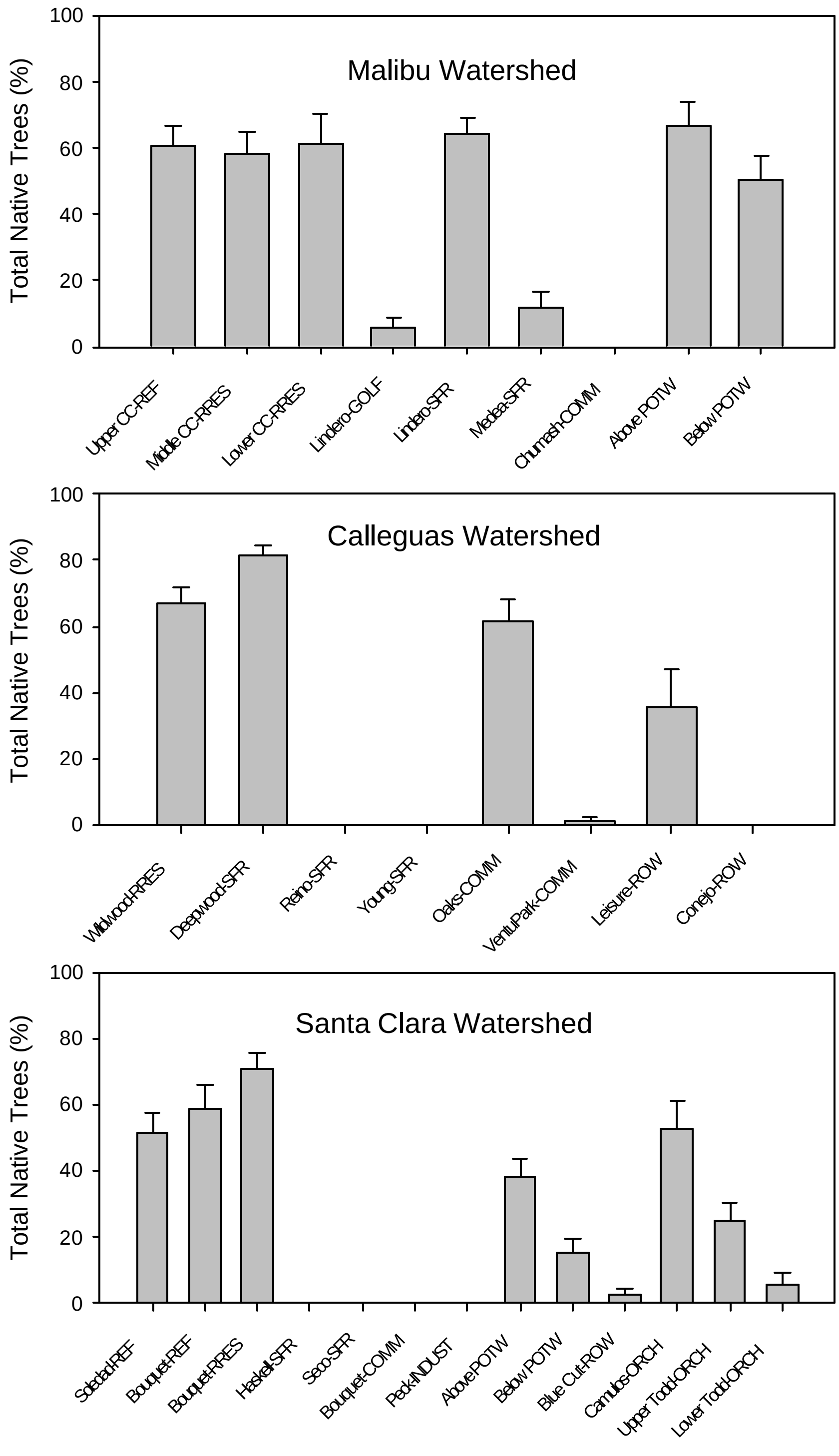


Figure 75. Total native tree cover at all sites.

Native tree estimates were made within a 10mX10m plot along each bank at each transect using EMAP methods. One departure from EMAP was that the plot started at the wetted width margin rather than from bankfull. All native trees except saplings were included in this native trees estimate.

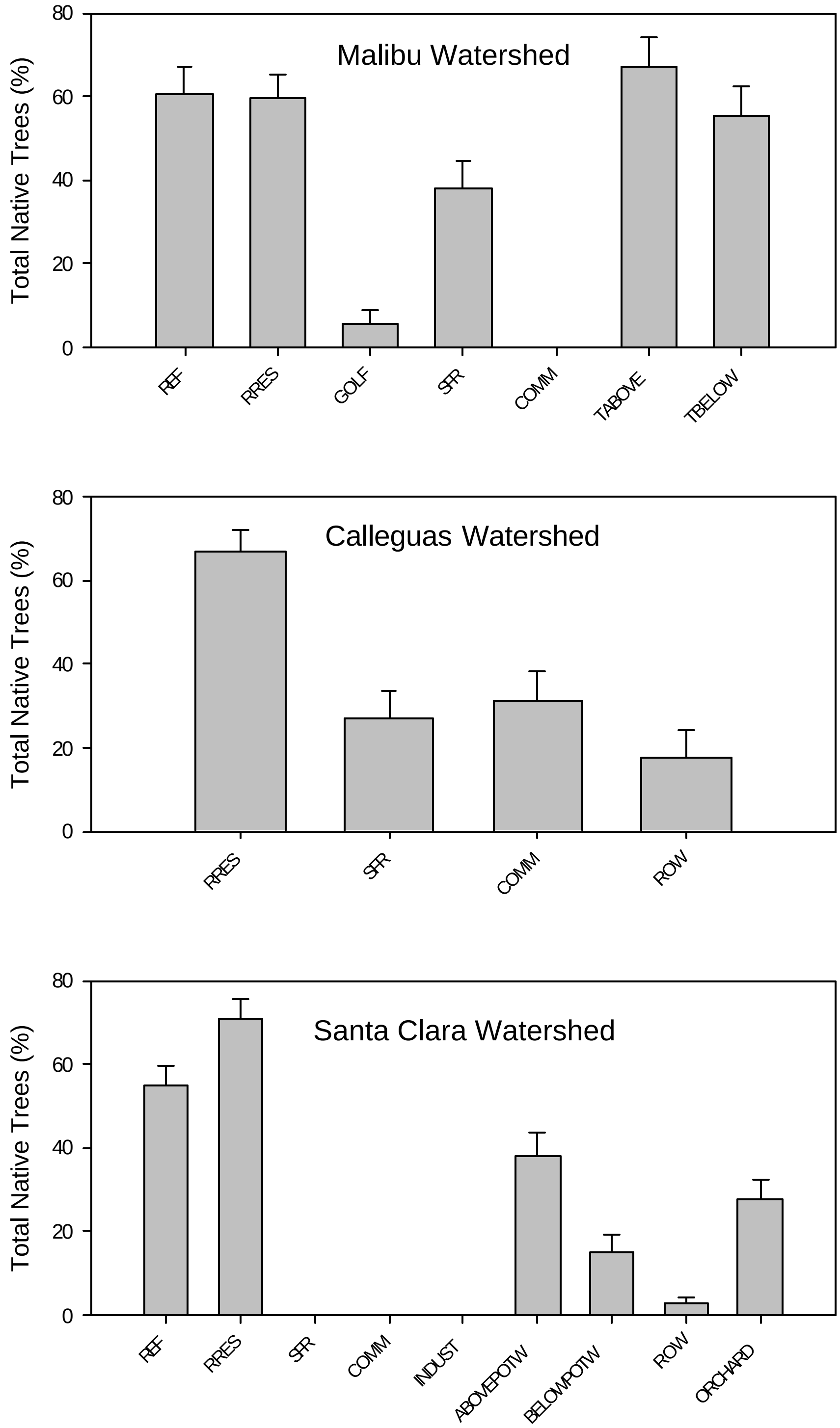


Figure 76. Total native tree cover by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

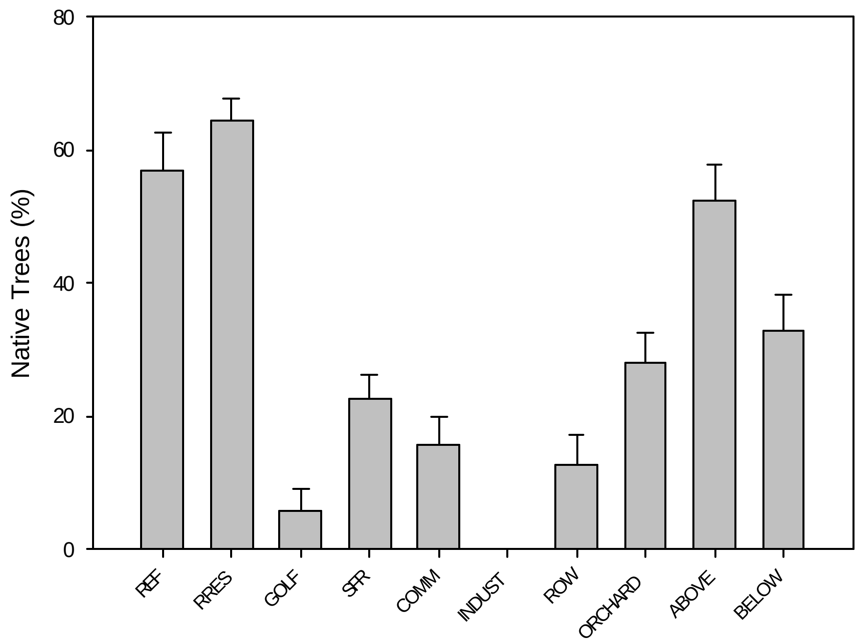


Figure 77. Total native tree cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

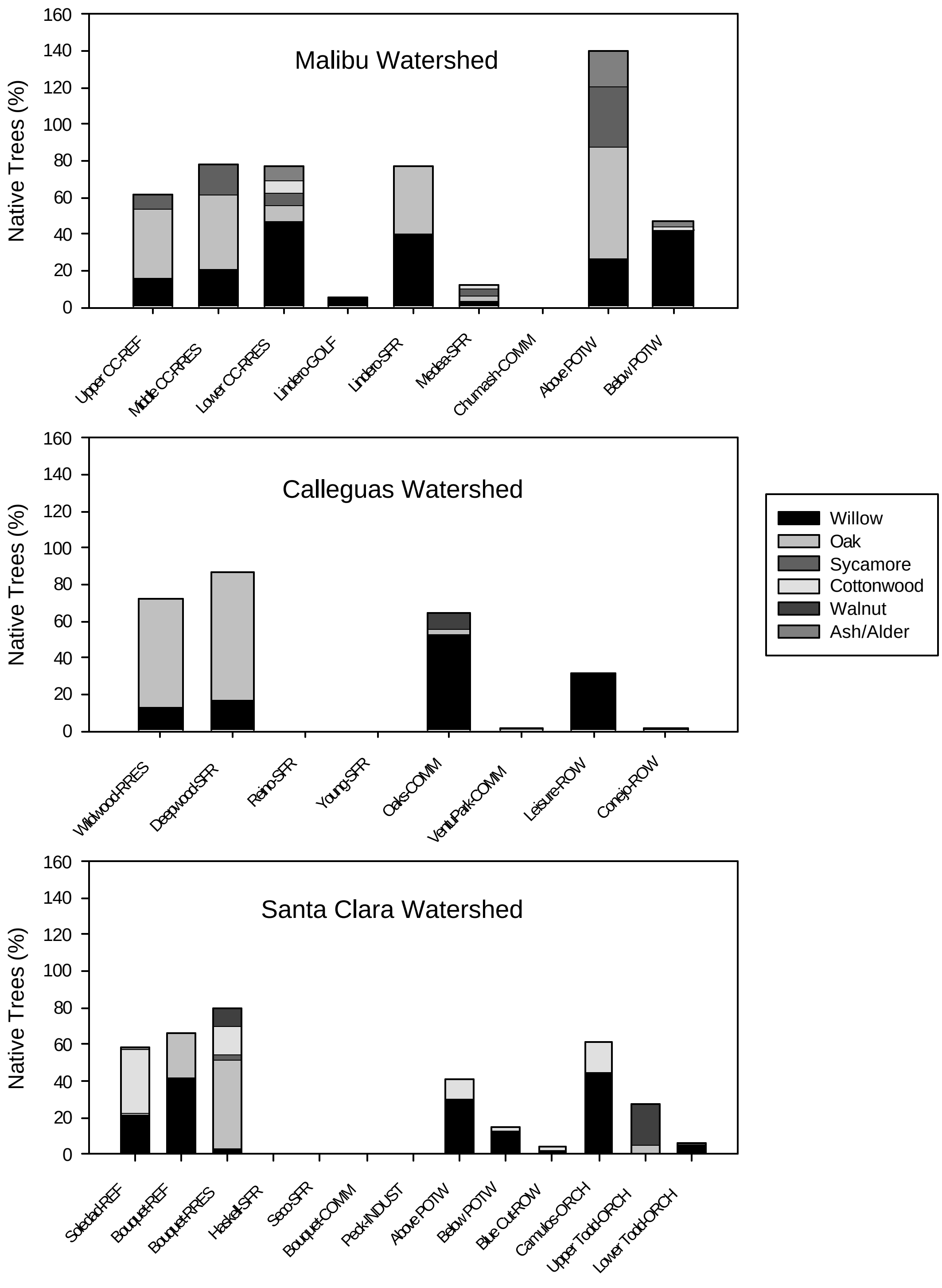


Figure 78. Native tree cover by taxa at all sites.

Native tree taxa estimates were made within a 10mX10m plot from the wetted width along each bank at each transect. All native trees except saplings were included in this native tree taxa estimate. Layering of different tree taxa caused greater than 100 percent cover in some graphs.

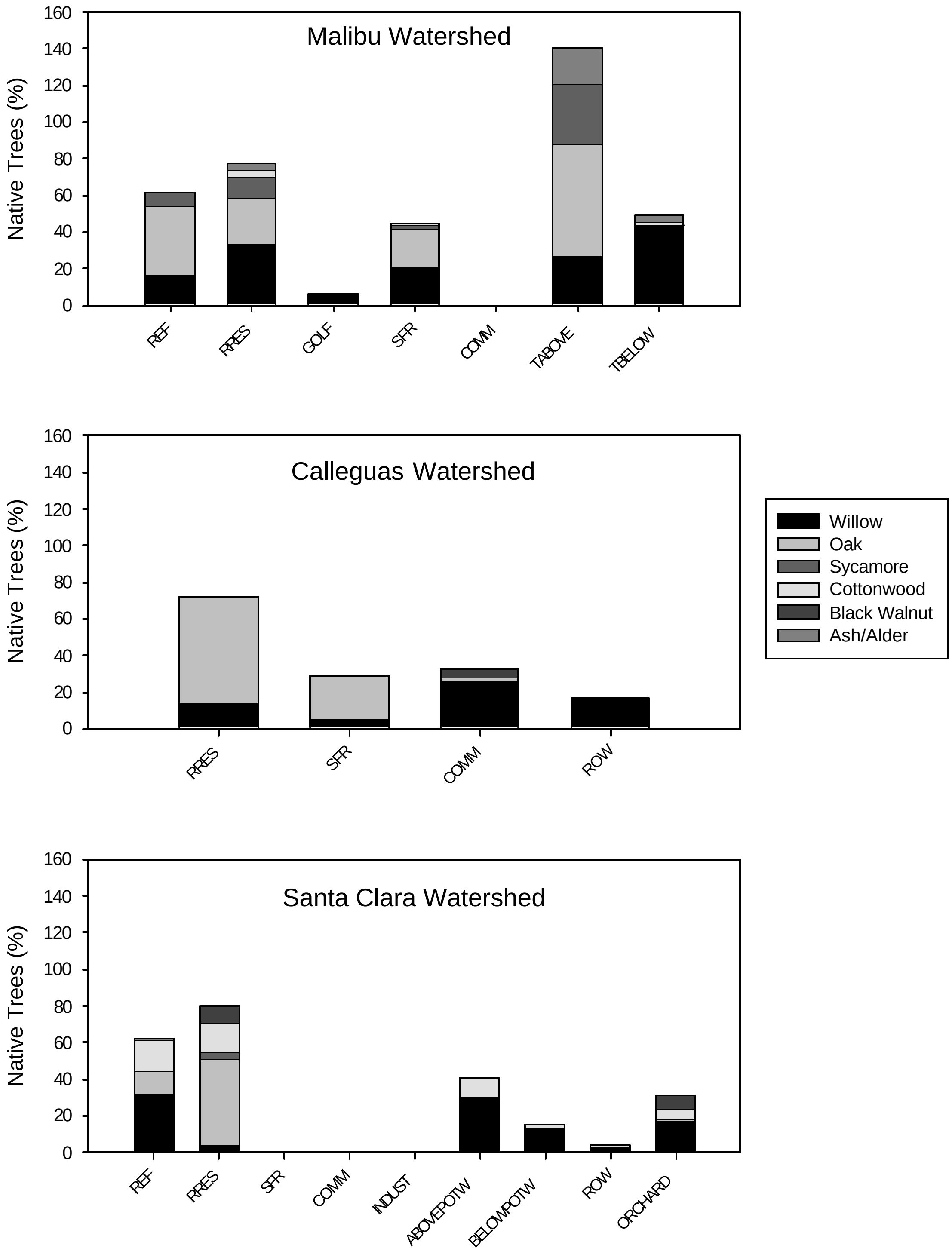


Figure 79. Native tree taxa cover by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

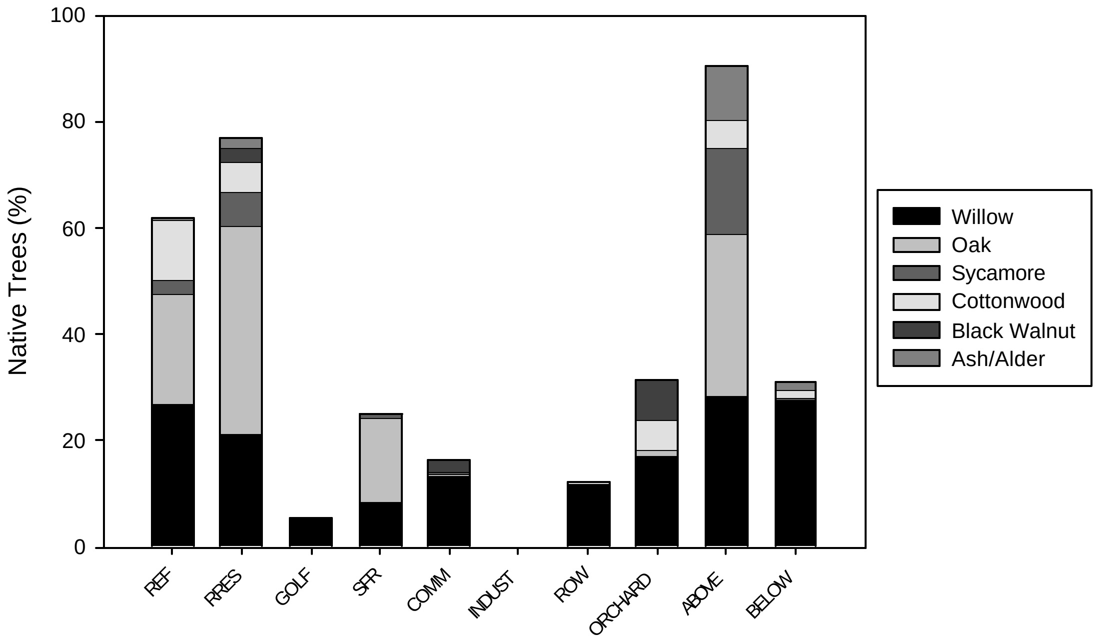


Figure 80. Native tree taxa cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

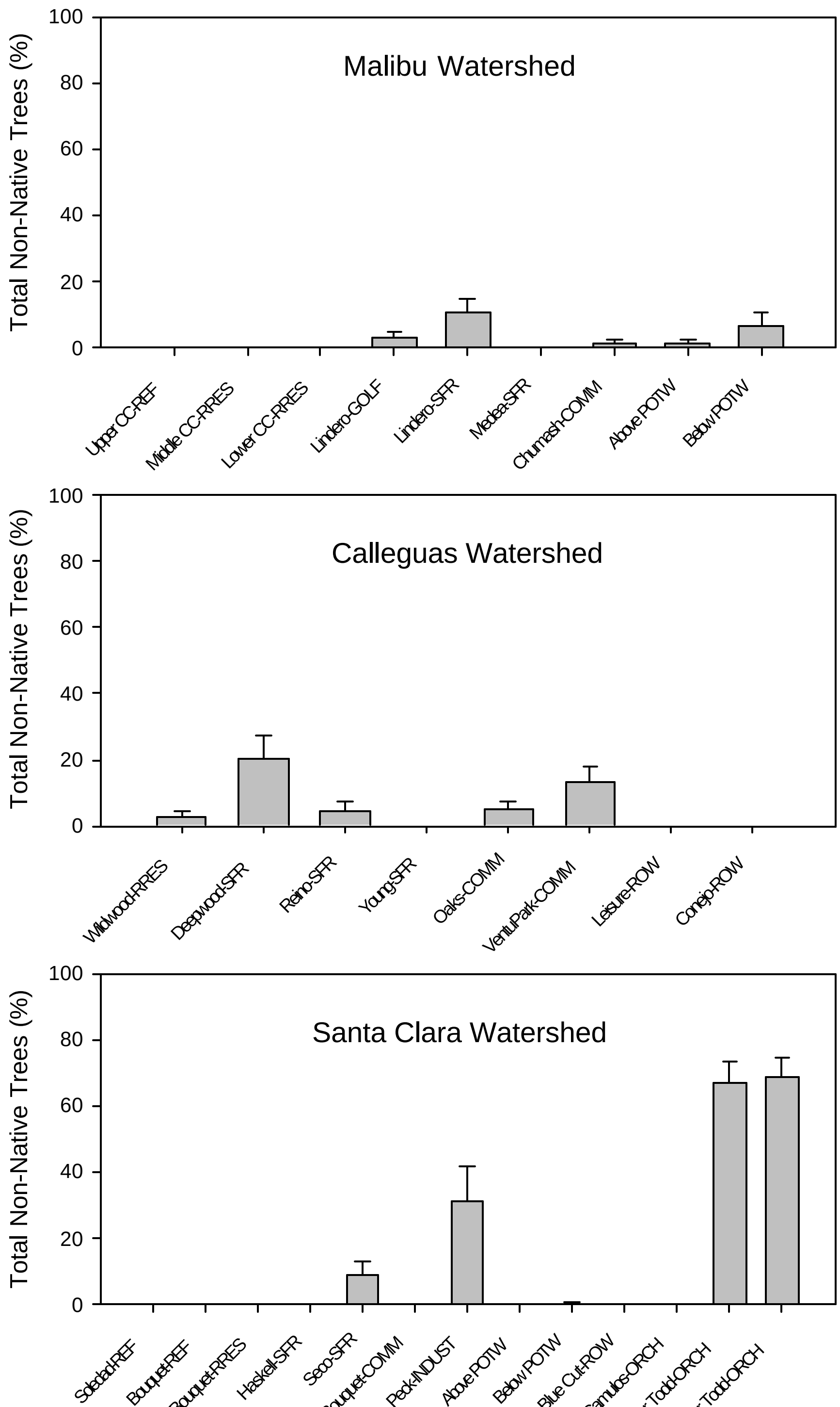


Figure 81. Total non-native tree cover at all sites.

Non-native tree estimates were made within a 10mX10m plot from the wetted width along each bank at each transect. All non-native trees except saplings were included in this non-native trees estimate.

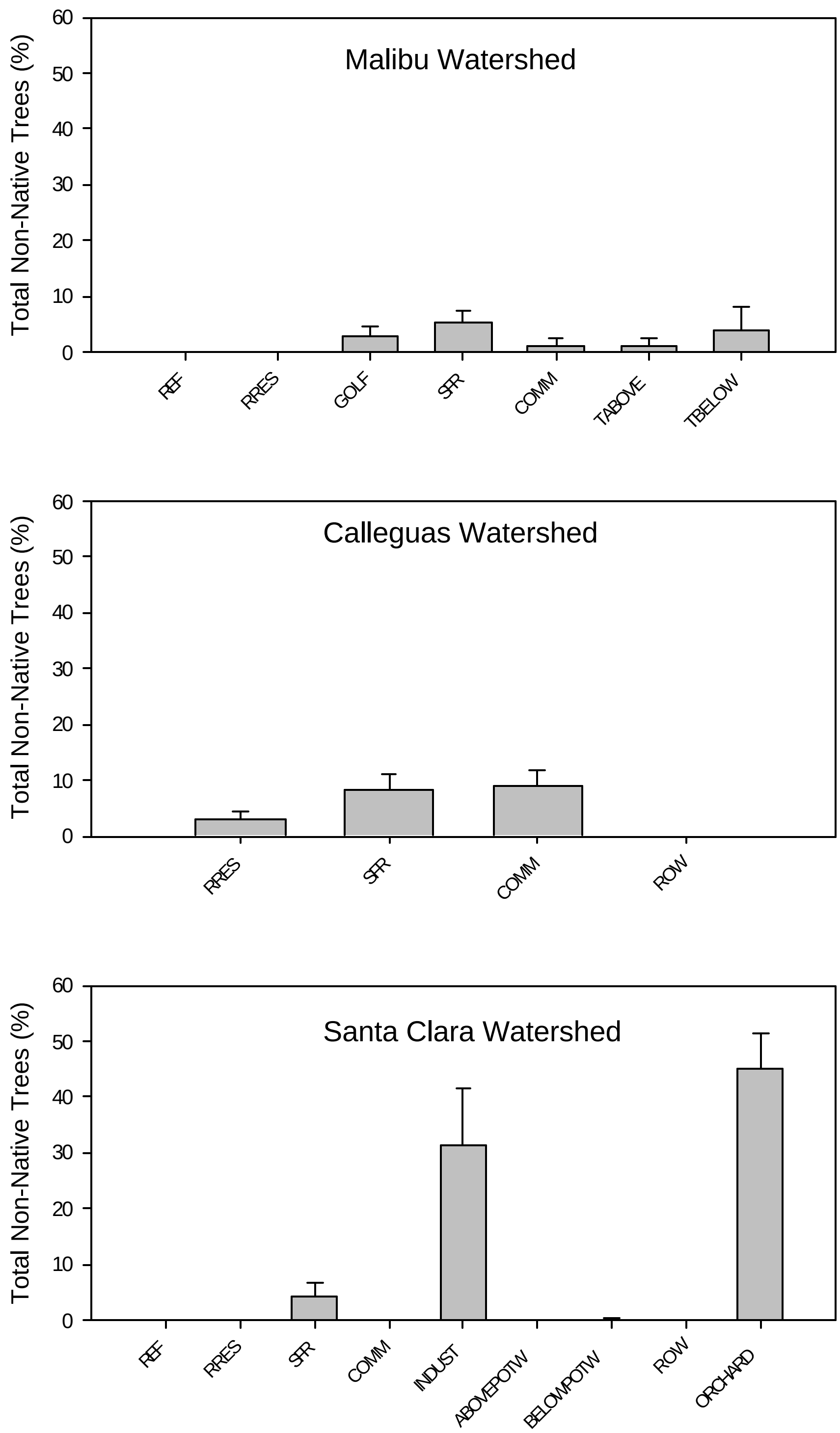


Figure 82. Total non-native tree cover by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

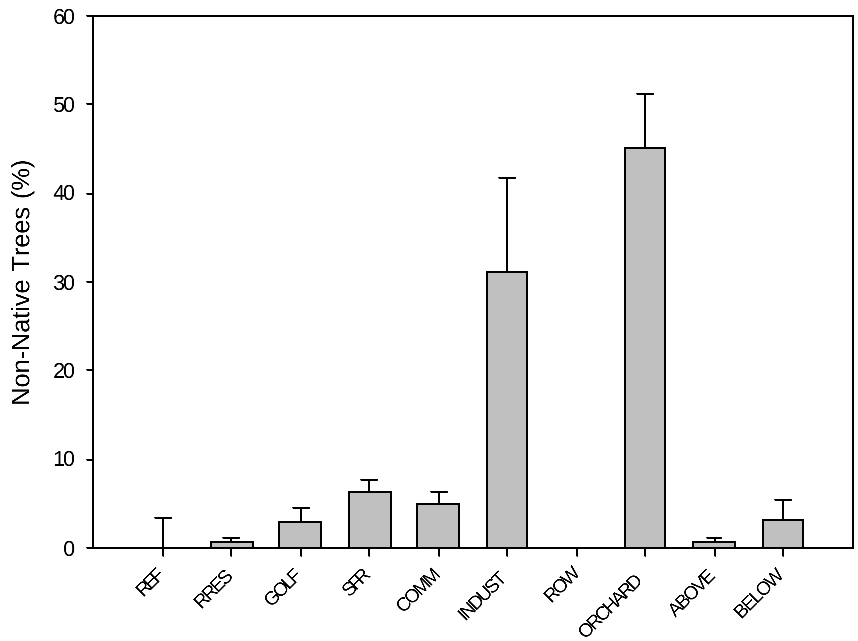


Figure 83. Total non-native tree cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

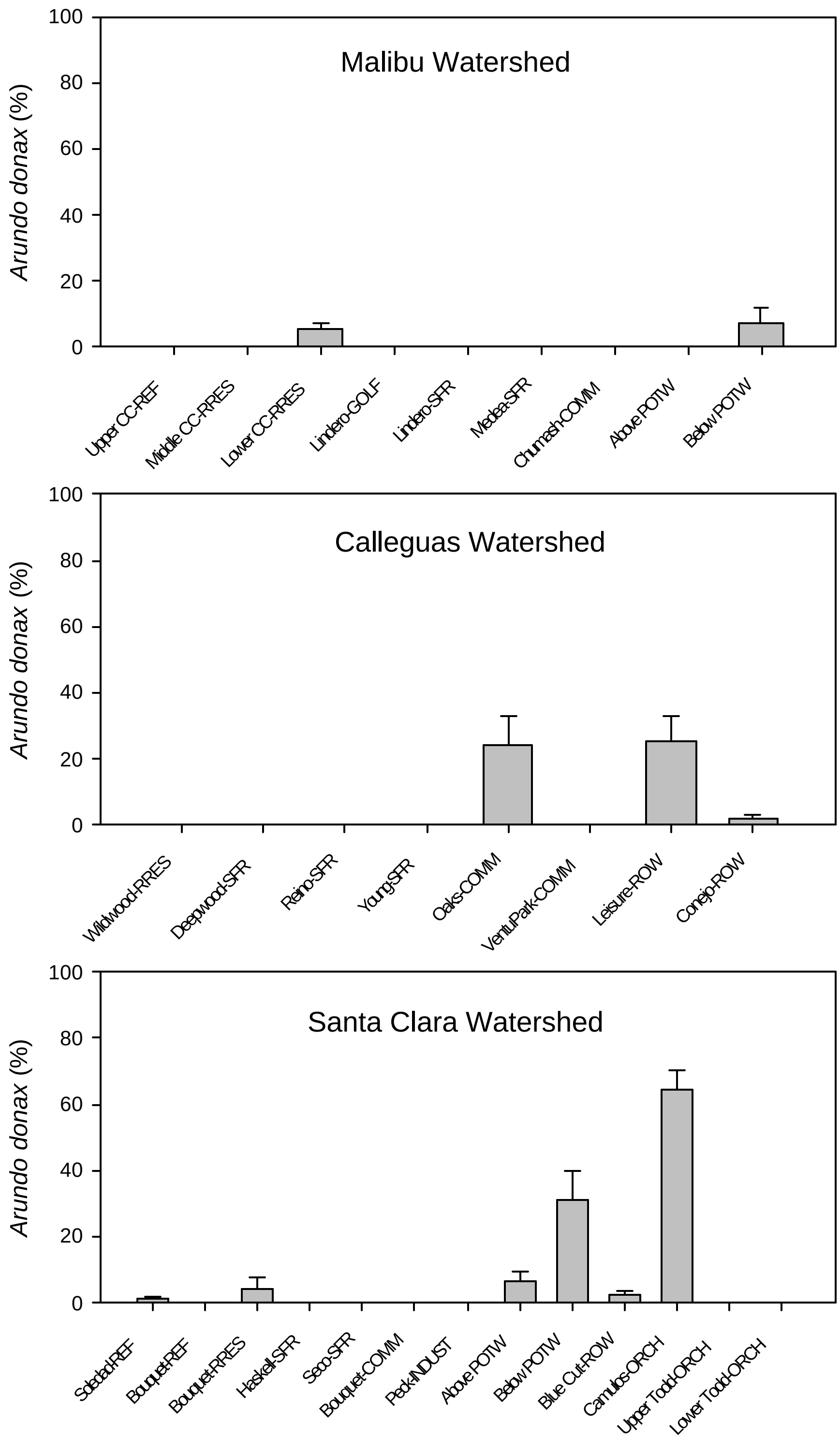


Figure 84. Total *Arundo donax* cover at all sites.

Arundo donax estimates were made within a 10mX10m plot from the wetted width along each bank at each transect. All *Arundo donax* was included in this *Arundo donax* estimate.

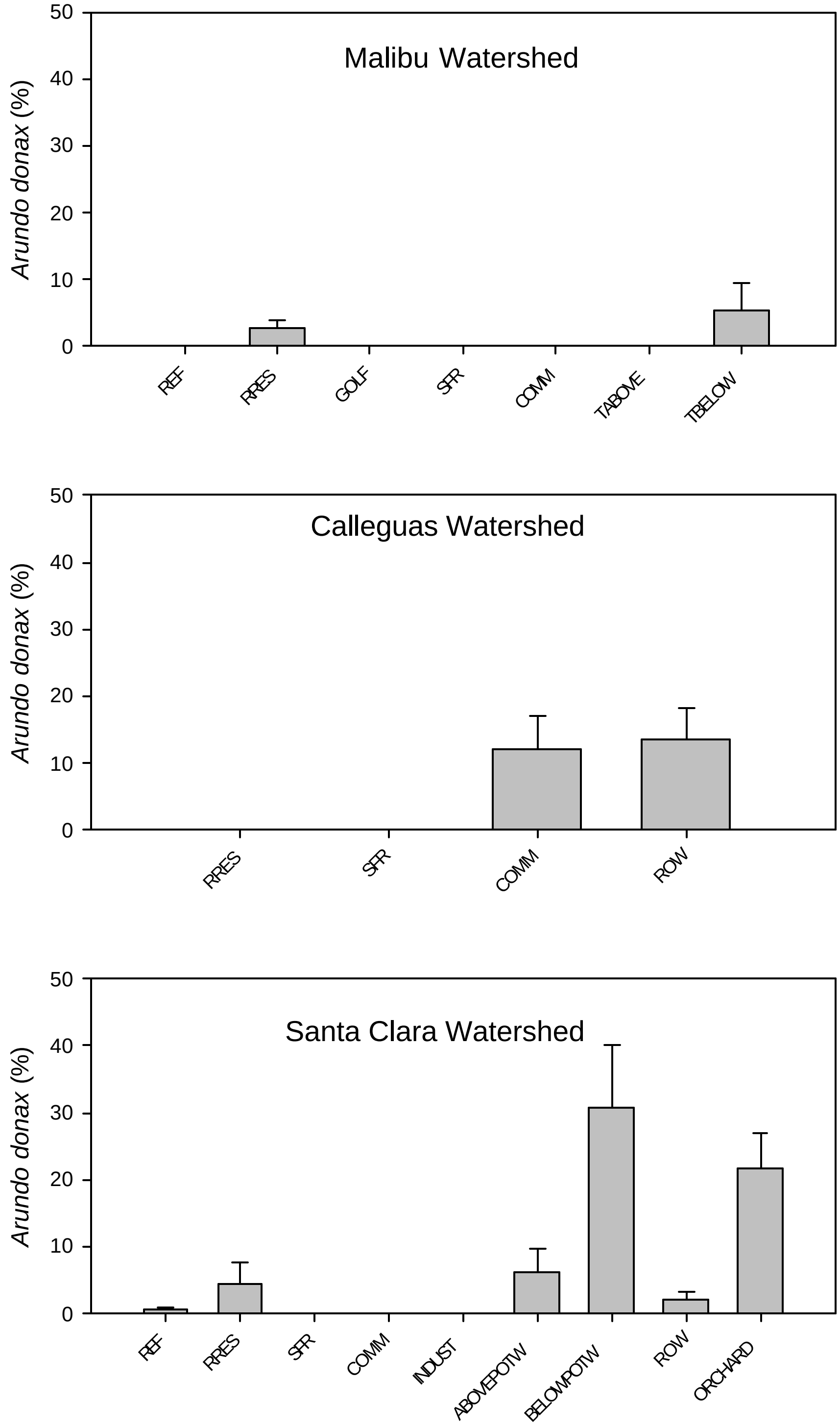


Figure 85. *Arundo donax* cover by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

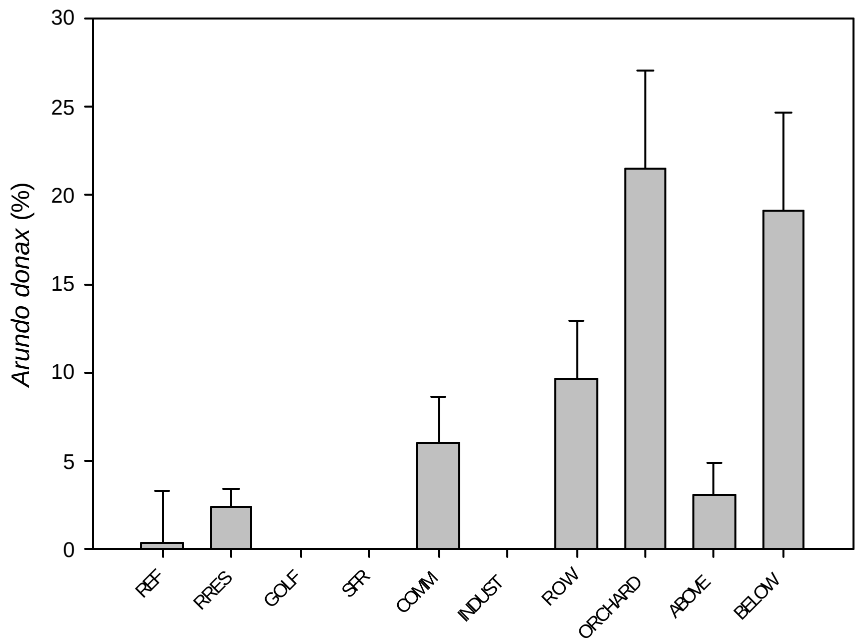


Figure 86. *Arundo donax* cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

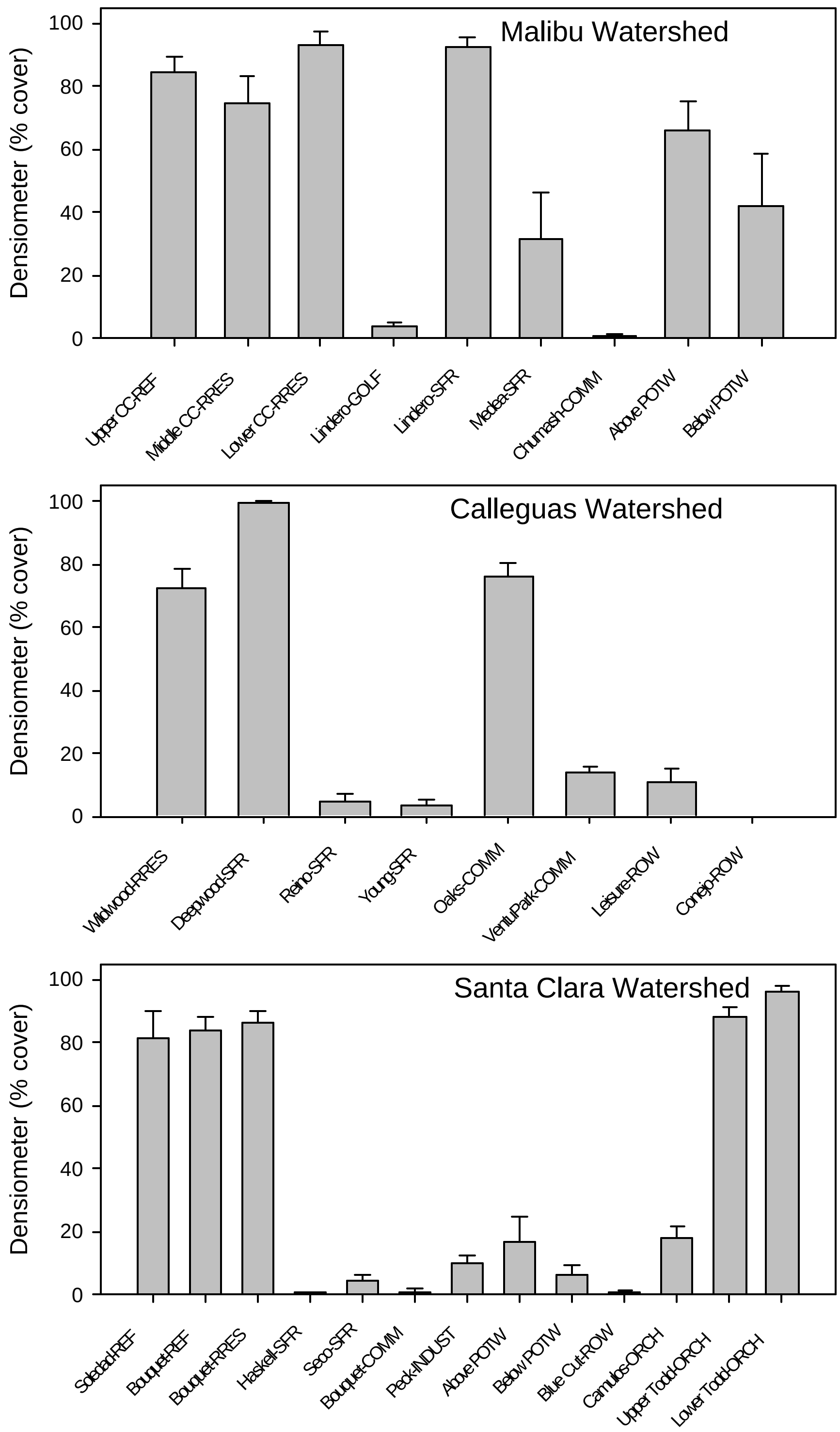


Figure 87. Densiometer cover at all sites.

Densiometer readings were made at six positions along each transect using EMAP methods.

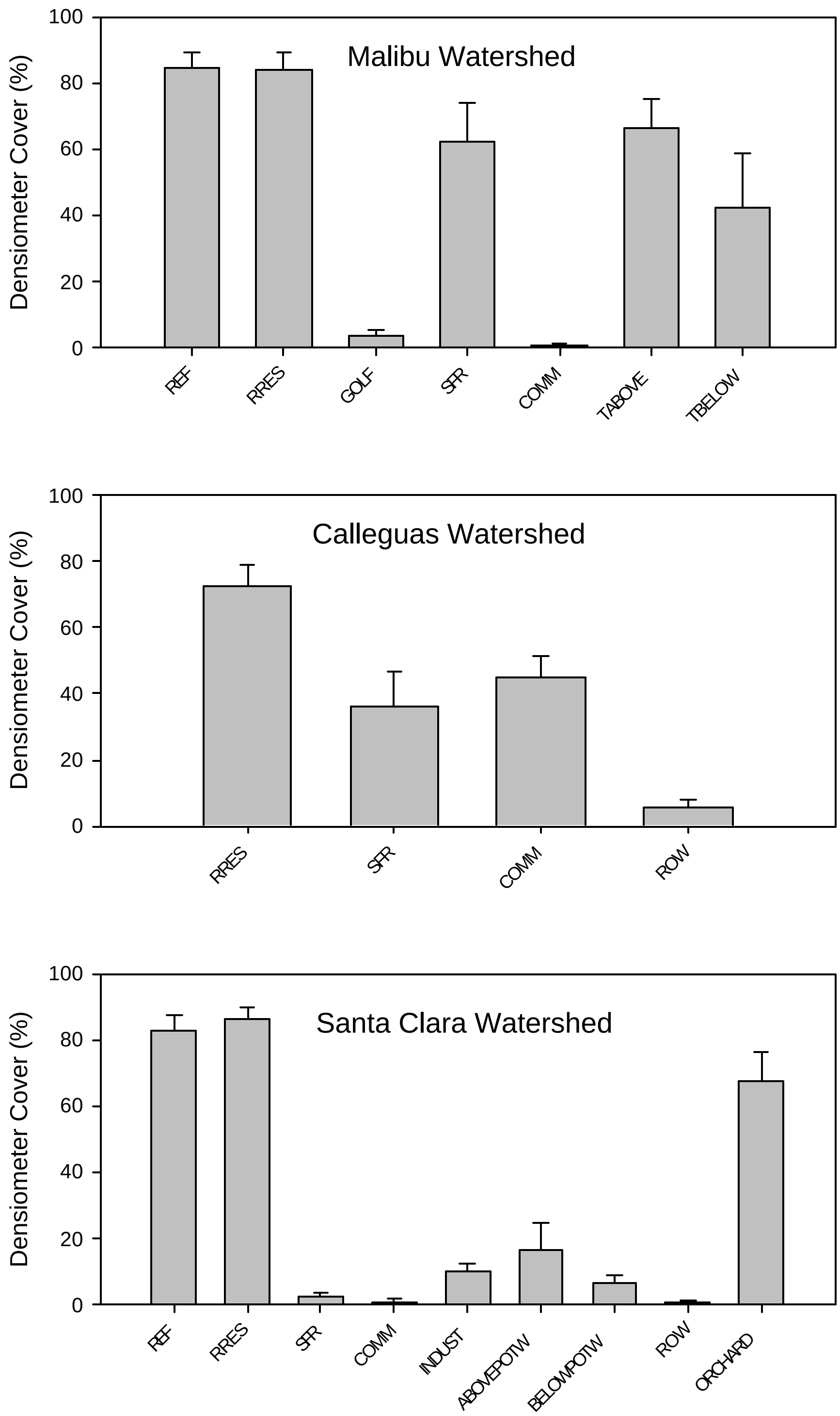


Figure 88. Densiometer cover by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

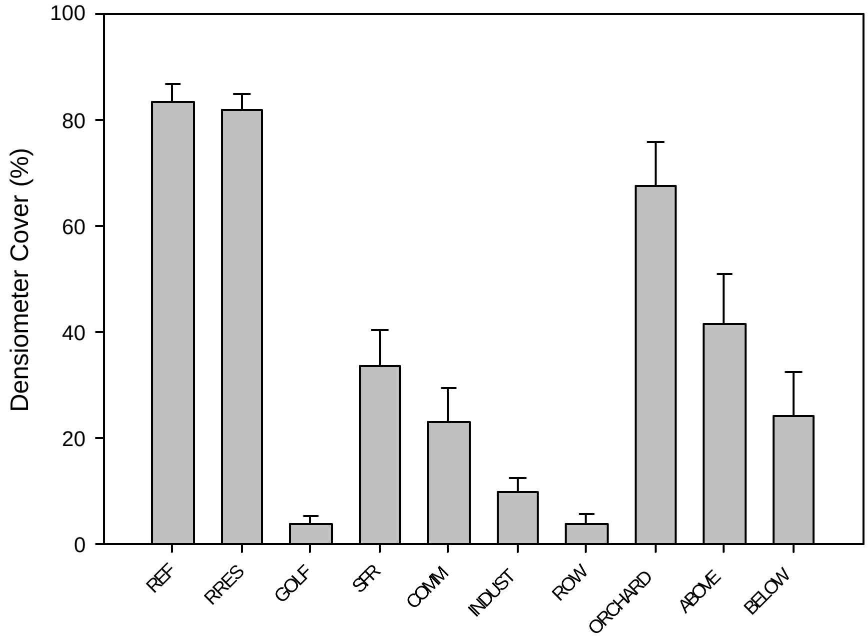


Figure 89. Densiometer cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

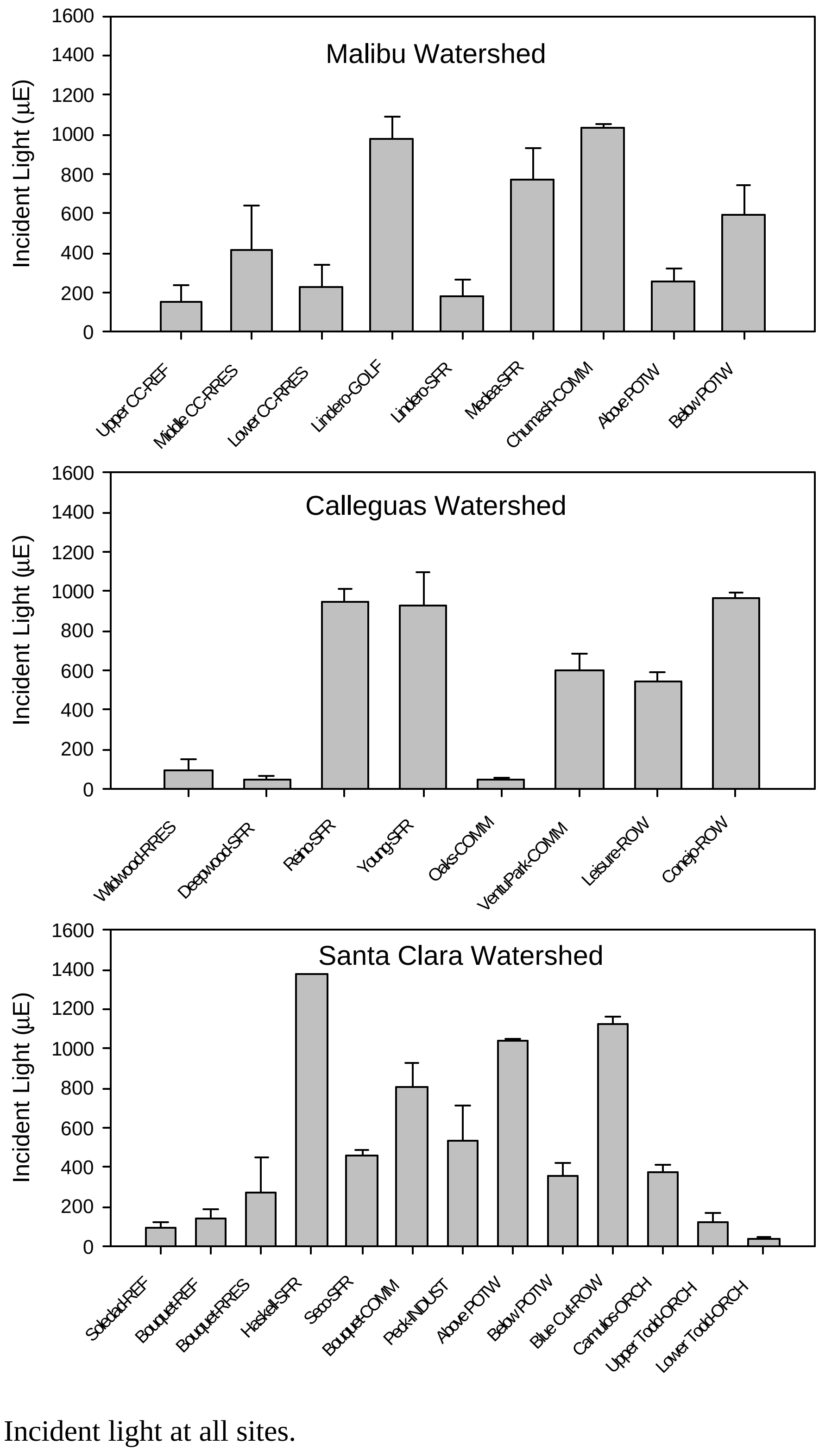


Figure 90. Incident light at all sites.

Incident light was measured using a 1m line quantum sensor at three positions on each transect.

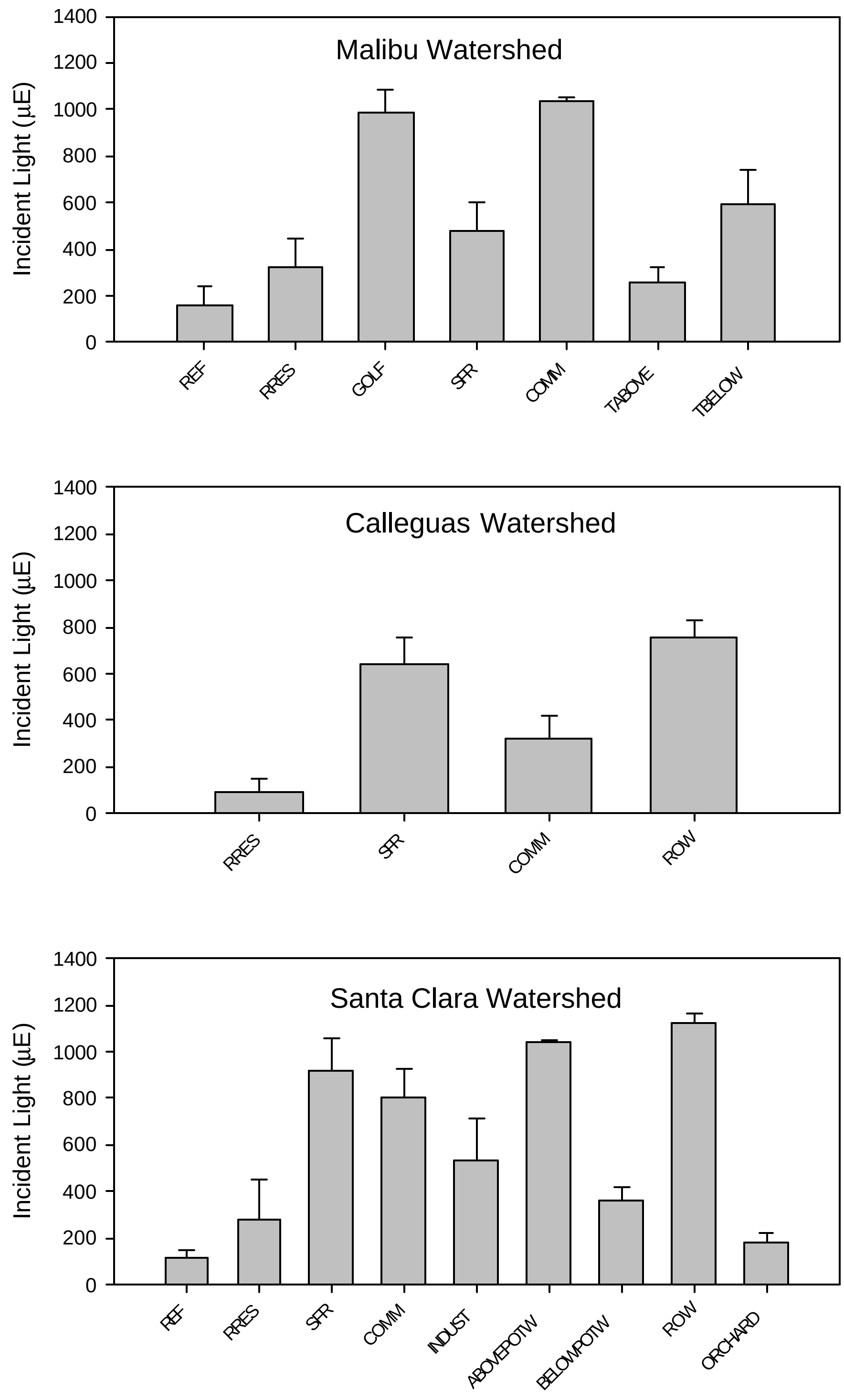


Figure 91. Incident light by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

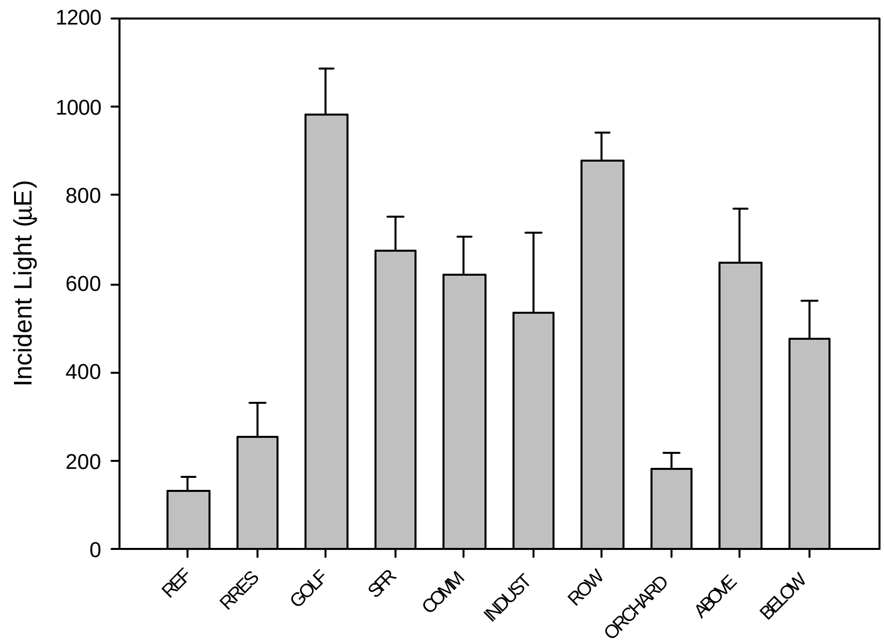


Figure 92. Incident light by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

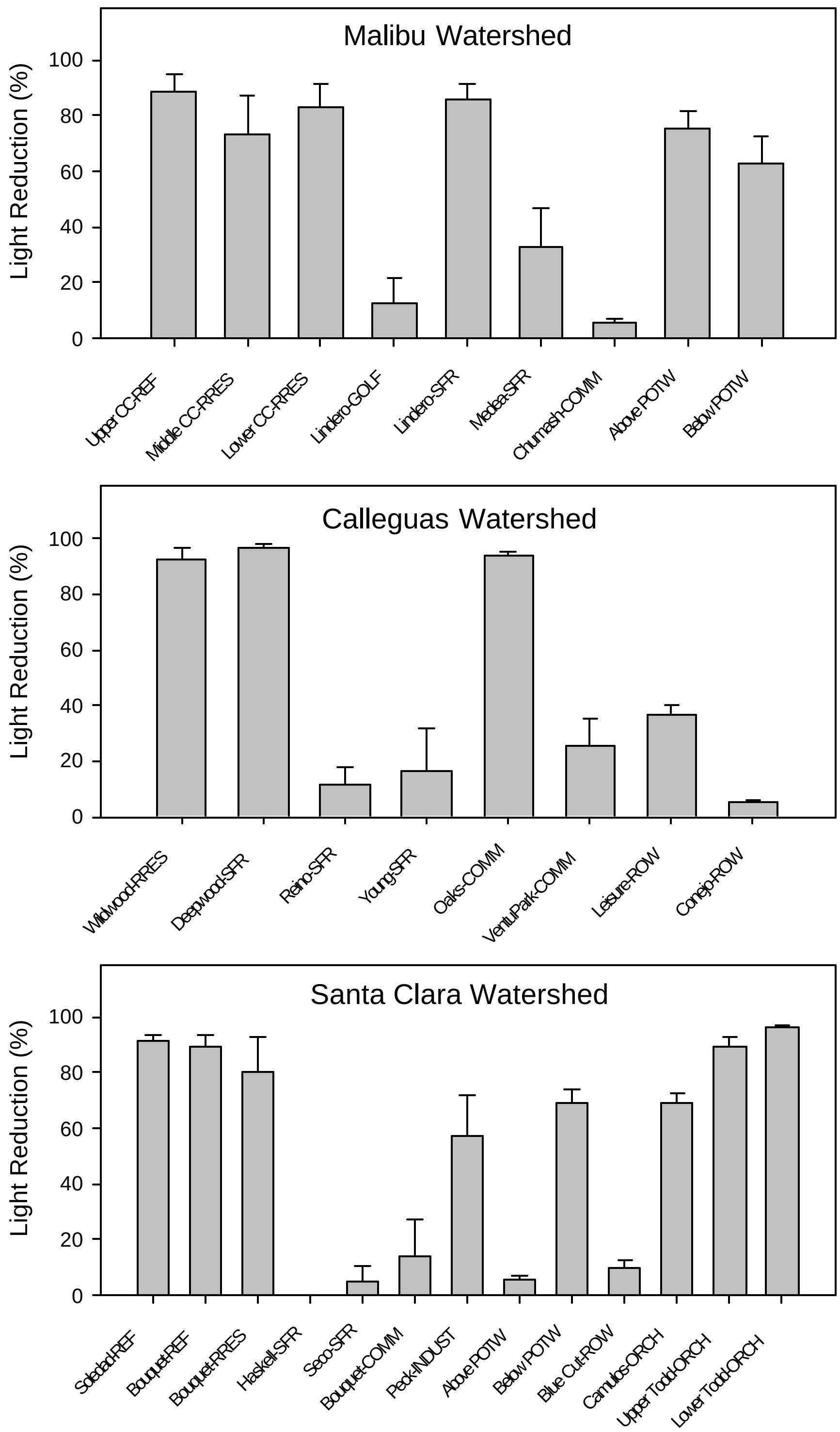


Figure 93. Light reduction at all sites.

Incident light was measured using a 1m line quantum sensor at three positions on each transect. Incident light was also measured in an open area to obtain a full sun reading. Light reduction was calculated for each incident light reading with respect to the full sun reading.

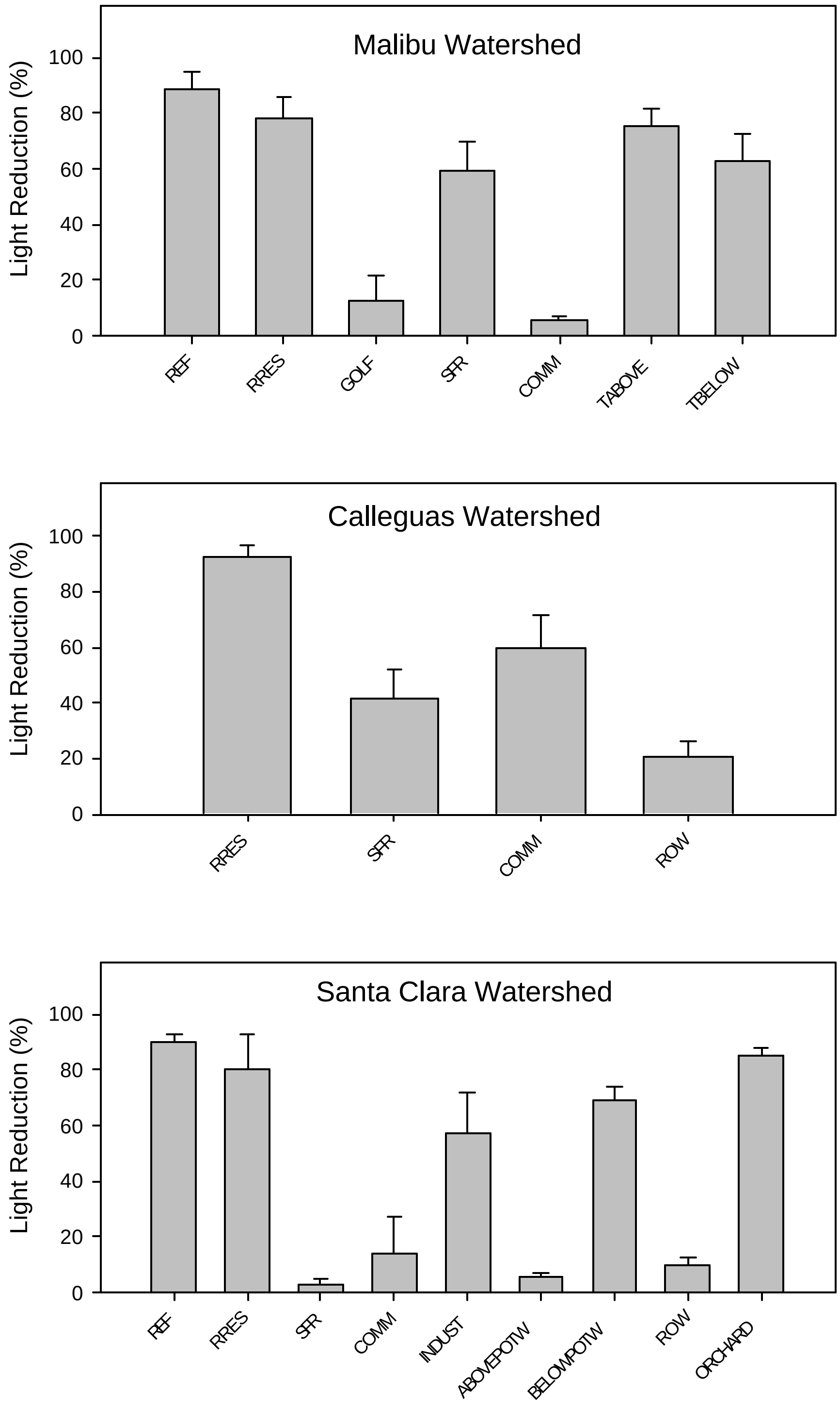


Figure 94. Light reduction by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

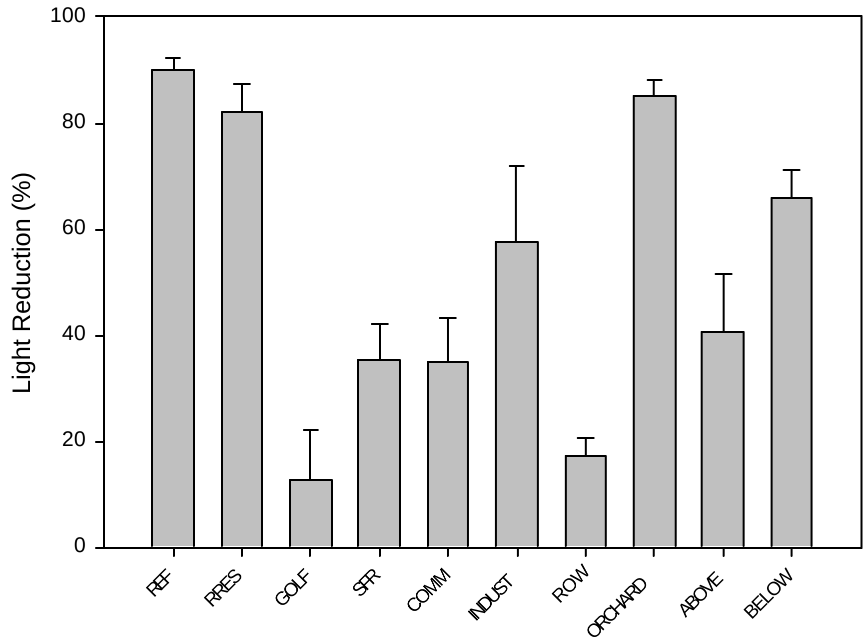


Figure 95. Light reduction by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

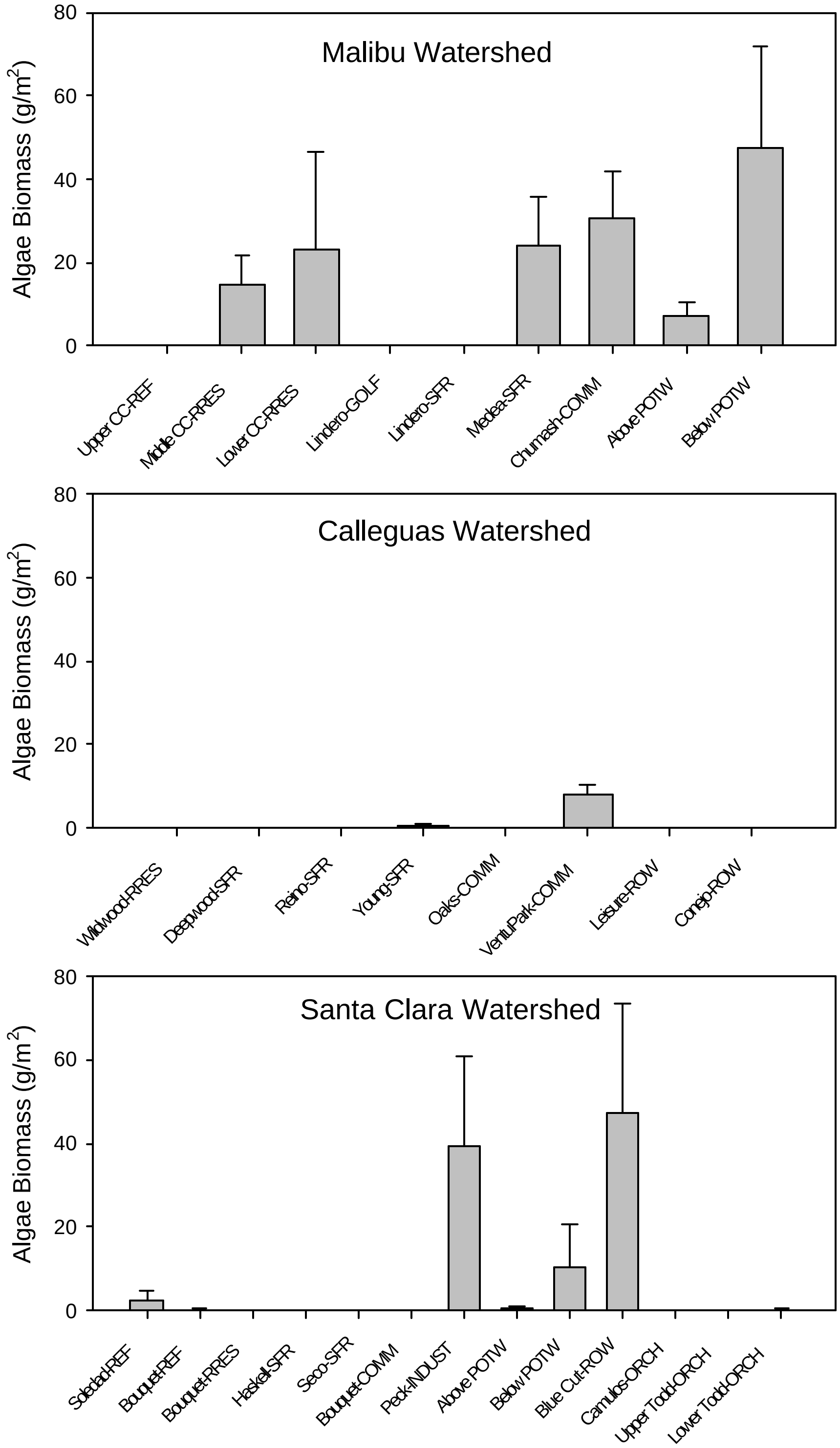


Figure 96. Algae biomass at all sites.

Algae biomass was collected within a 5 gallon bucket (1 gal, if wetted width < 1m) with the bottom cut off at three random positions on each transect.

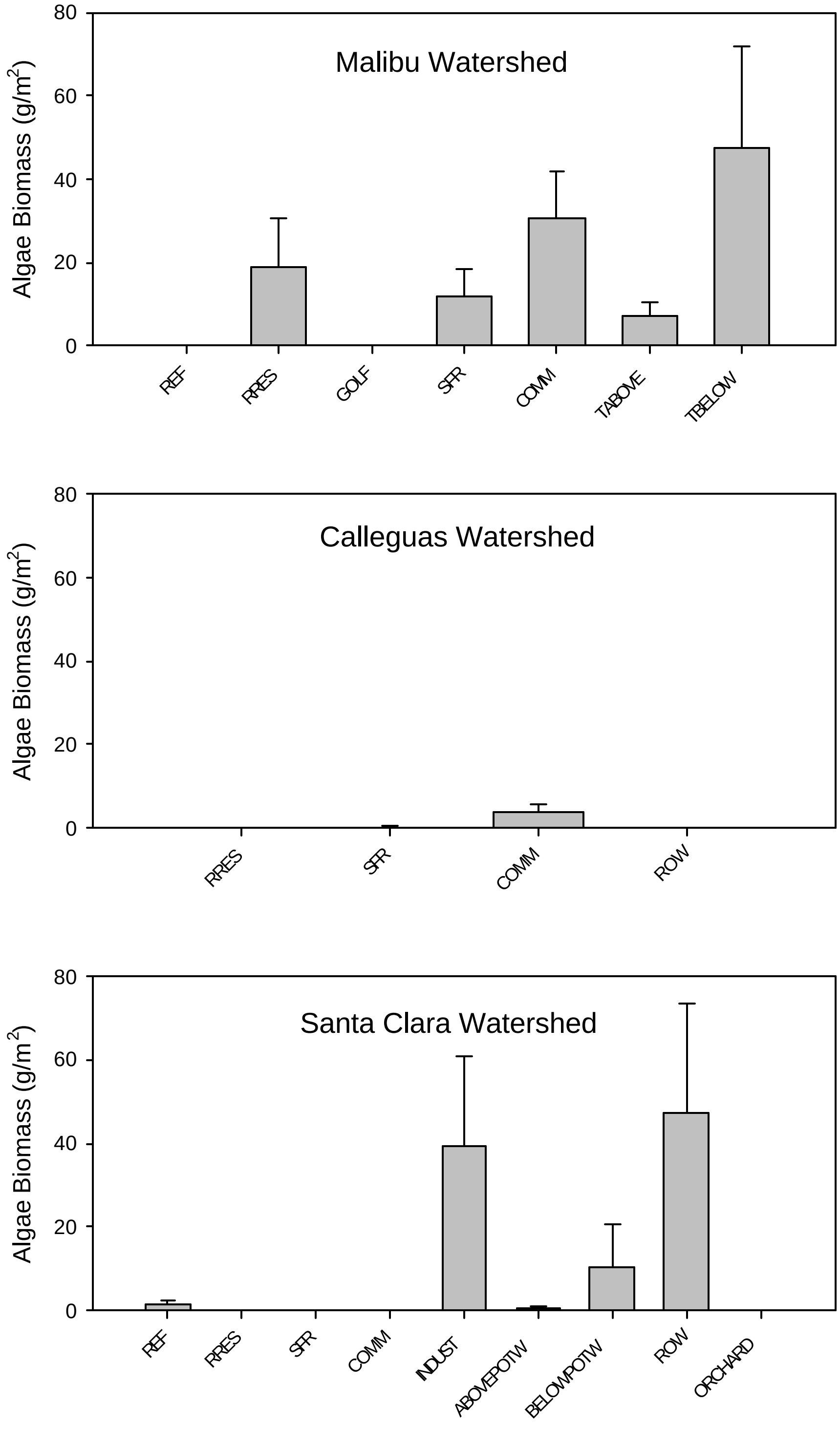


Figure 97. Algae biomass by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

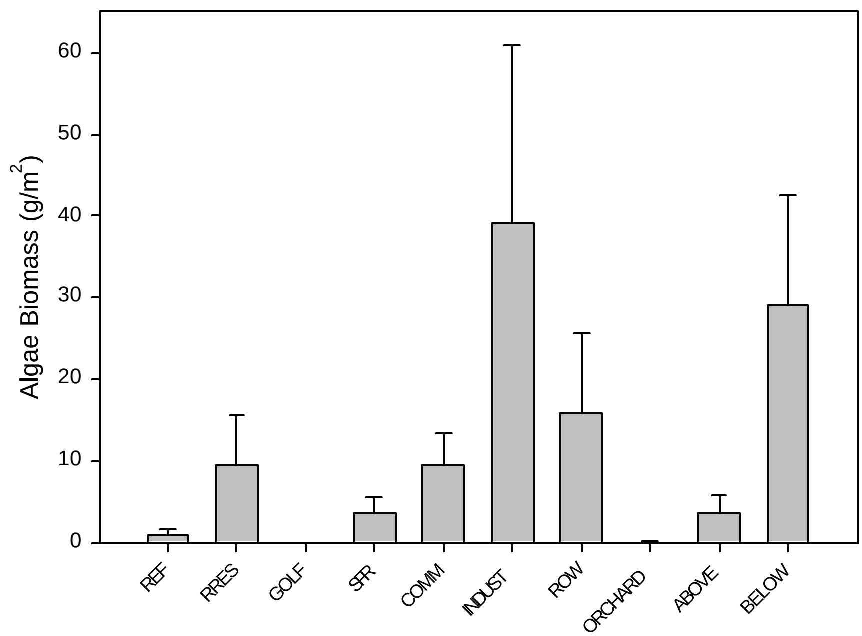


Figure 98. Algae biomass by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

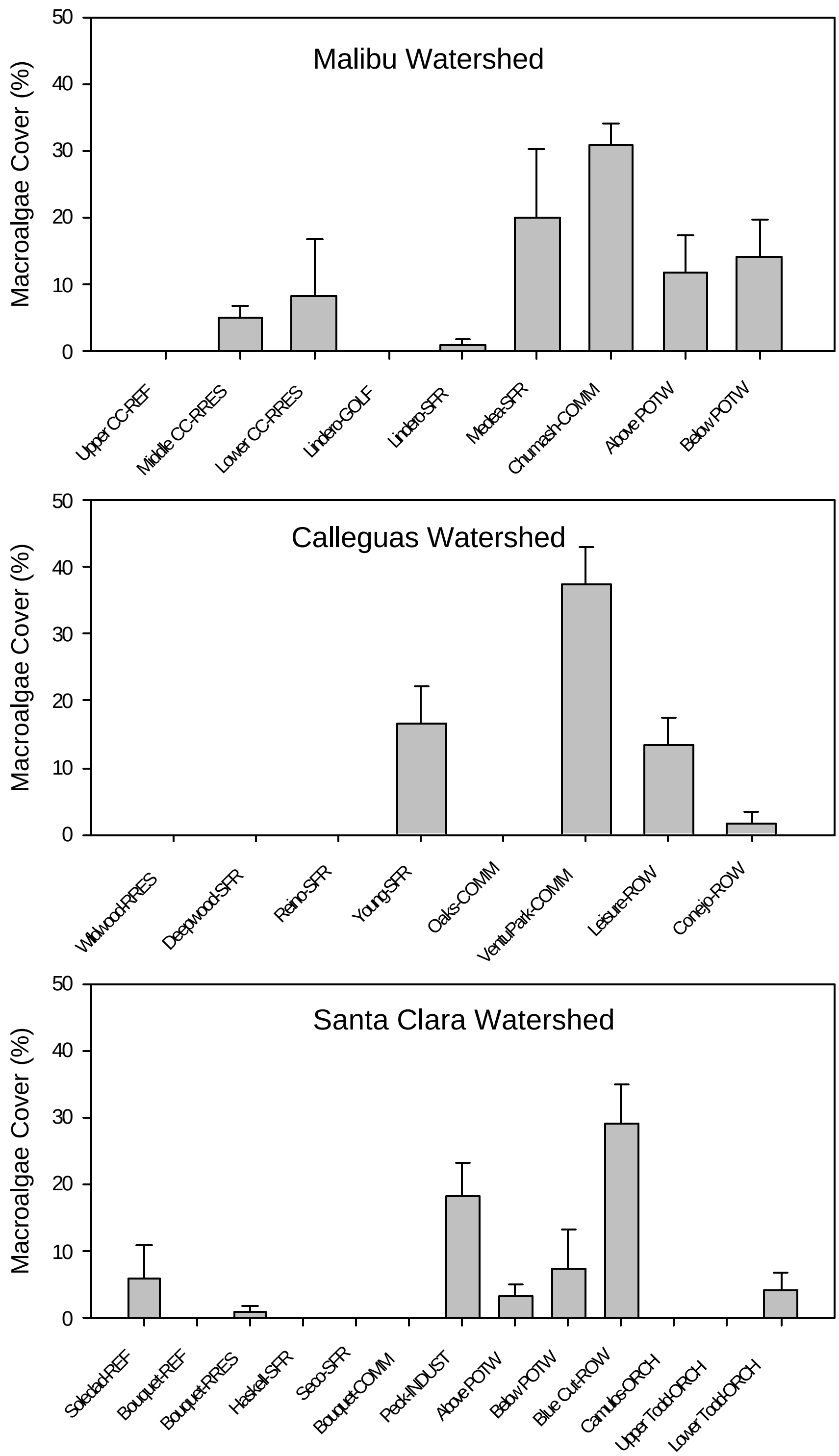


Figure 99. Macroalgae cover at all sites.

Macroalgae was recorded at twenty (ten, if wetted width < 1m) positions across the wetted width at each transect.

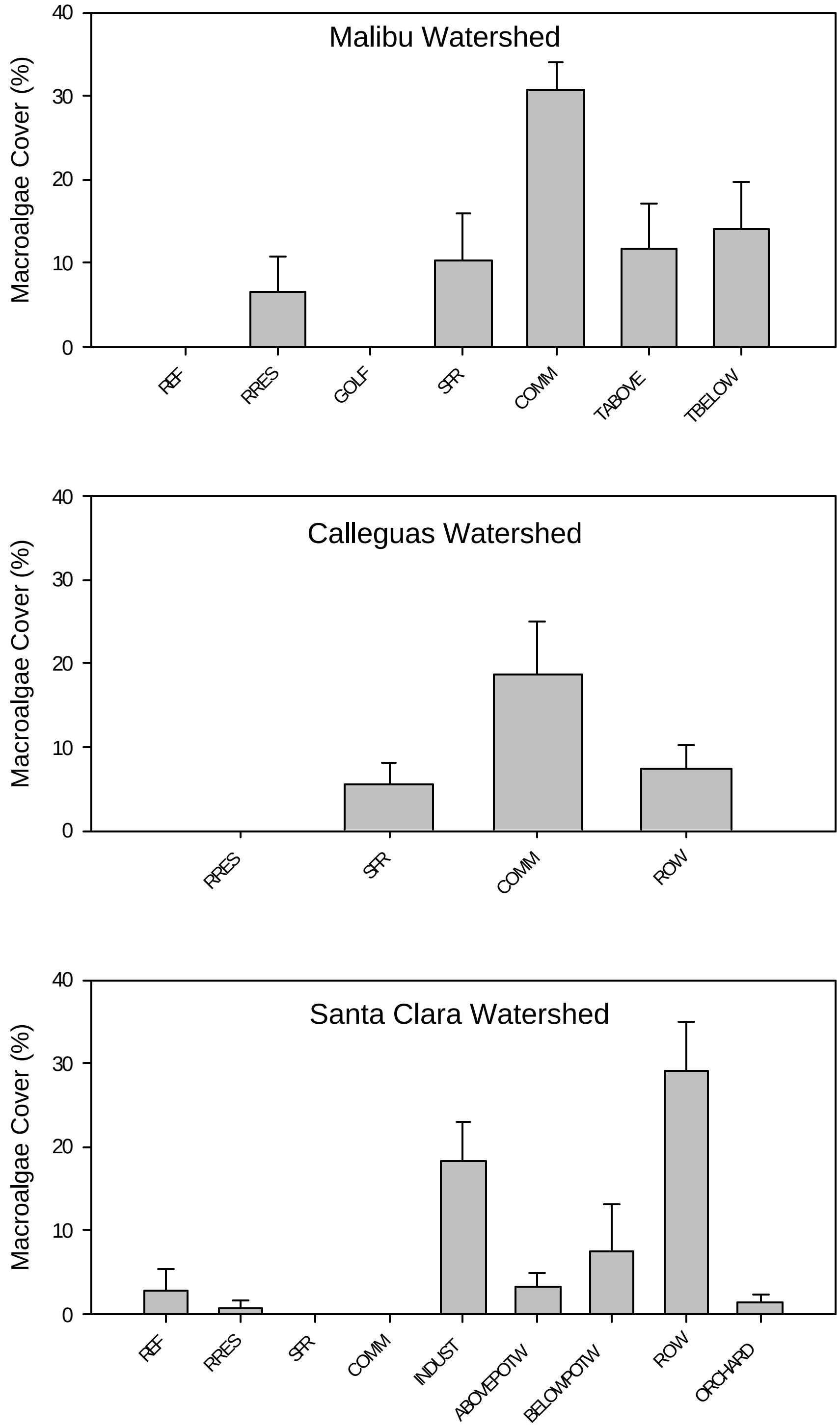


Figure 100. Macroalgae cover by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

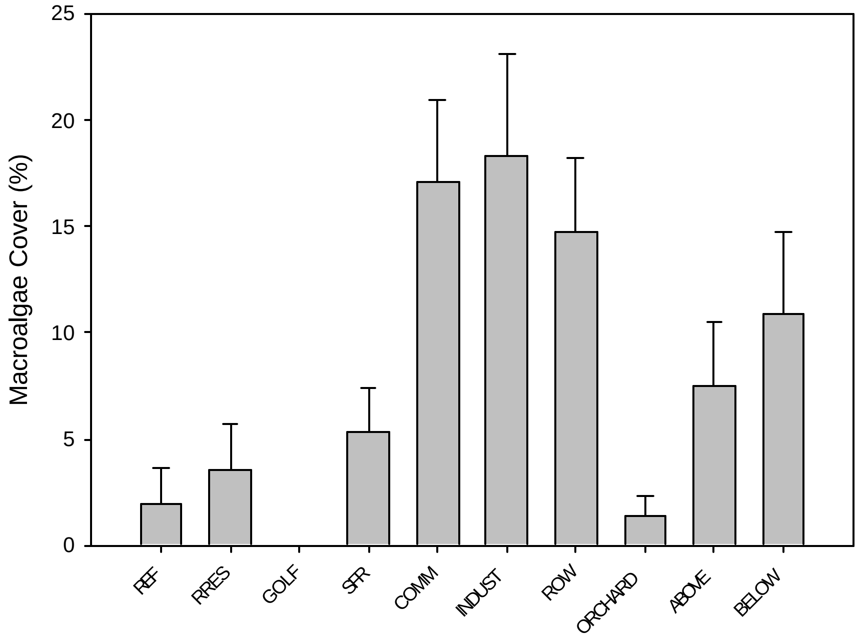


Figure 101. Macroalgae cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

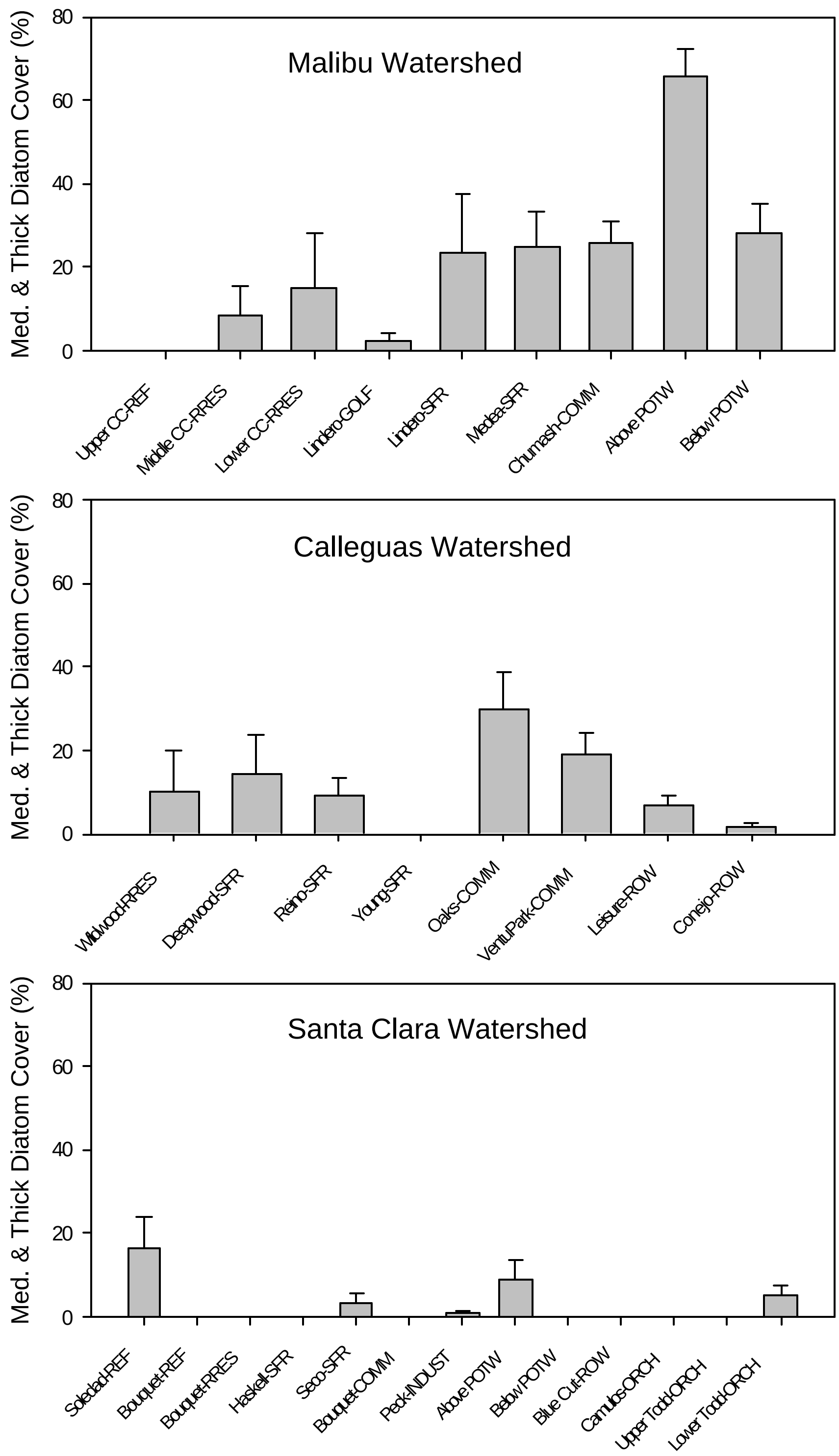


Figure 102. Medium and thick diatom cover at all sites.

Diatoms were recorded at twenty (ten, if wetted width < 1m) positions across the wetted width at each transect. Diatoms were categorized according to the thickness of the periphyton (DF <1mm, 1mm<DM<5mm, DT>5mm).

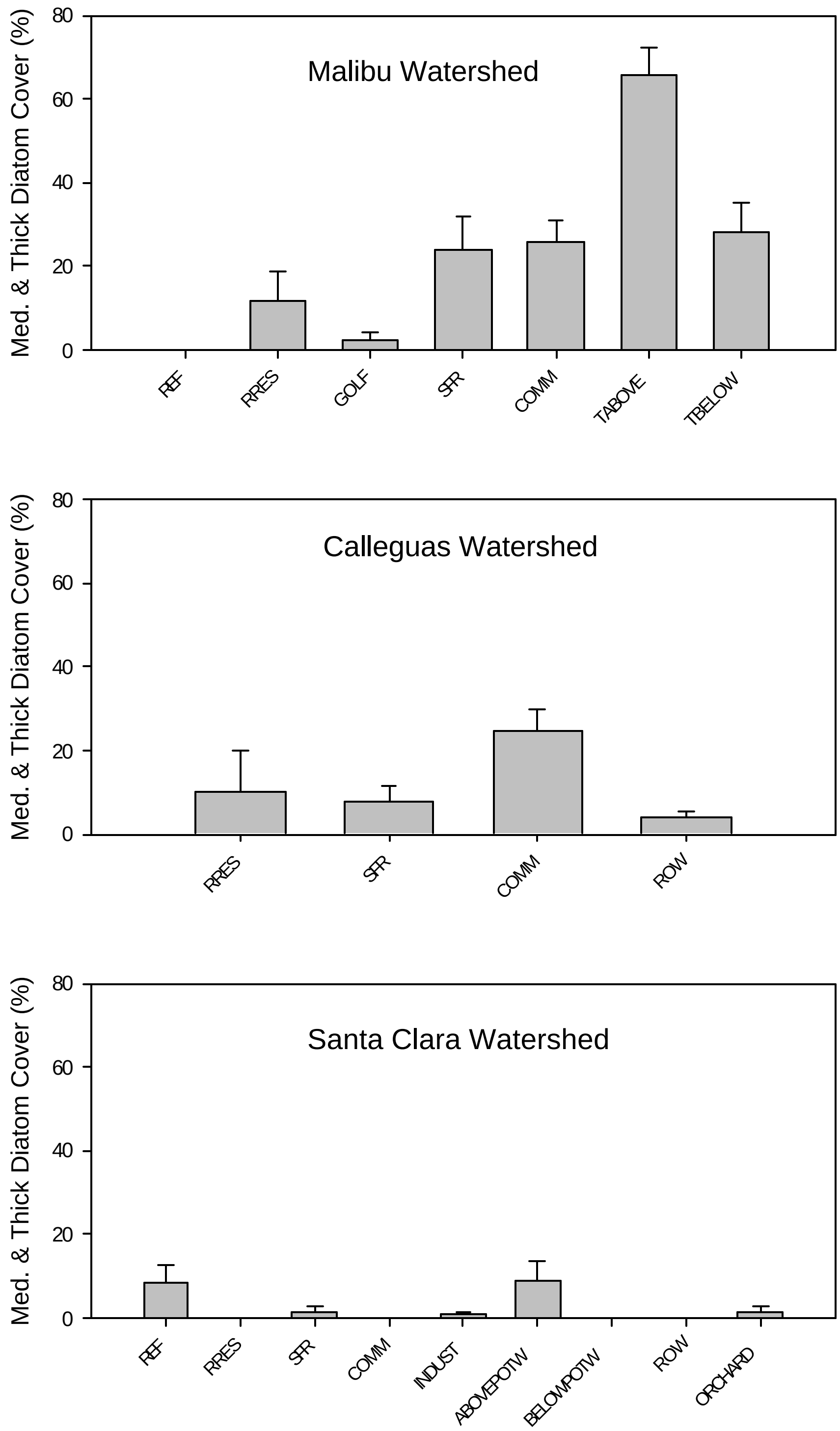


Figure 103. Medium and thick diatom cover by land use within each watershed. Sites of similar land use were combined within each of the three watersheds.

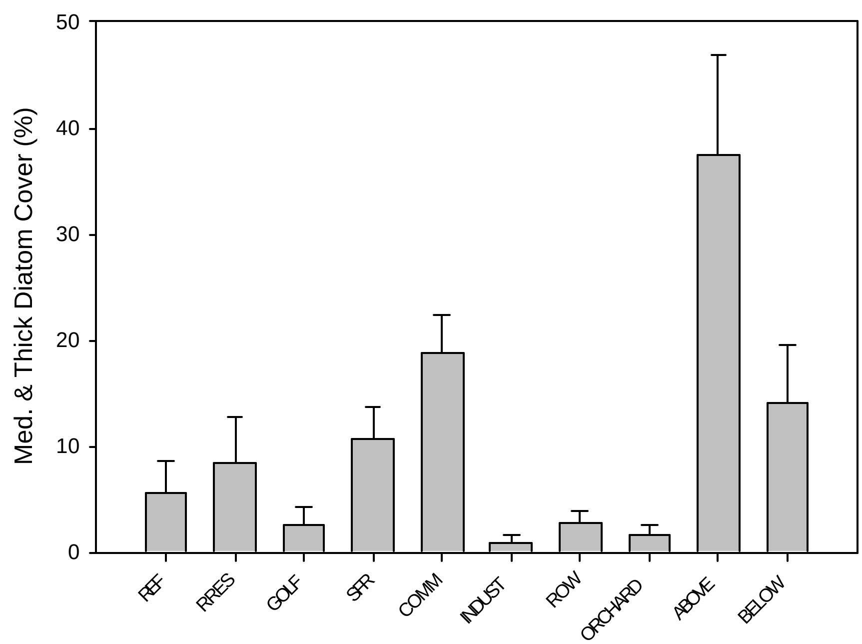


Figure 104. Medium and thick diatom cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

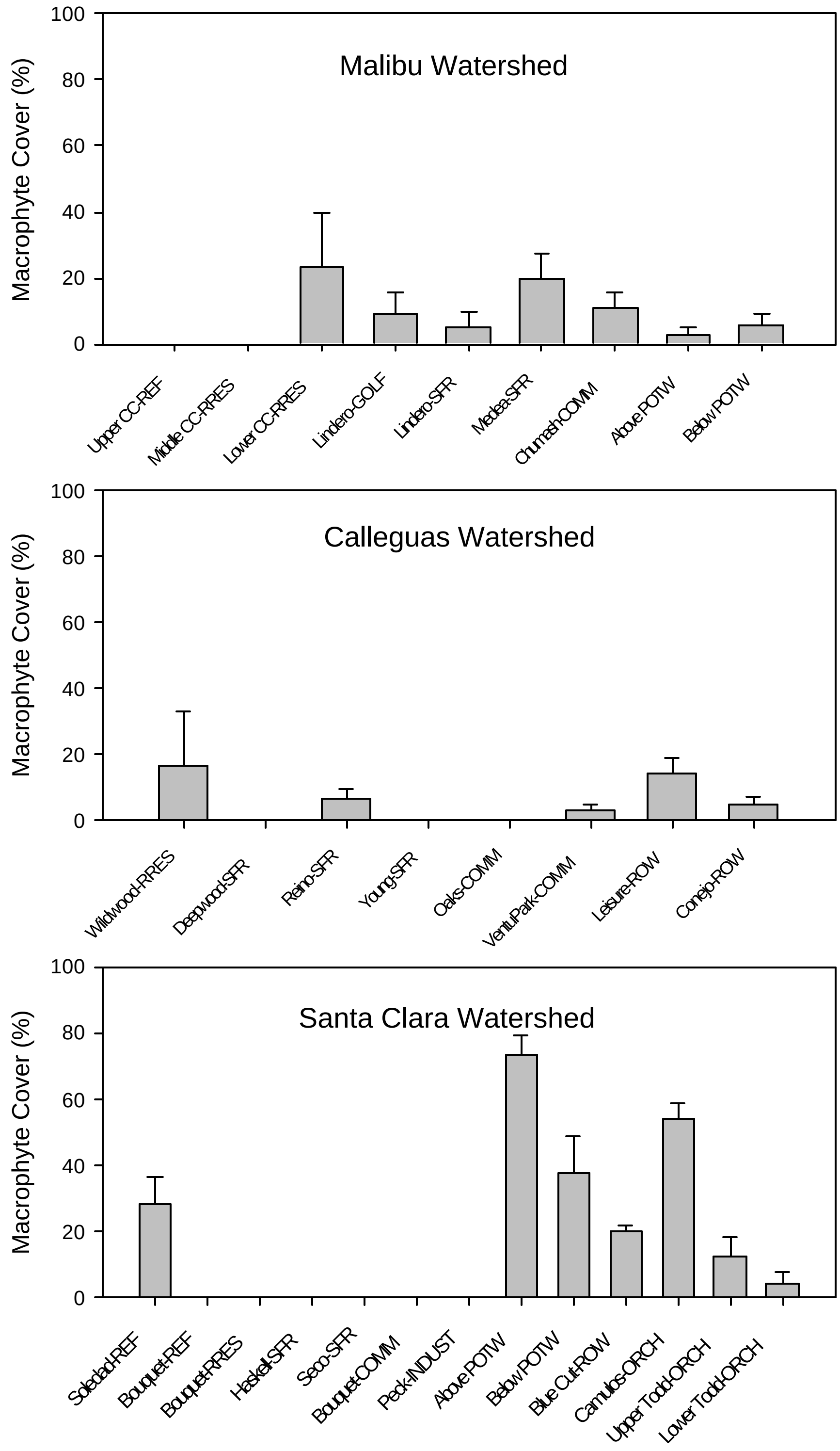


Figure 105. Vascular macrophyte cover at all sites.

Macrophytes were recorded at twenty (ten, if wetted width < 1m) positions across the wetted width at each transect.

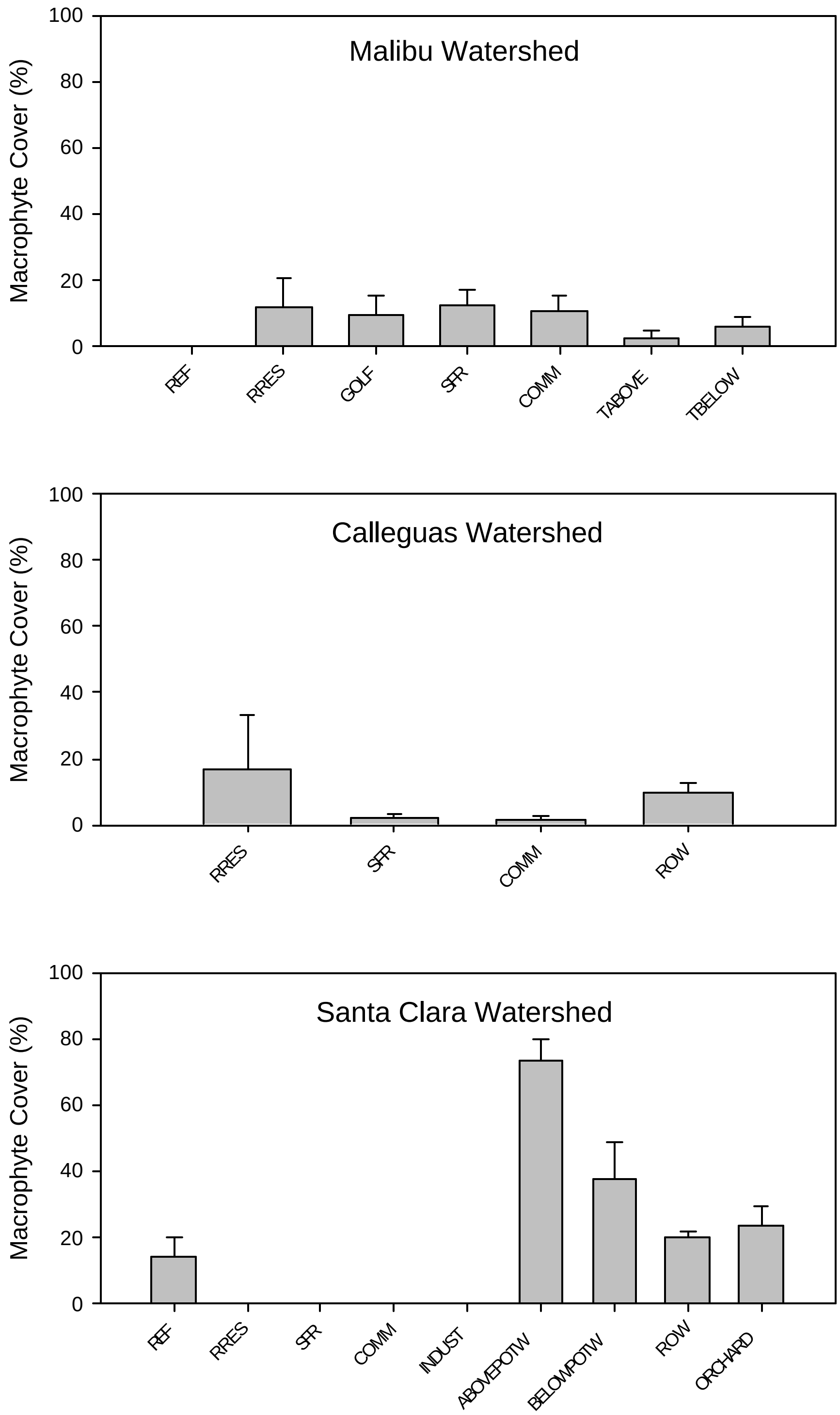


Figure 106. Vascular macrophyte cover by land use within each watershed. Sites of similar land use were combined within each of the three watersheds.

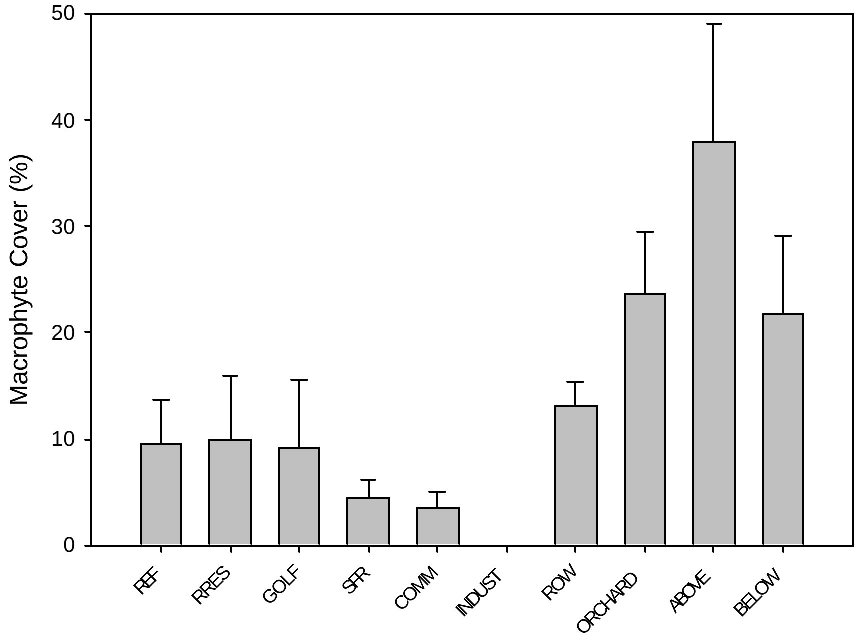


Figure 107. Vascular macrophyte cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

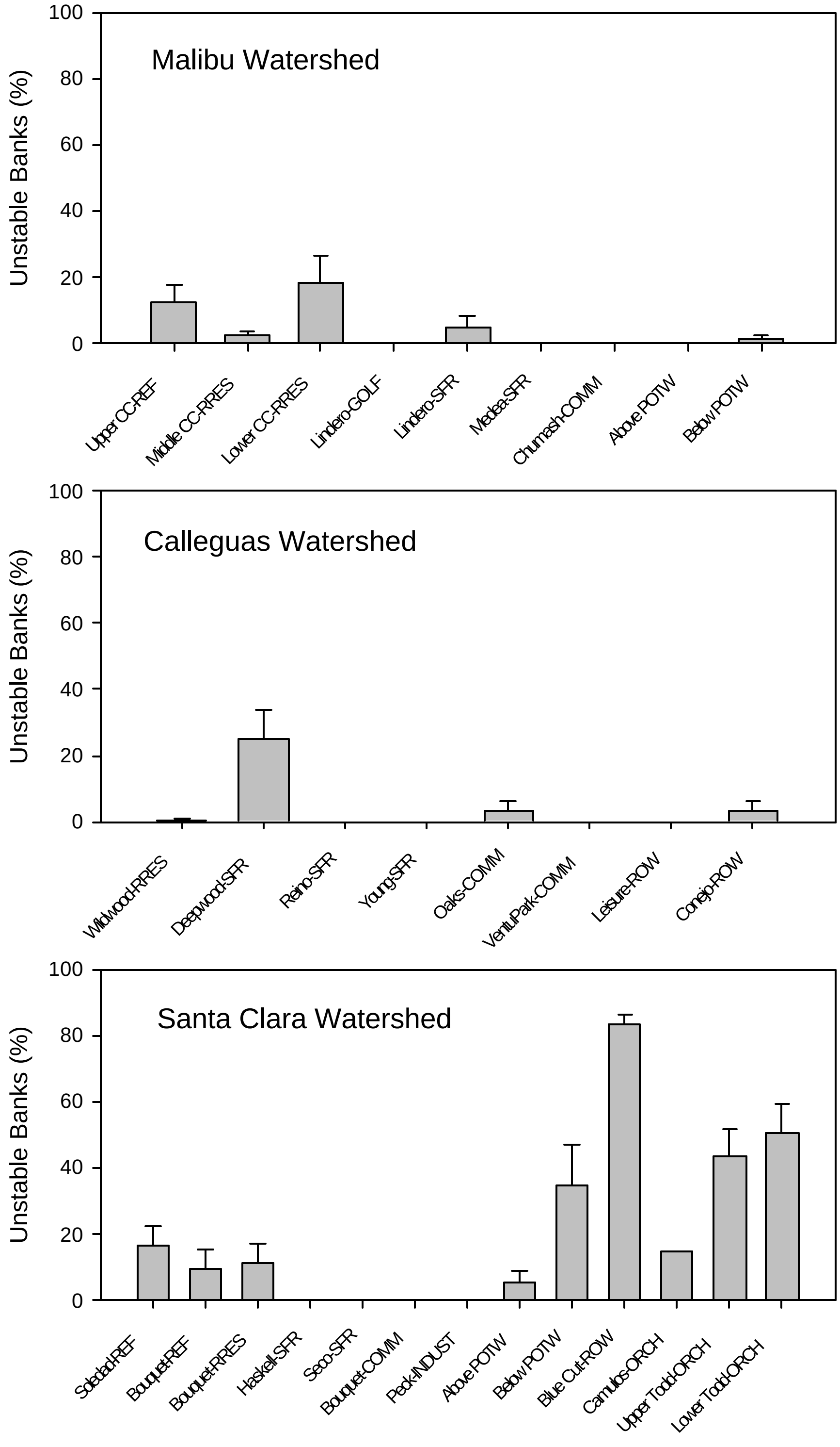


Figure 108. Unstable banks at all sites.

Unstable banks were estimated within 5m upstream and downstream of each transect.

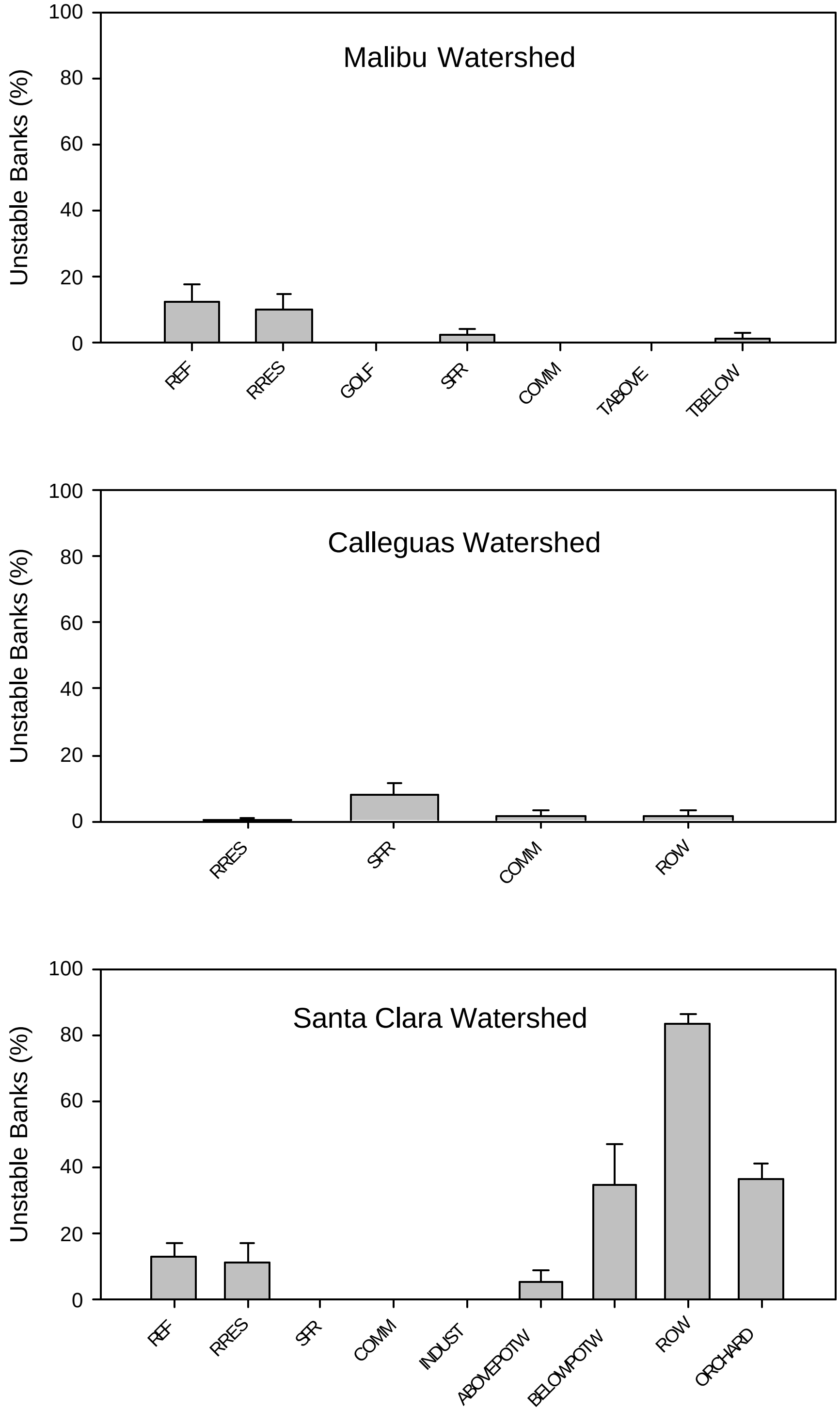


Figure 109. Unstable banks by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

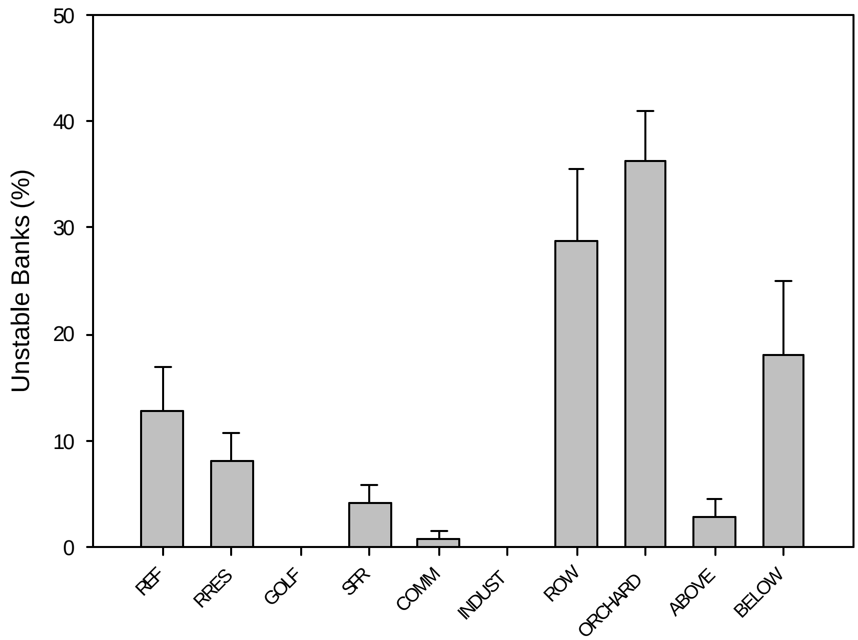


Figure 110. Unstable banks by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

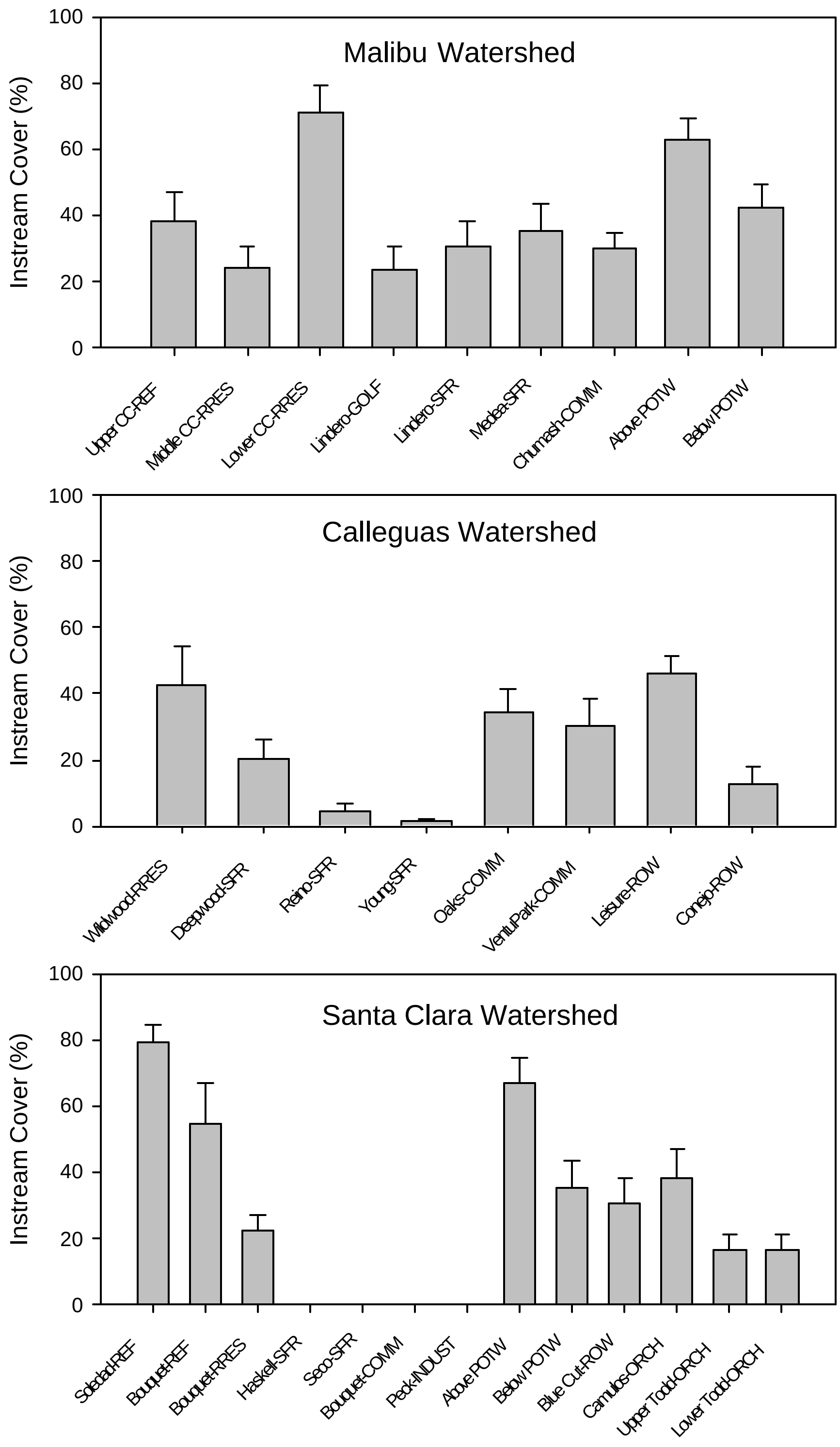


Figure 111. Instream cover at all sites.

Instream cover suitable for possible fish habitat was estimated within the wetted width 5m upstream and downstream of each transect.

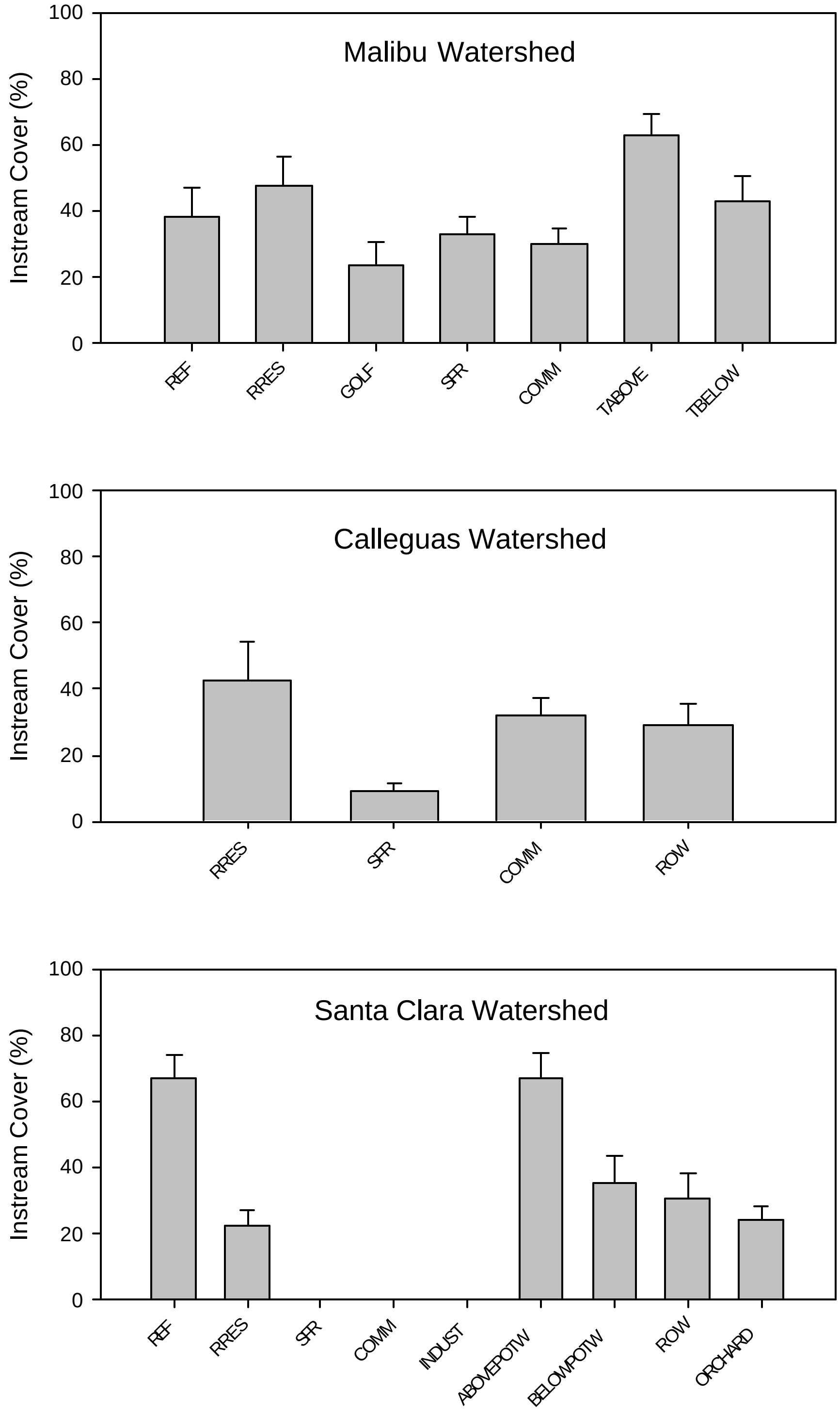


Figure 112. Instream cover by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

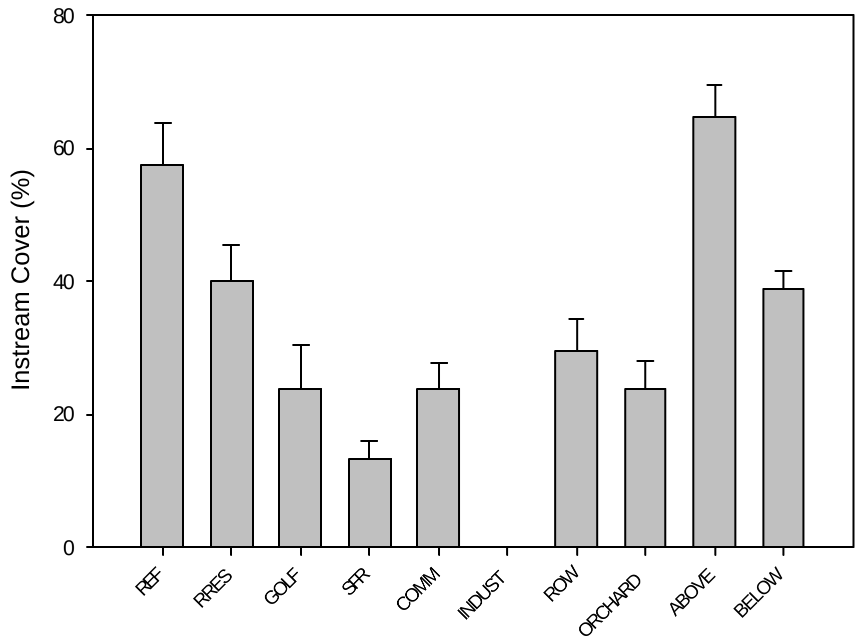


Figure 113. Instream cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

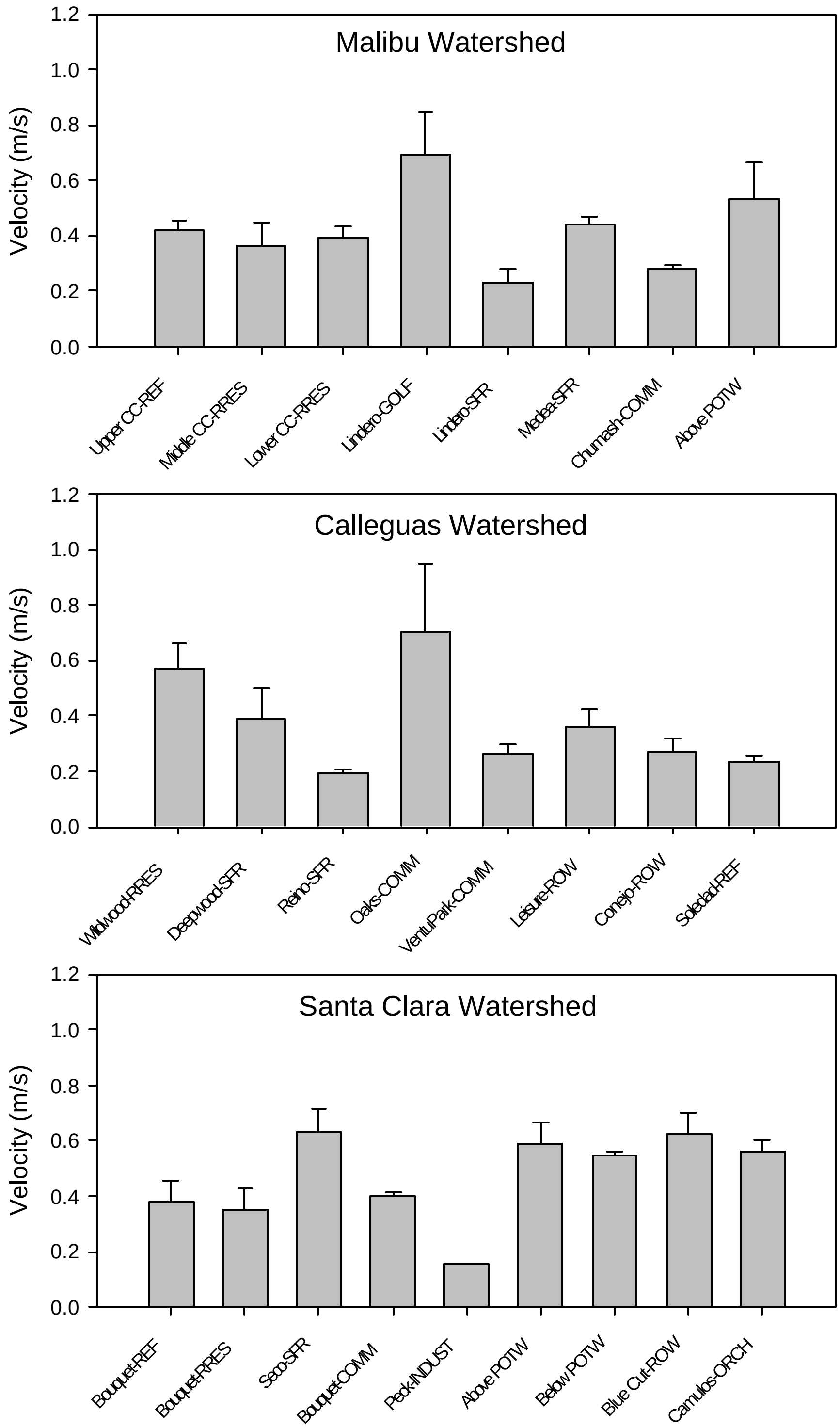


Figure 114. Riffle velocity at all sites.

Velocity measurements were taken with the flow sensor centered within the 1X2 ft BMI sampling plots and positioned just above the benthos at each riffle.

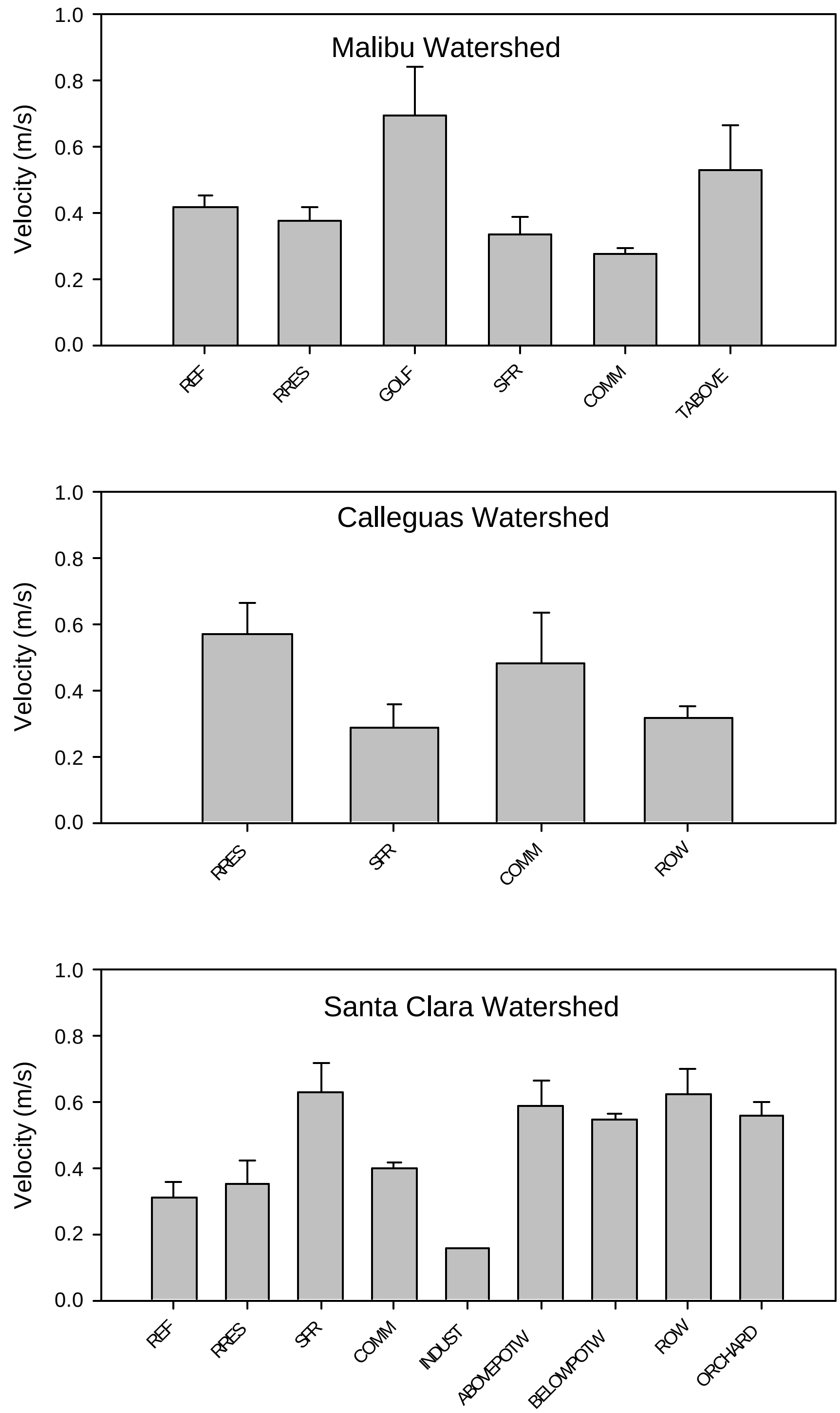


Figure 115. Riffle velocity by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

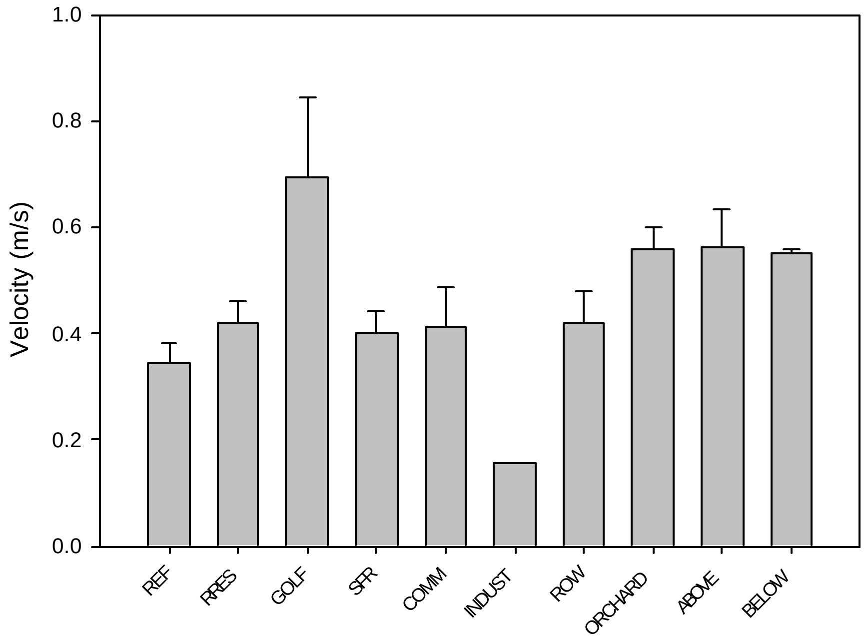


Figure 116. Riffle velocity by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

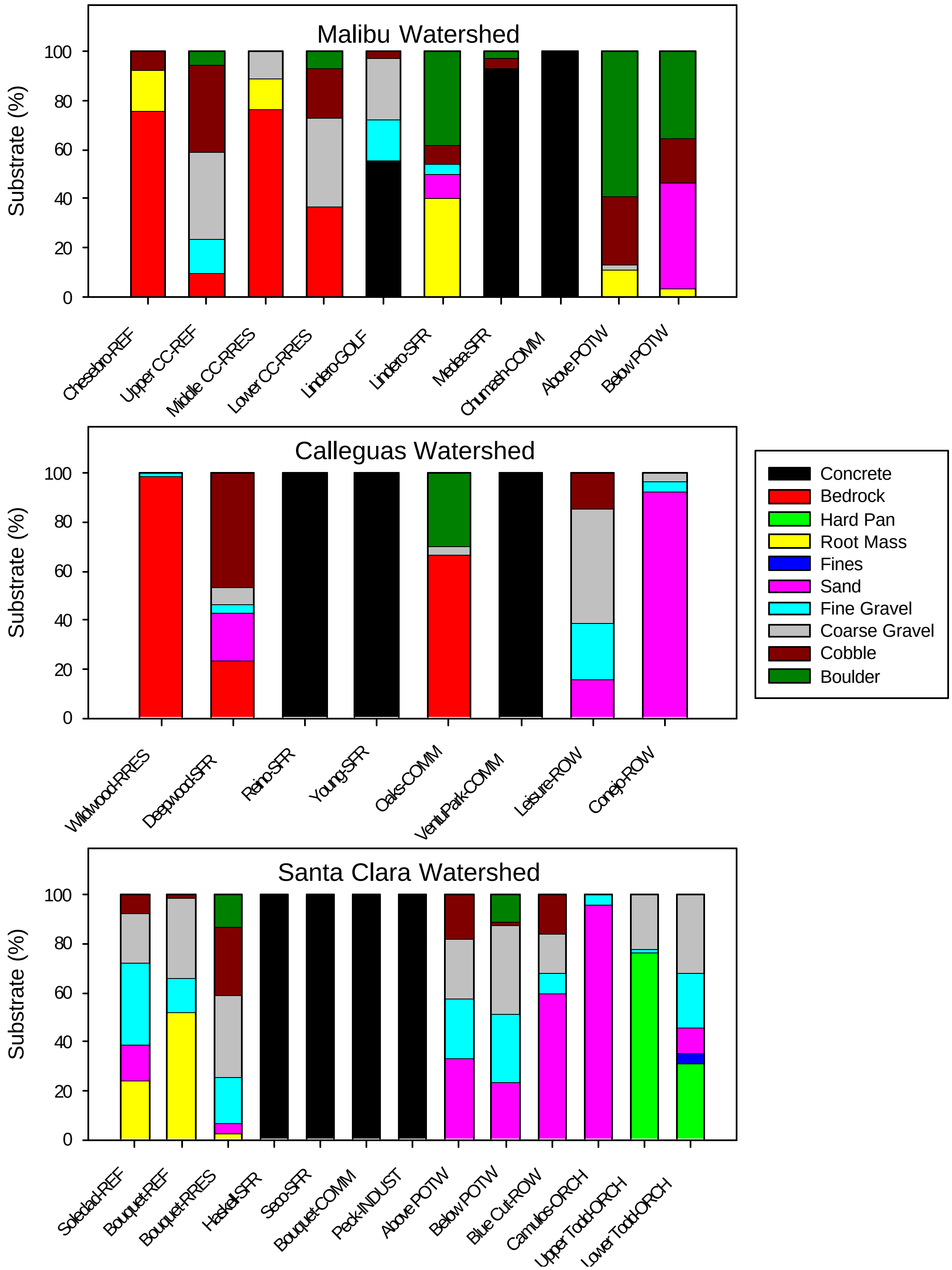


Figure 117. Riffle substrate at all sites.

Substrate was estimated within the 1X2 ft BMI sampling plots at each riffle.

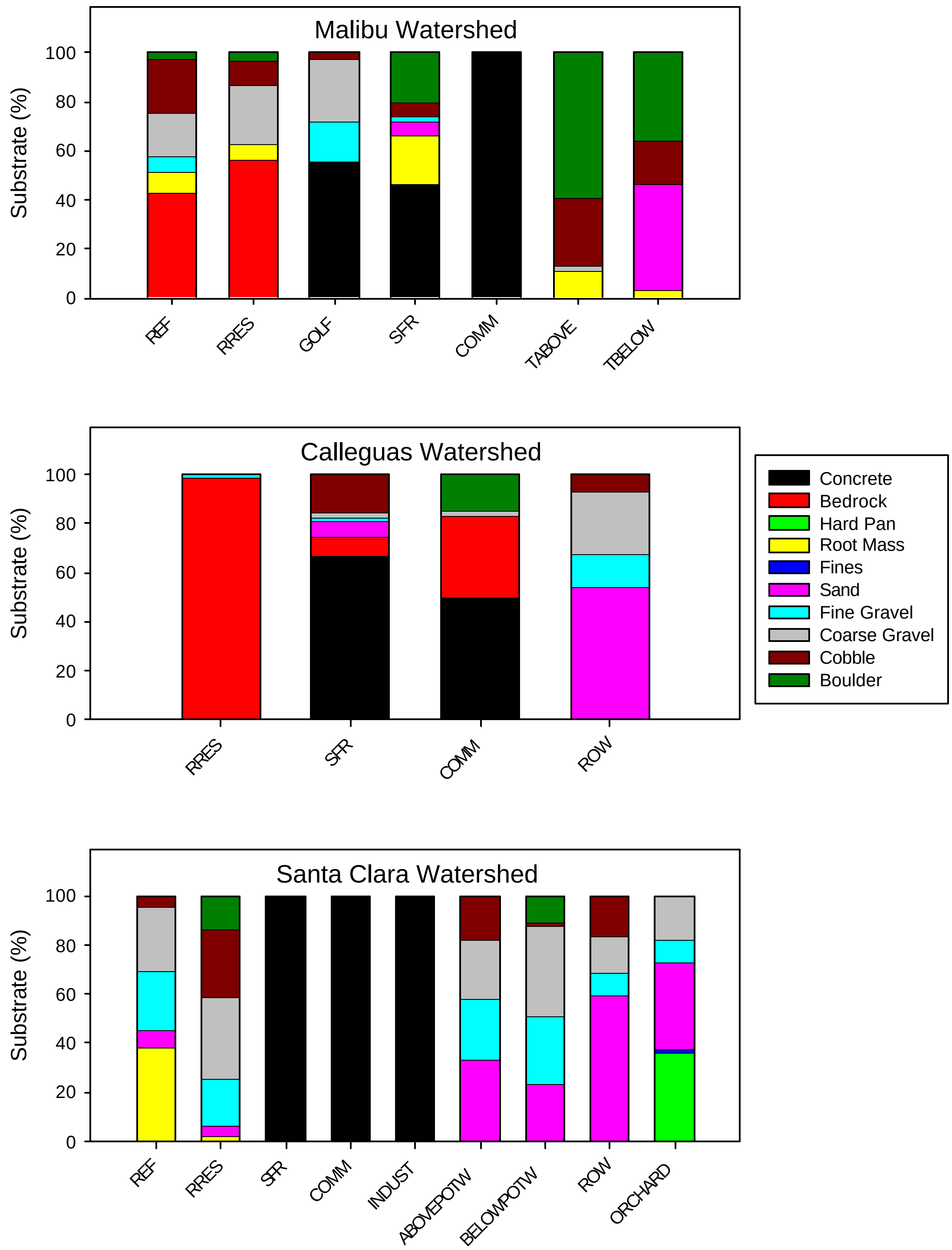


Figure 118. Riffle substrate by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

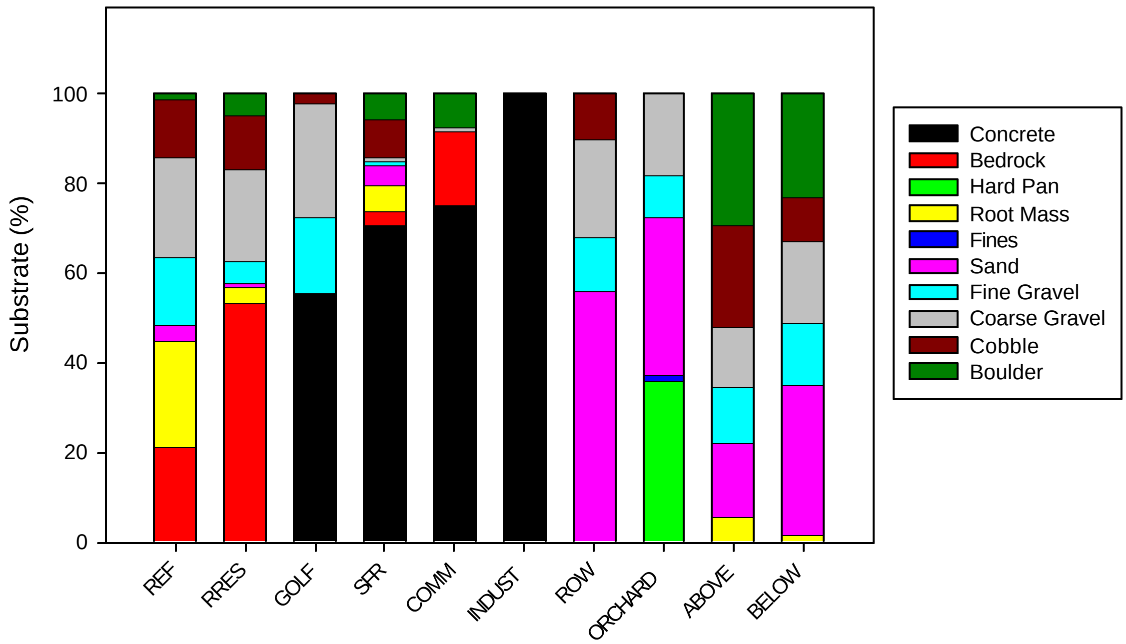


Figure 119. Riffle substrate by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

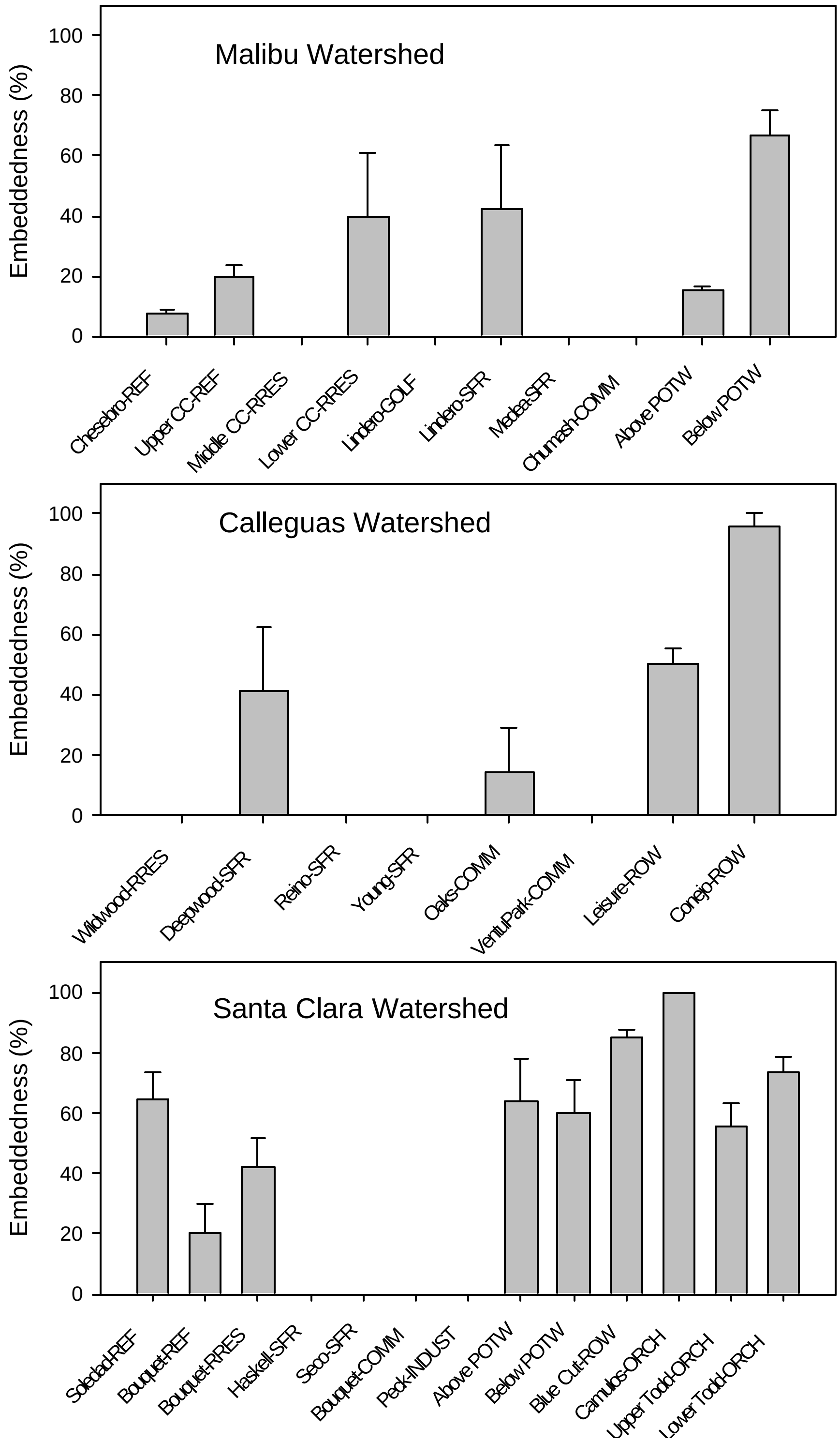


Figure 120. Riffle embeddedness at all sites.

Embeddedness was estimated within the 1X2 ft BMI sampling plots at each riffle.

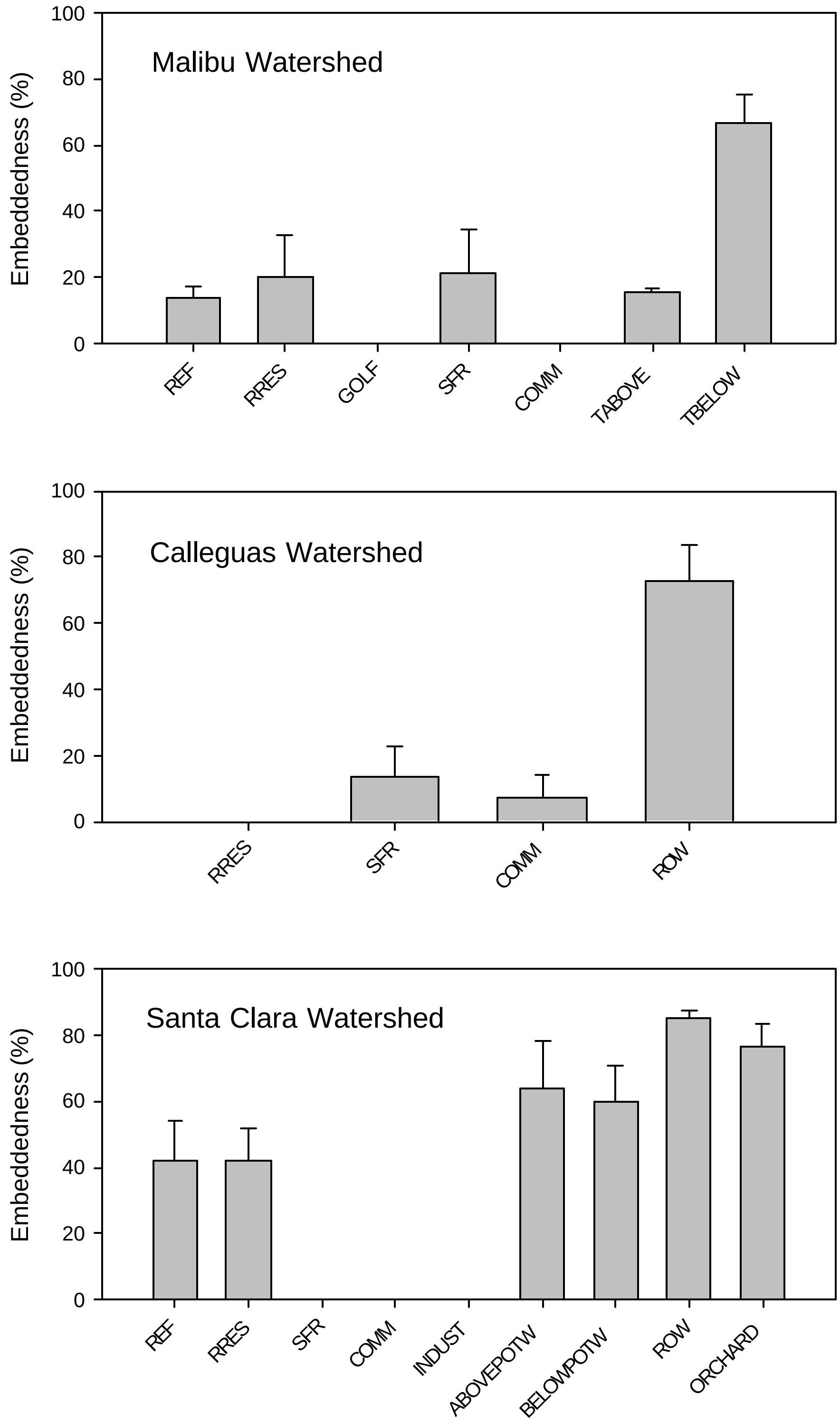


Figure 121. Riffle embeddedness by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

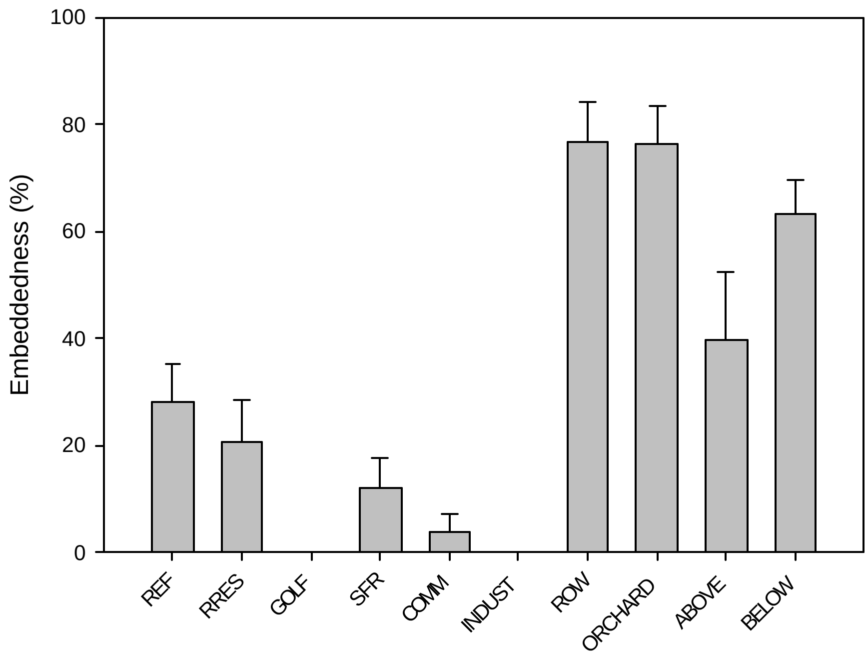


Figure 122. Riffle embeddedness by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

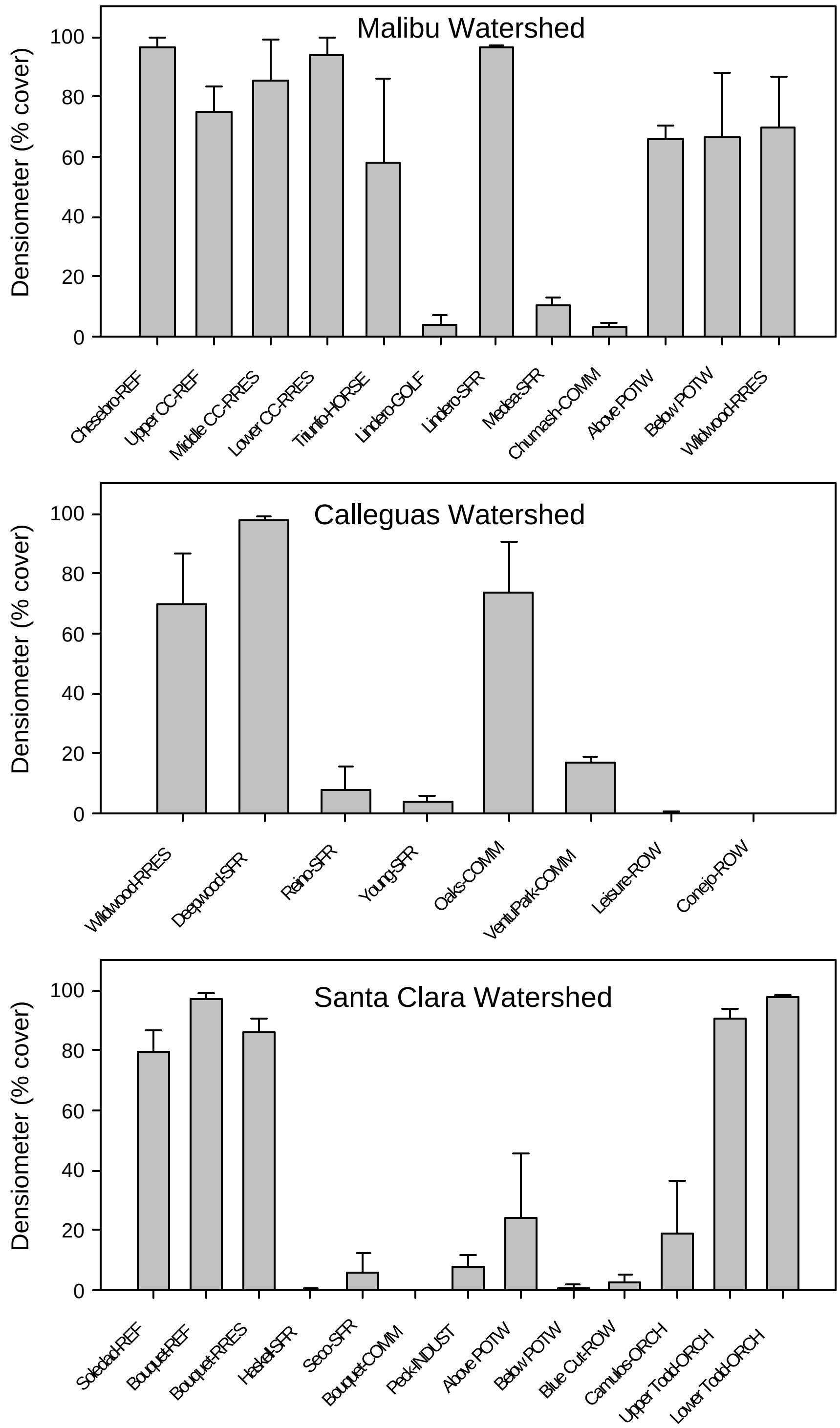


Figure 123. Riffle densiometer cover at all sites.

Densiometer readings were made at six positions across each riffle using EMAP methods.

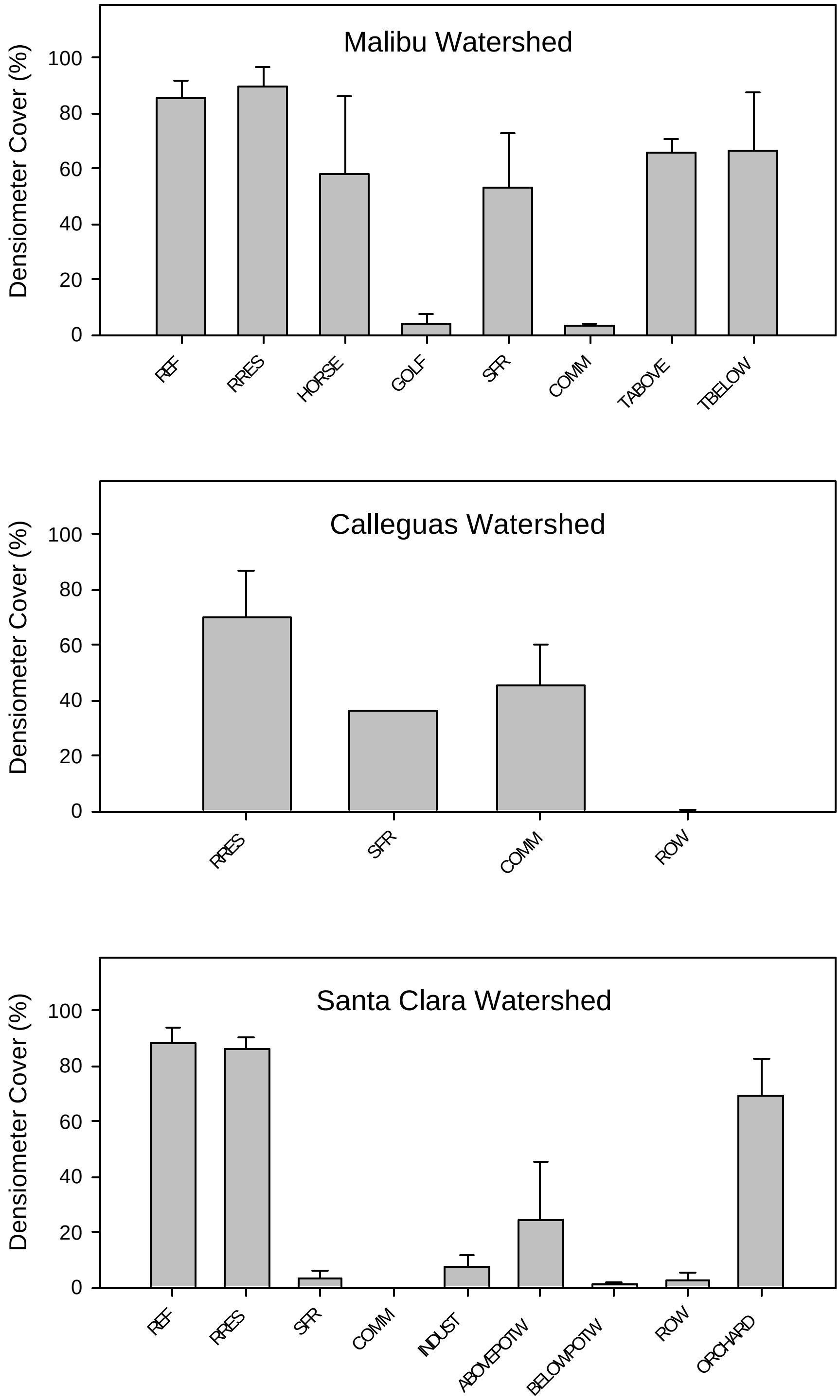


Figure 124. Riffle densiometer cover by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

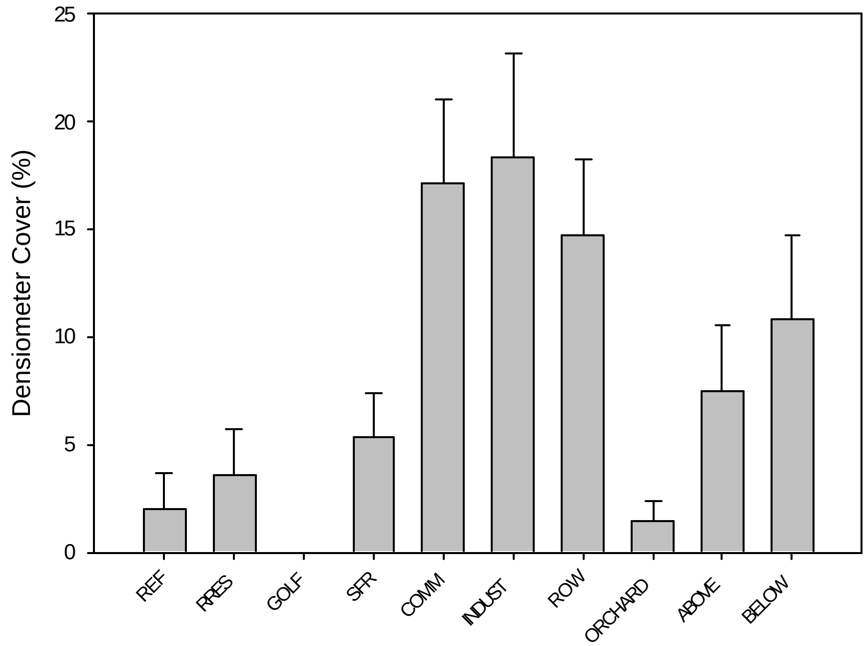


Figure 125. Riffle densiometer cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

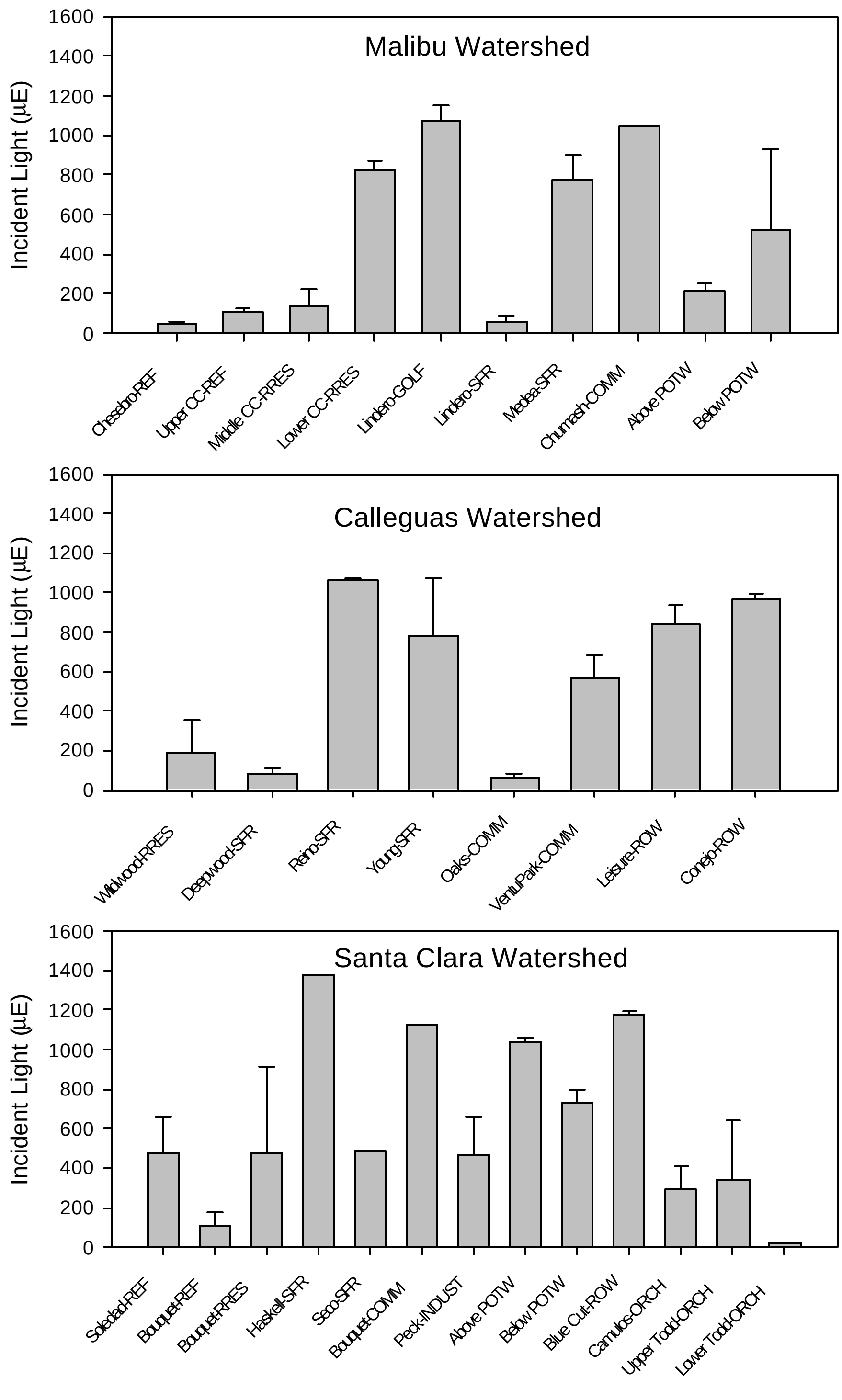


Figure 126. Incident light (Riffles) at all sites.

Incident light was measured using a 1m line quantum sensor centered within the 1X2 ft BMI sampling plots and positioned just above the water at each riffle.

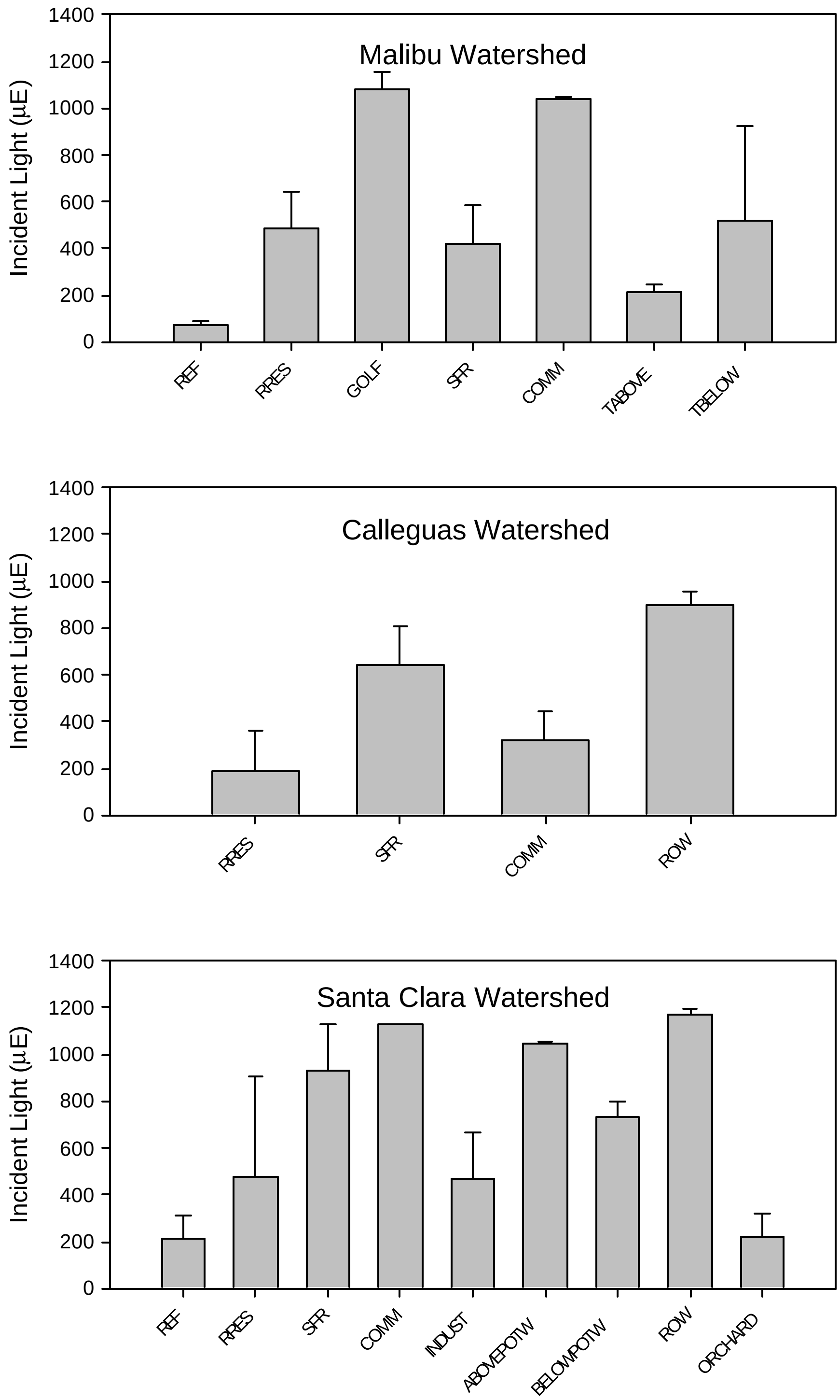


Figure 127. Incident light (Riffles) by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

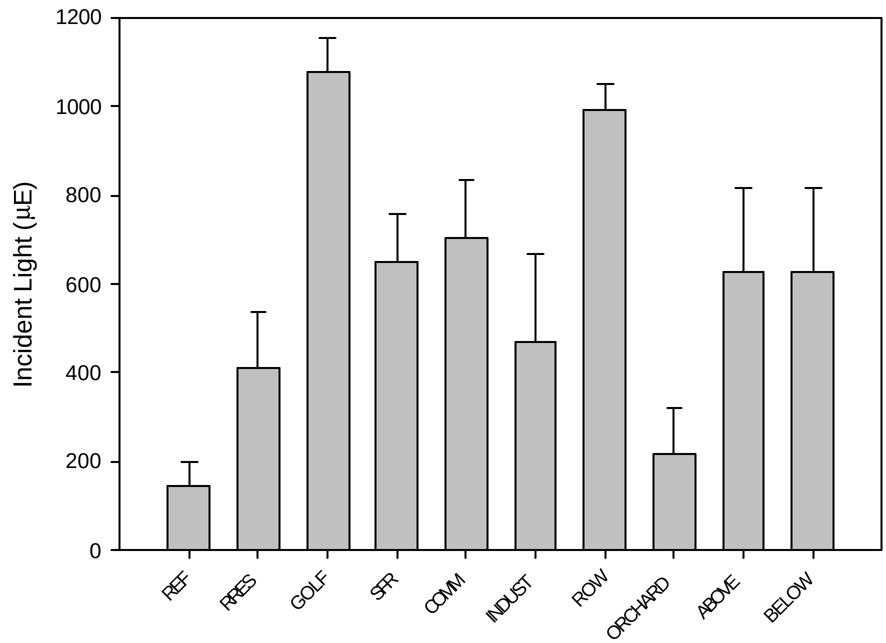


Figure 128. Incident light (Riffles) by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

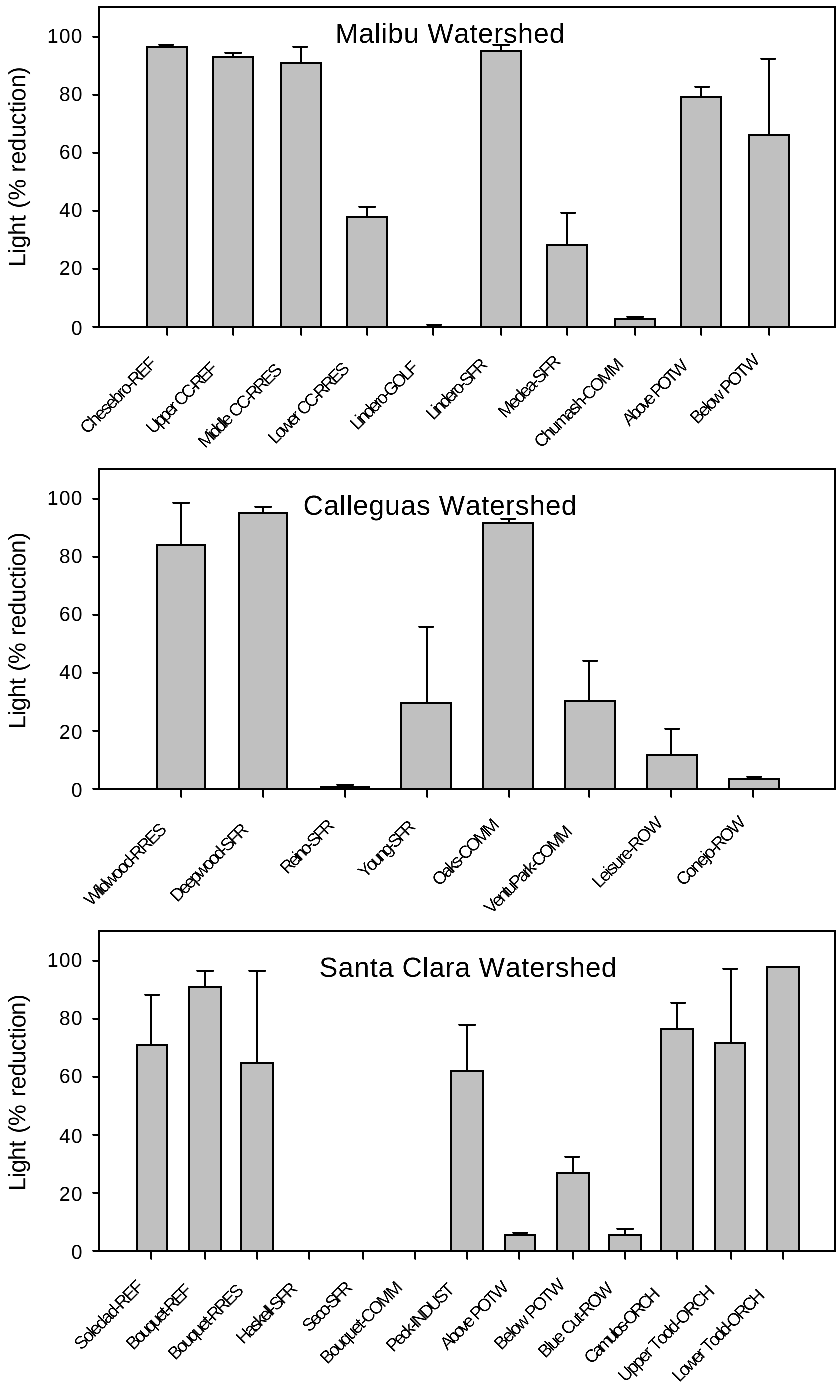


Figure 129. Light reduction (Riffles) at all sites.

Incident light was measured using a 1m line quantum sensor centered within the 1X2 ft BMI sampling plots and positioned just above the water at each riffle. Incident light was also measured in an open area to obtain a full sun reading. Light reduction was calculated for each incident light reading with respect to the full sun reading.

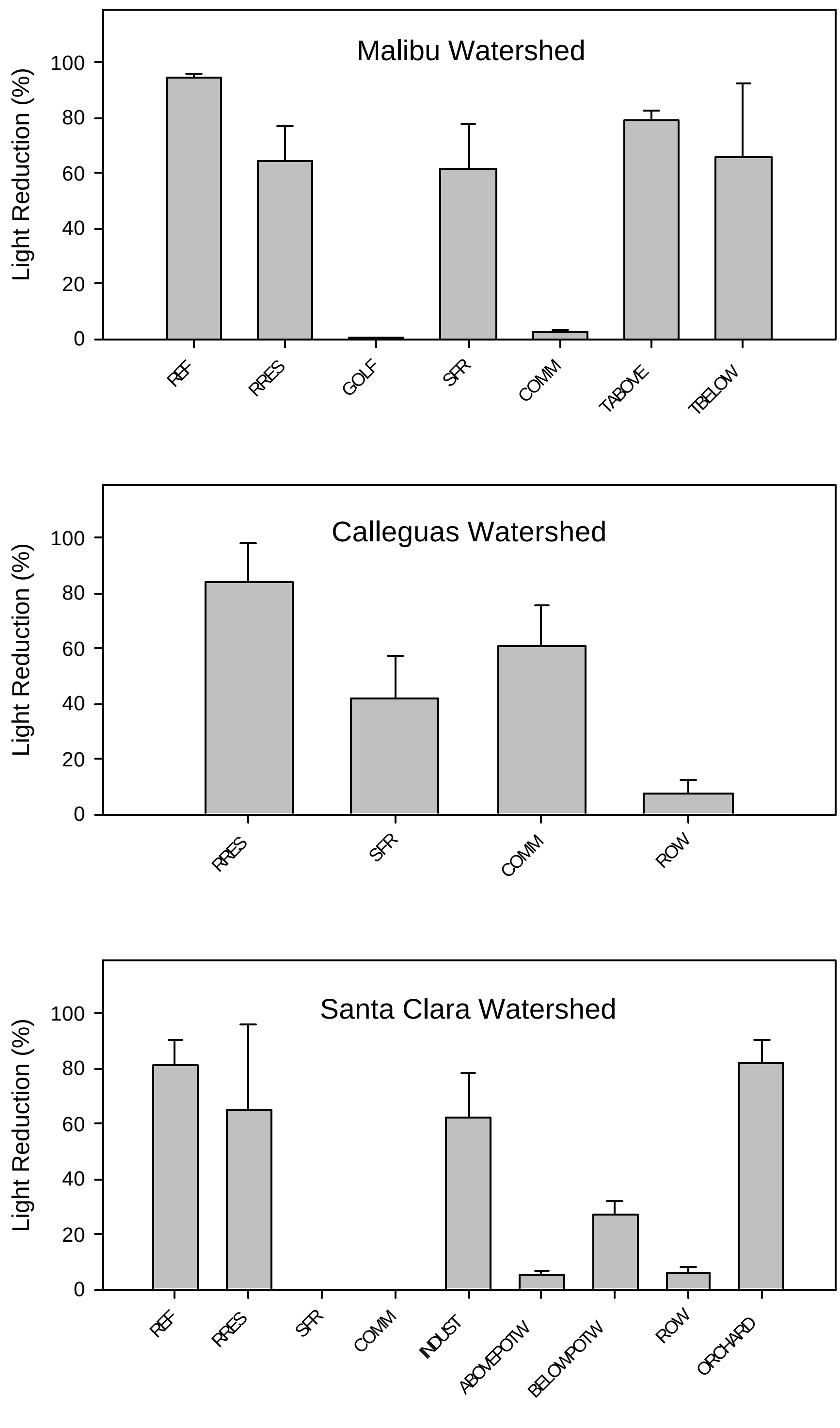


Figure 130. Light reduction (Riffles) by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

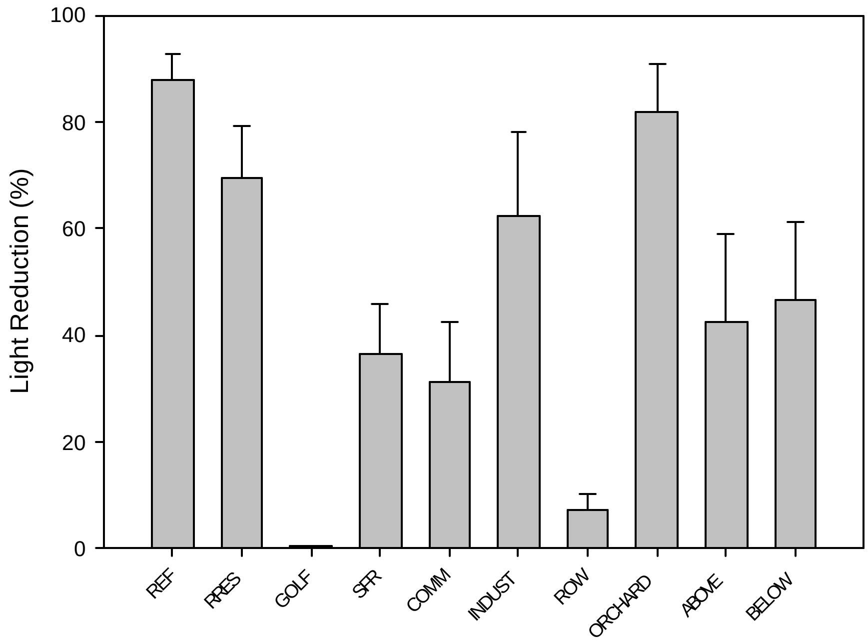


Figure 131. Light reduction (Riffles) by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

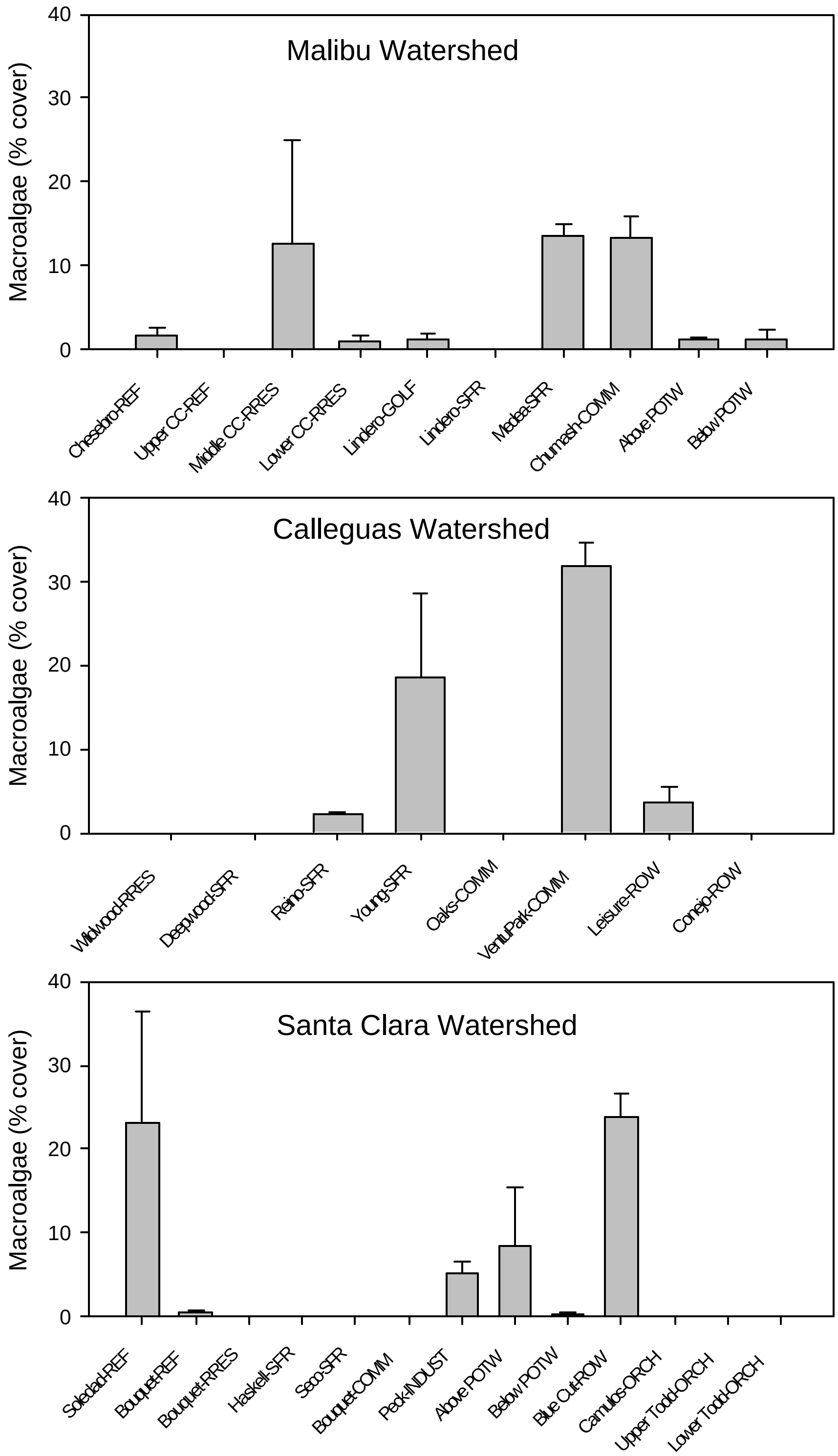


Figure 132. Riffle macroalgae cover at all sites.

Macroalgae was estimated within the 1X2 ft BMI sampling plots at each riffle.

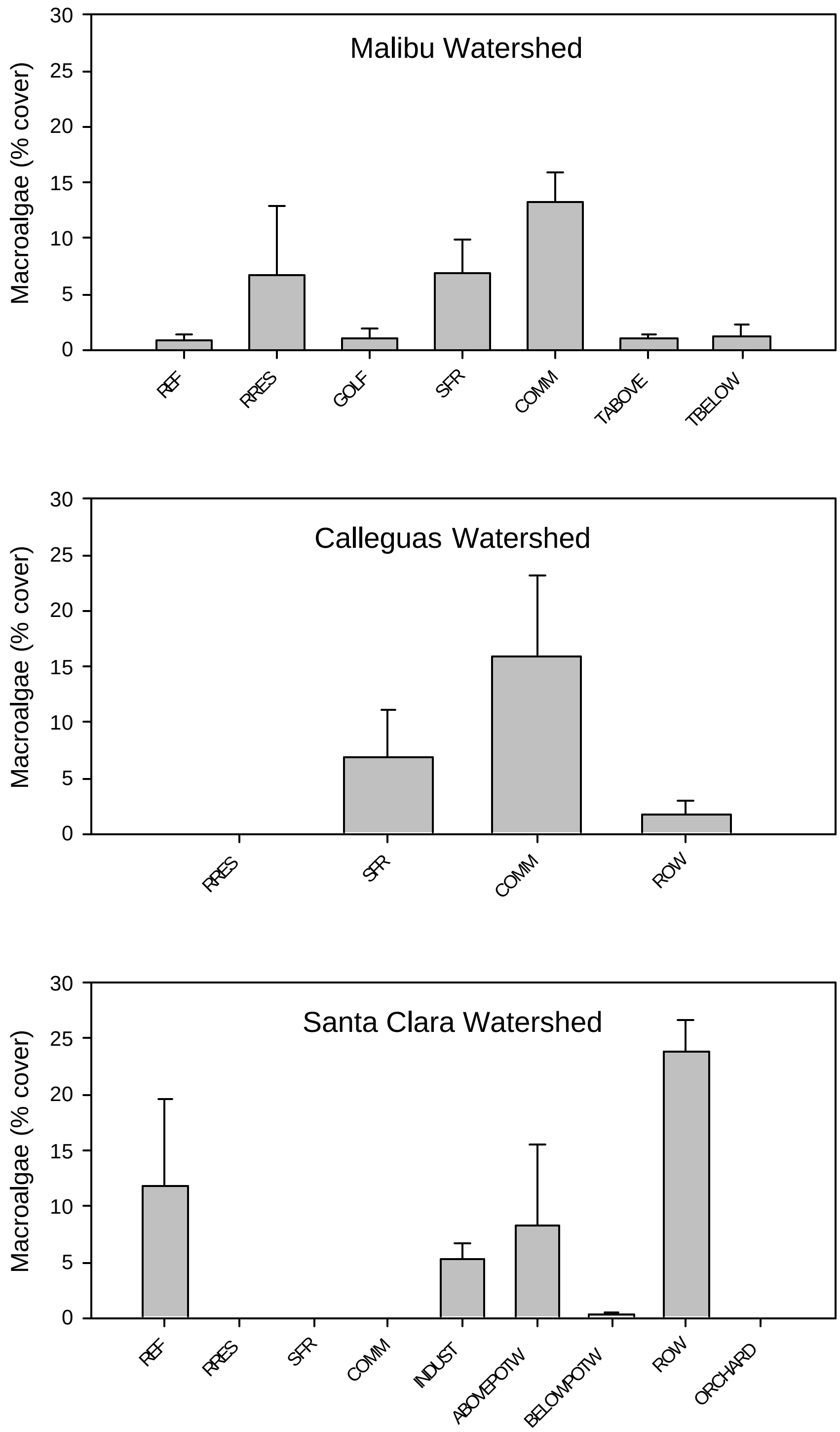


Figure 133. Riffle macroalgae cover by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

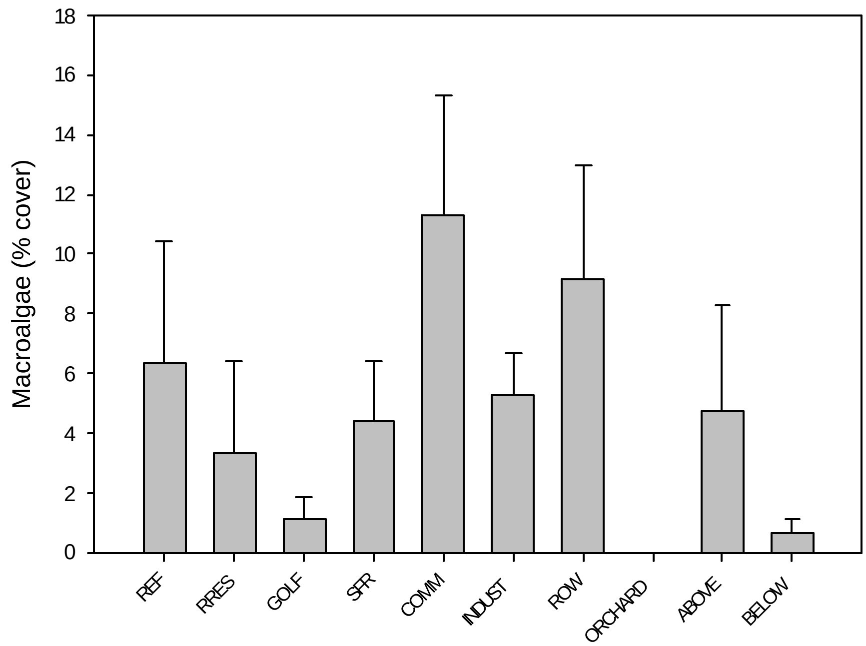


Figure 134. Riffle macroalgae cover by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

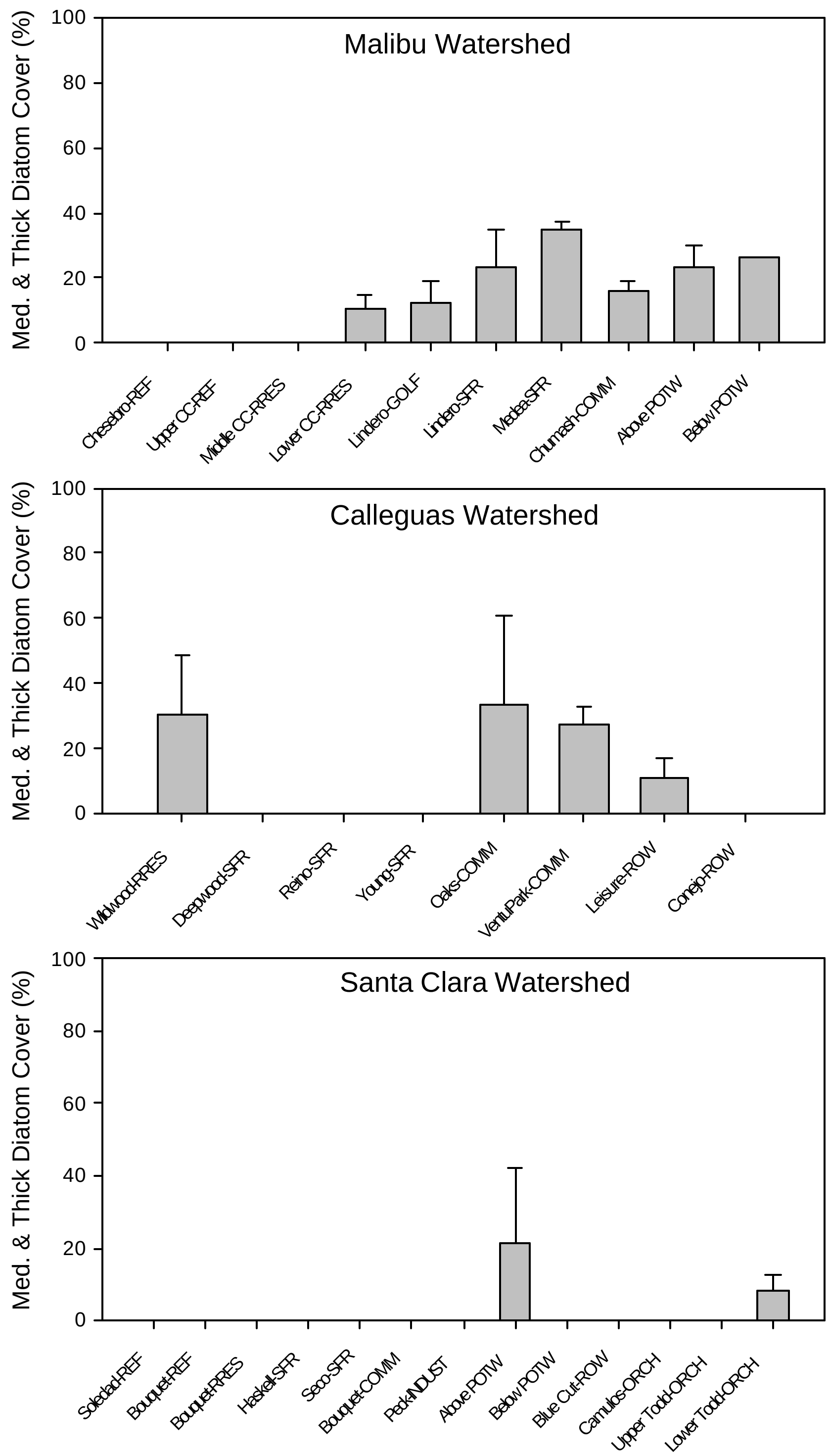


Figure 135. Medium and thick diatom cover (Riffles) at all sites.

Diatoms were estimated within the 1X2 ft BMI sampling plots at each riffle. Diatoms were categorized according to the thickness of the periphyton (DF <1mm, 1mm<DM<5mm, DT>5mm).

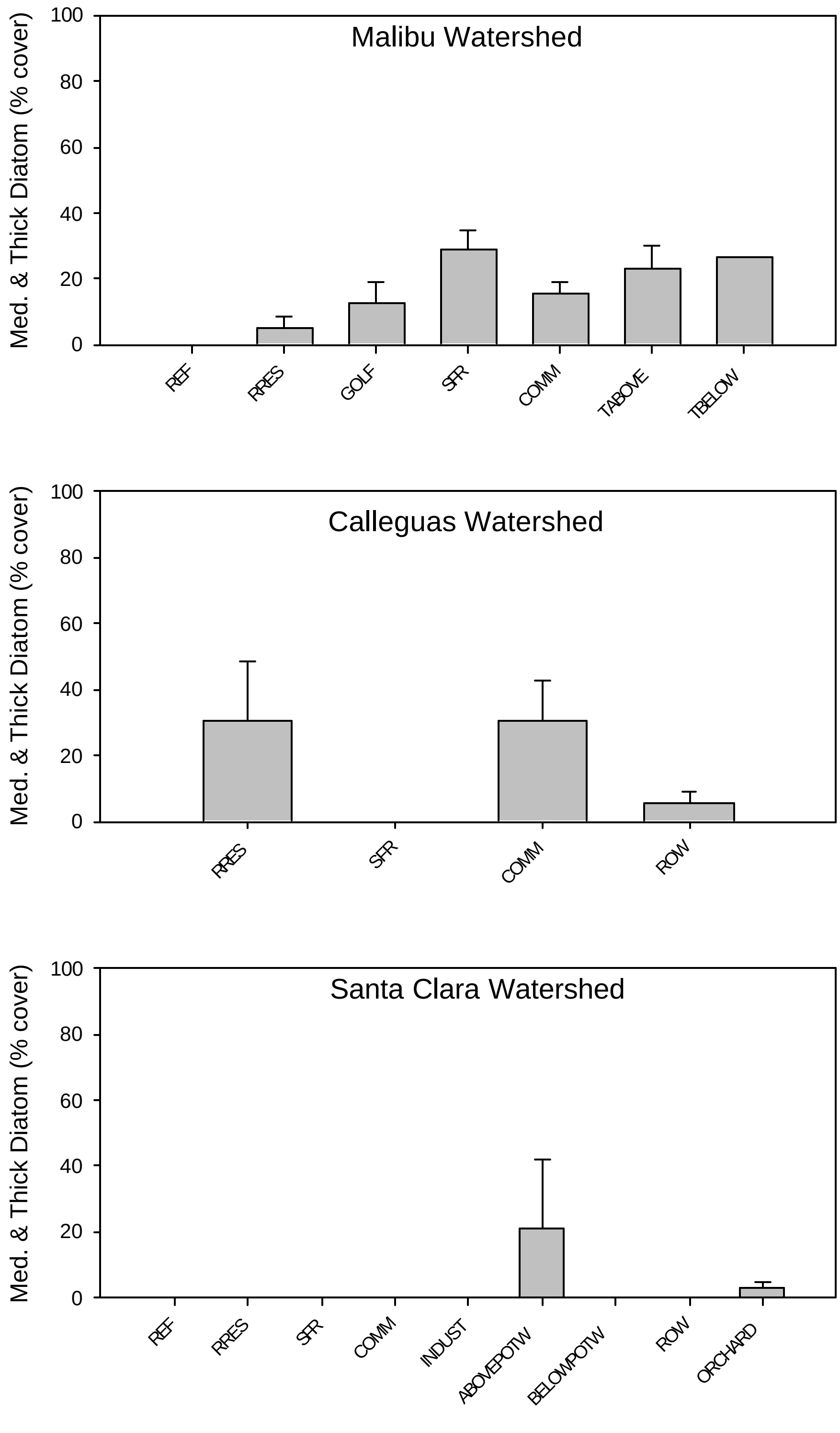


Figure 136. Medium and thick diatom cover (Riffles) by land use within each watershed. Sites of similar land use were combined within each of the three watersheds.

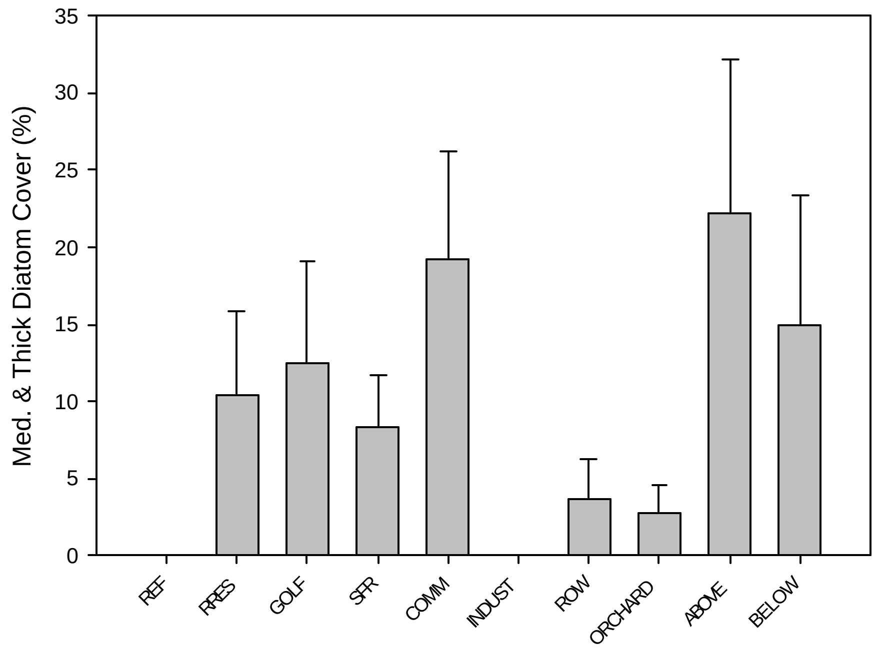


Figure 137. Medium and thick diatom cover (Riffles) by land use among watersheds. Sites of similar land use were combined or averaged across all three watersheds.

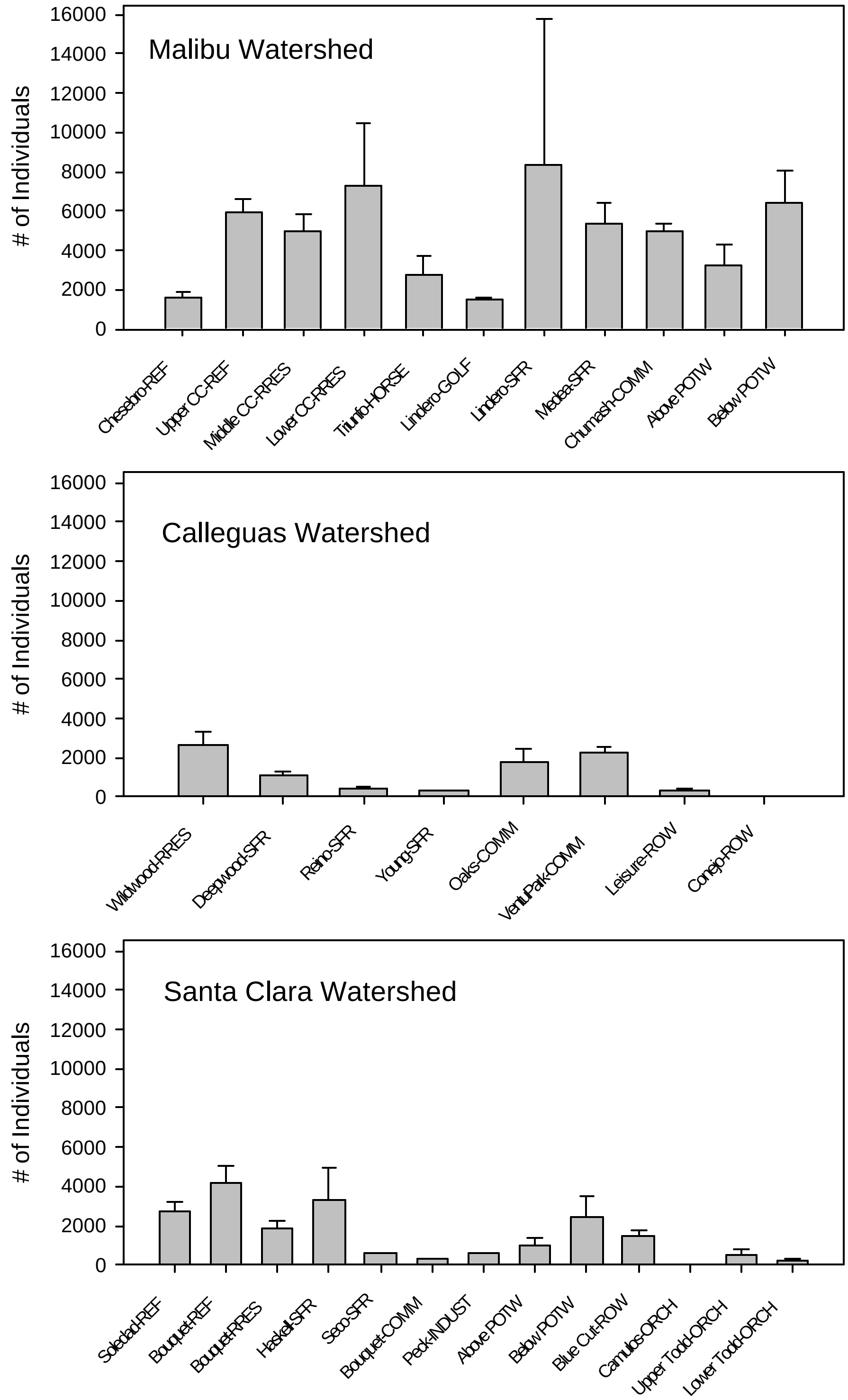


Figure 138. Number of benthic macroinvertebrate individuals at all sites.

Benthic macroinvertebrates were sampled within three 1X2 ft plots at each riffle, using Dept. of Fish and Game methods.

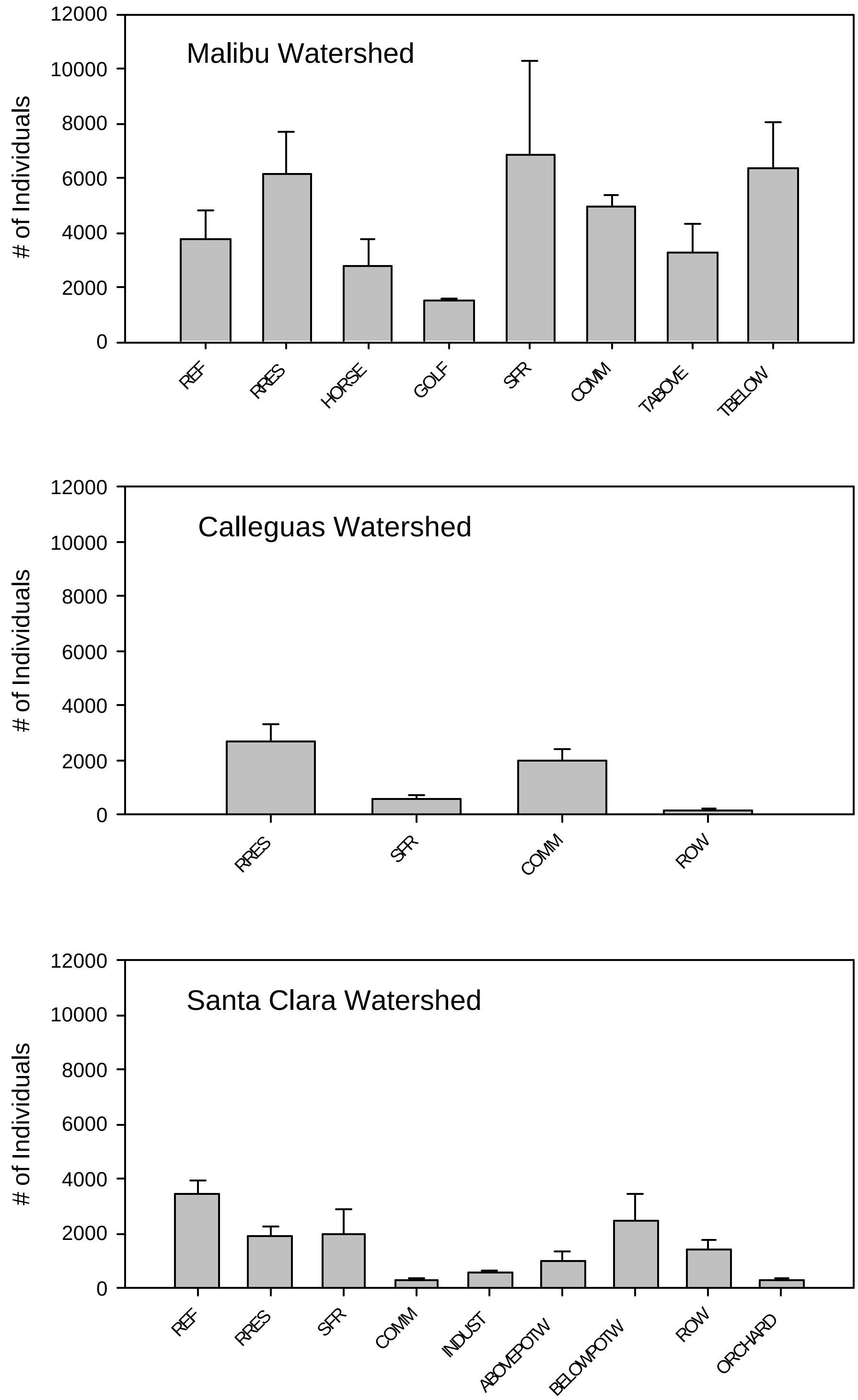


Figure 139. Number of benthic macroinvertebrate individuals by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

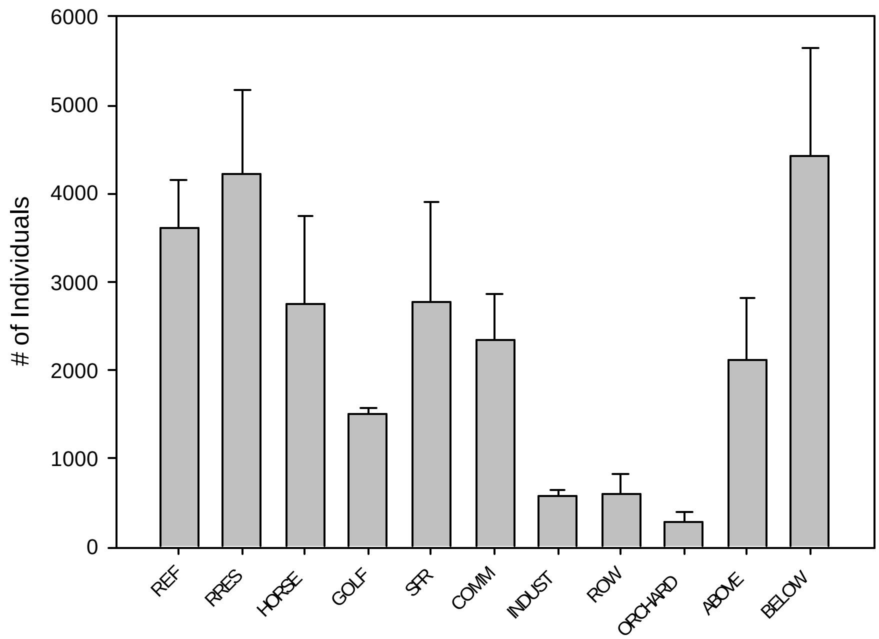


Figure 140. Number of benthic macroinvertebrate individuals by land use among watersheds. Sites of similar land use were combined or averaged across all three watersheds.

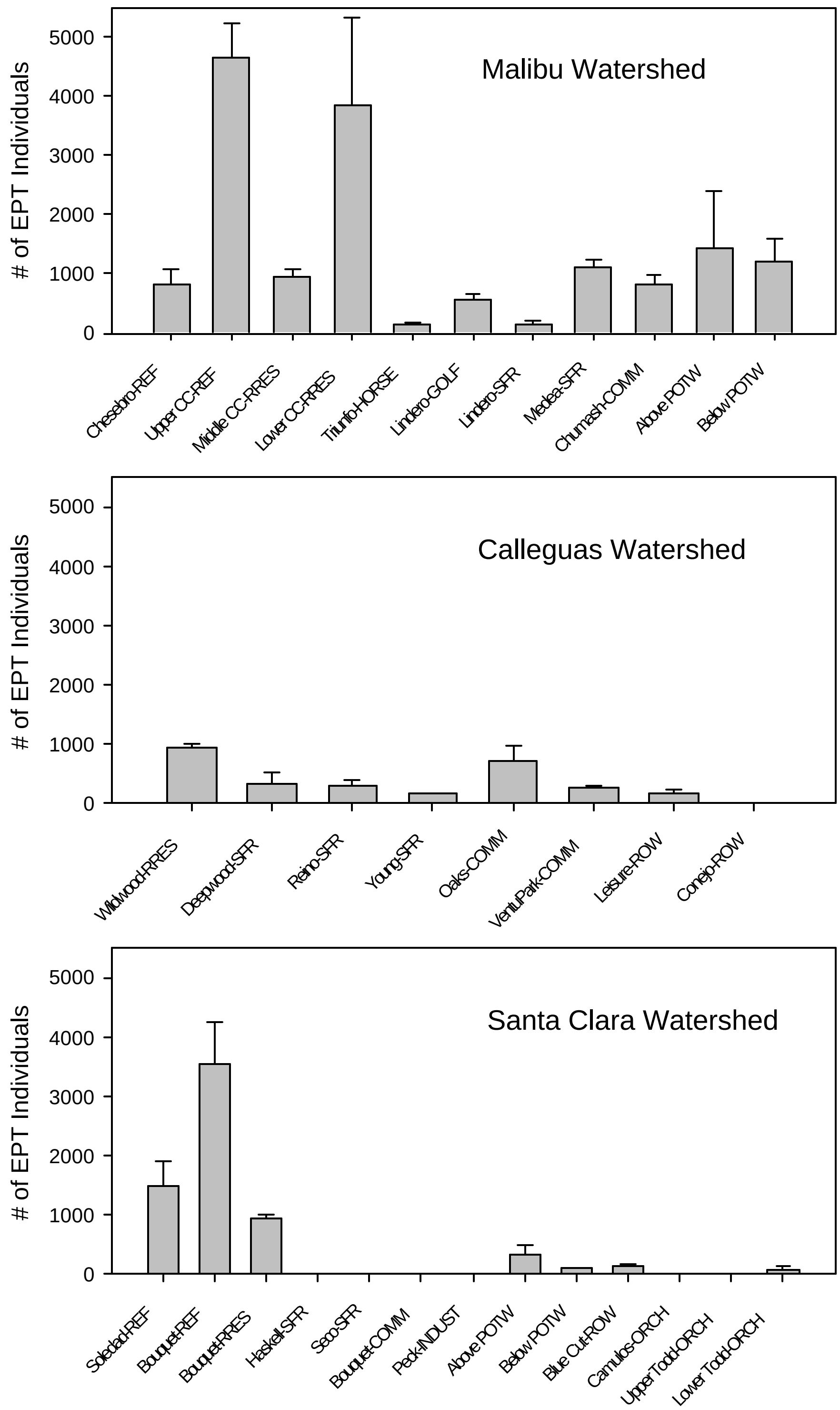


Figure 141. Number of EPT benthic macroinvertebrate individuals at all sites.

Benthic macroinvertebrates were sampled within three 1X2 ft plots at each riffle, using Dept. of Fish and Game methods.

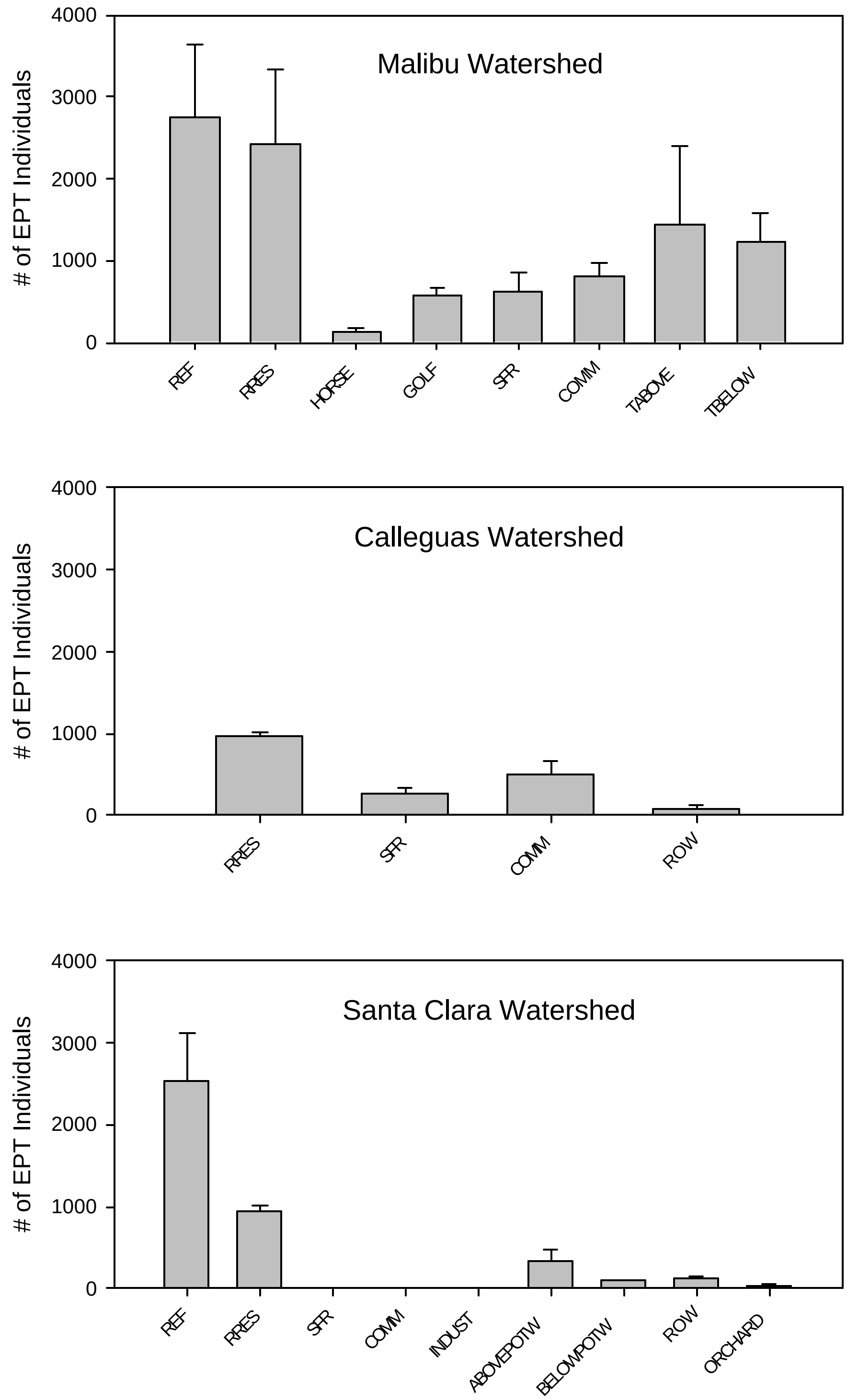


Figure 142. Number of EPT benthic macroinvertebrate individuals by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

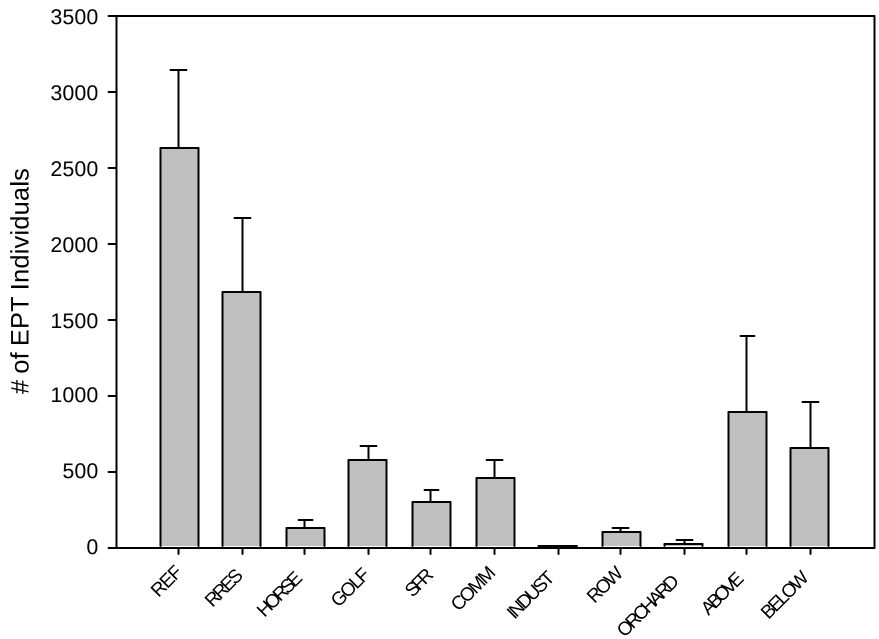


Figure 143. Number of EPT benthic macroinvertebrate individuals by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

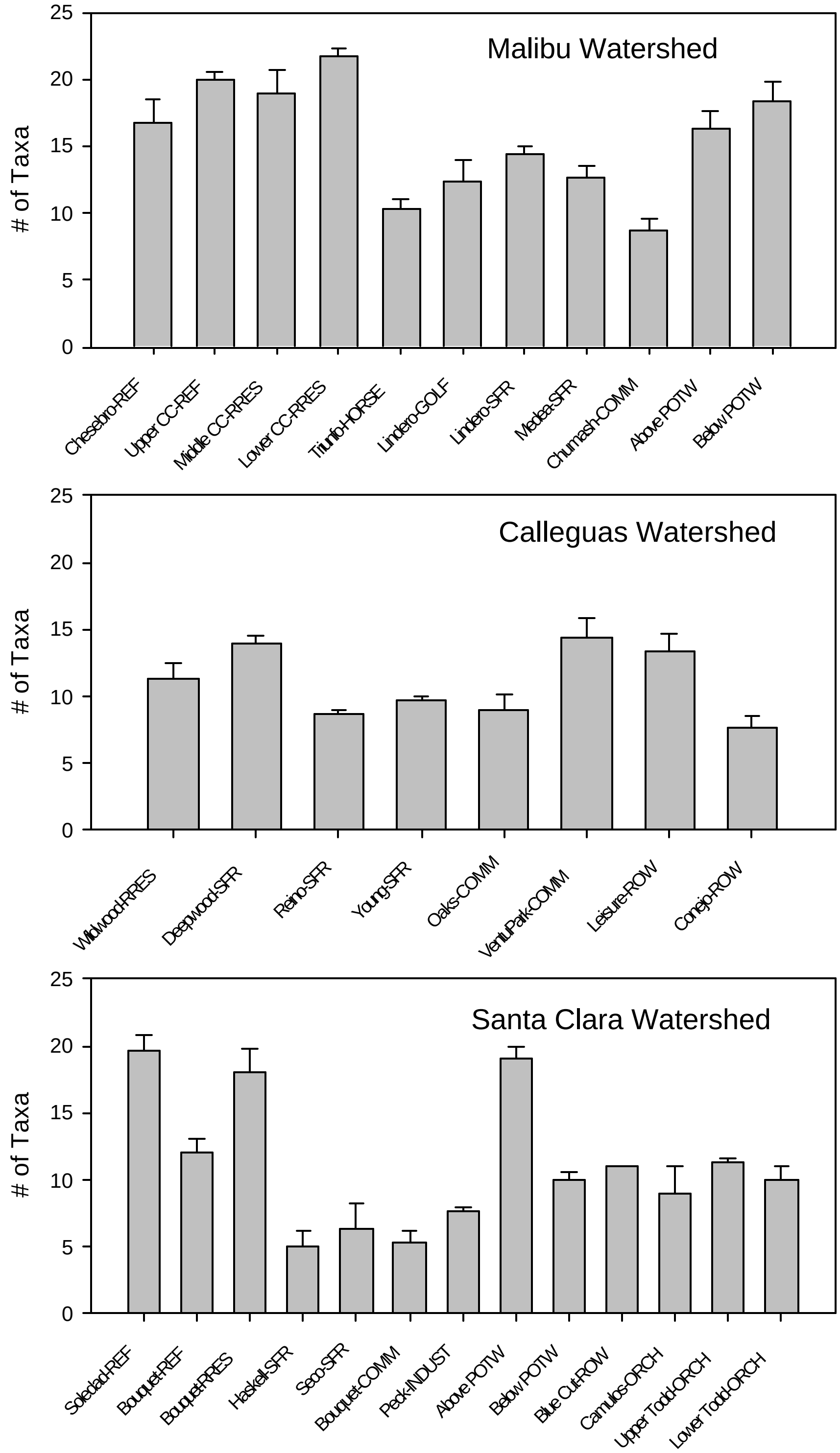


Figure 144. Number of benthic macroinvertebrate taxa at all sites.

Benthic macroinvertebrates were sampled within three 1X2 ft plots at each riffle, using Dept. of Fish and Game methods.

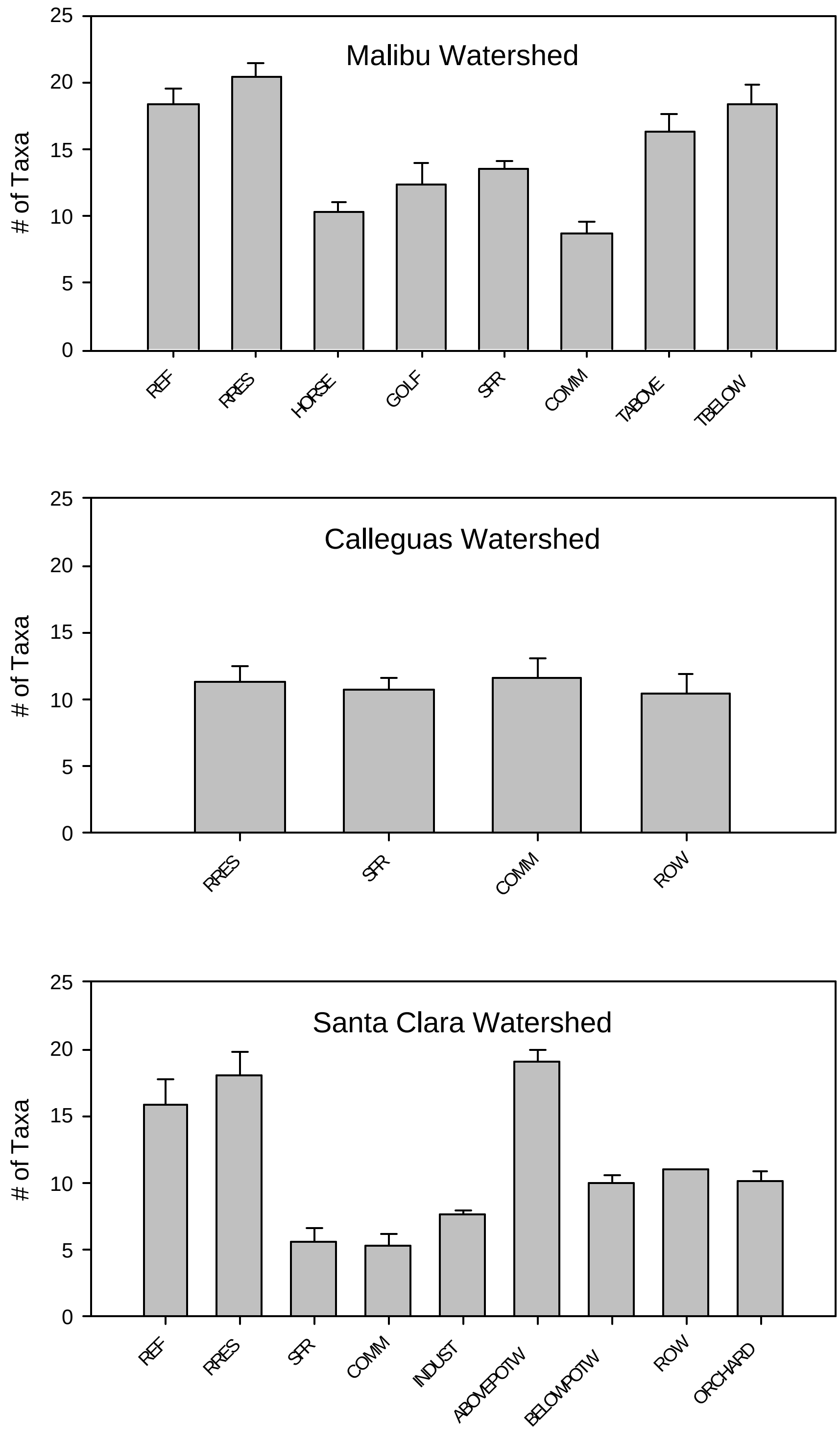


Figure 145. Number of benthic macroinvertebrate taxa by land use within each watershed. Sites of similar land use were combined within each of the three watersheds.

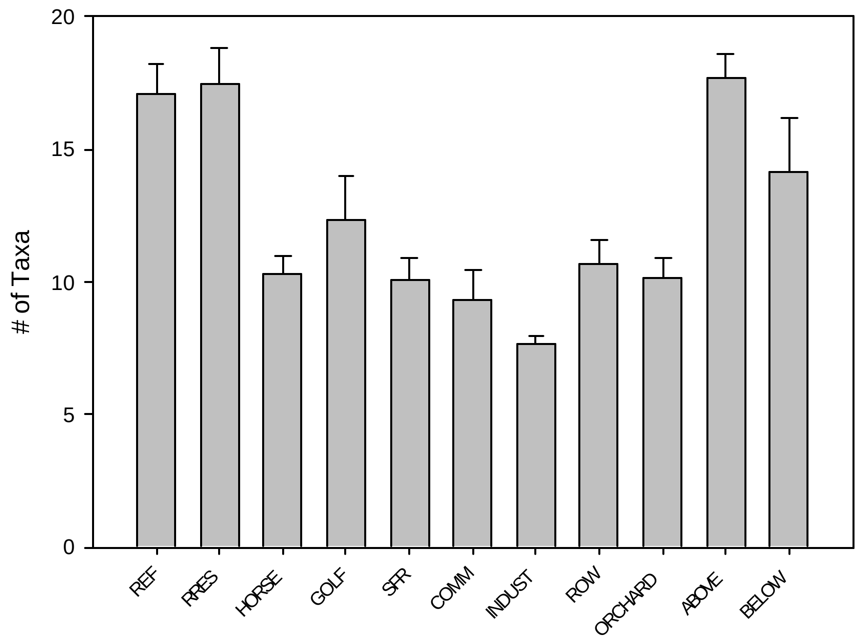


Figure 146. Number of benthic macroinvertebrate taxa by land use among watersheds. Sites of similar land use were combined or averaged across all three watersheds.

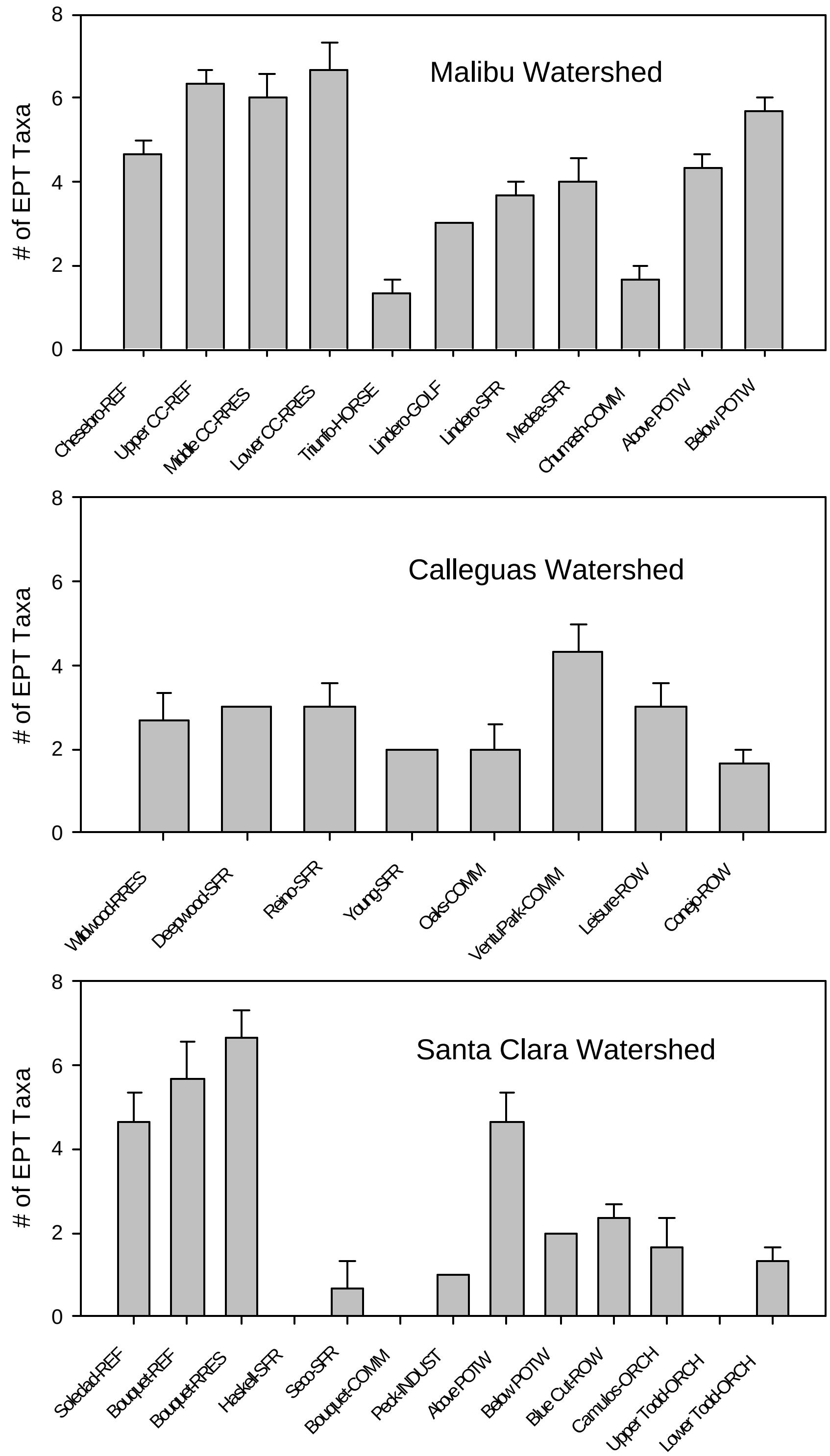


Figure 147. Number of EPT benthic macroinvertebrate taxa at all sites.

Benthic macroinvertebrates were sampled within three 1X2 ft plots at each riffle, using Dept. of Fish and Game methods.

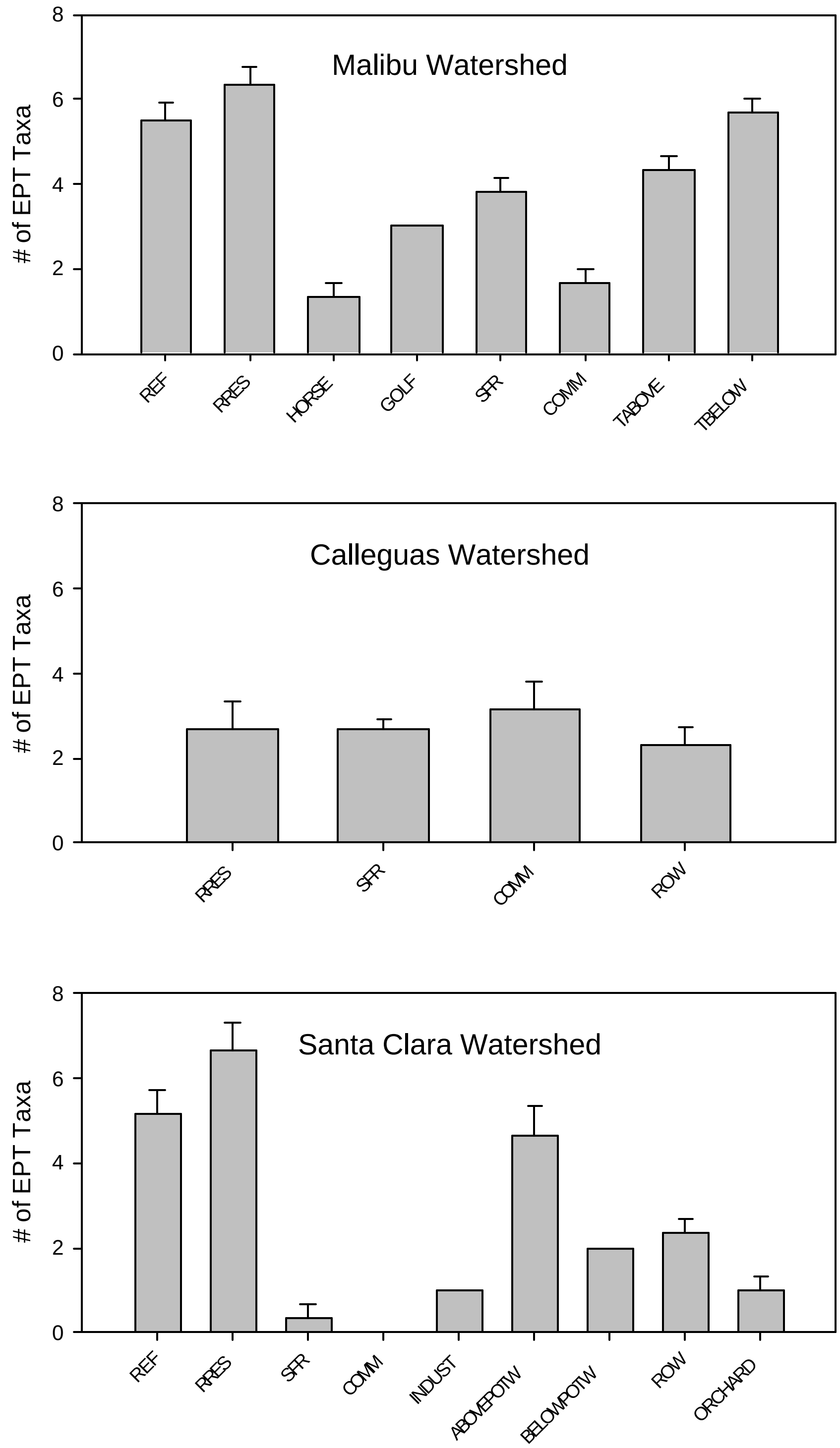


Figure 148. Number of EPT benthic macroinvertebrate taxa by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

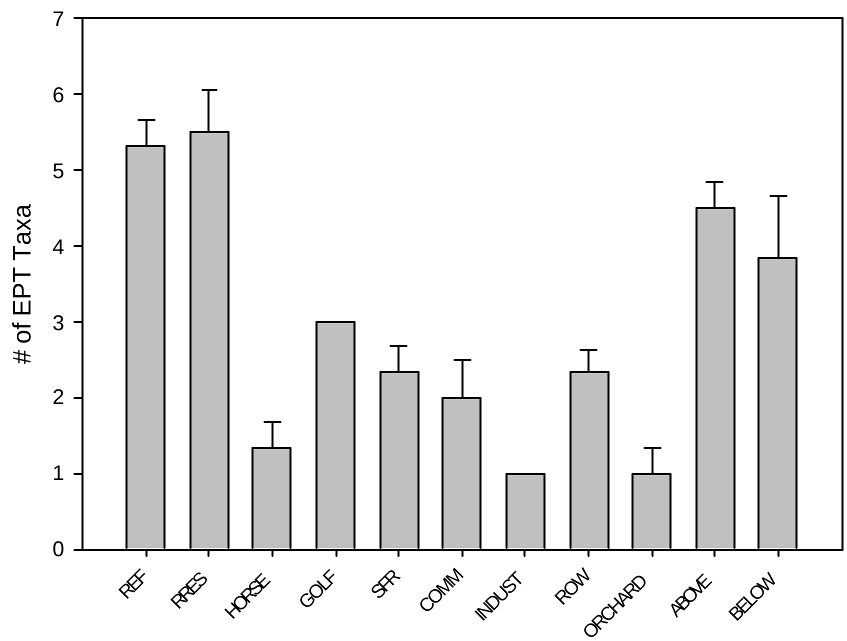


Figure 149. Number of EPT benthic macroinvertebrate taxa by land use among watersheds. Sites of similar land use were combined or averaged across all three watersheds.

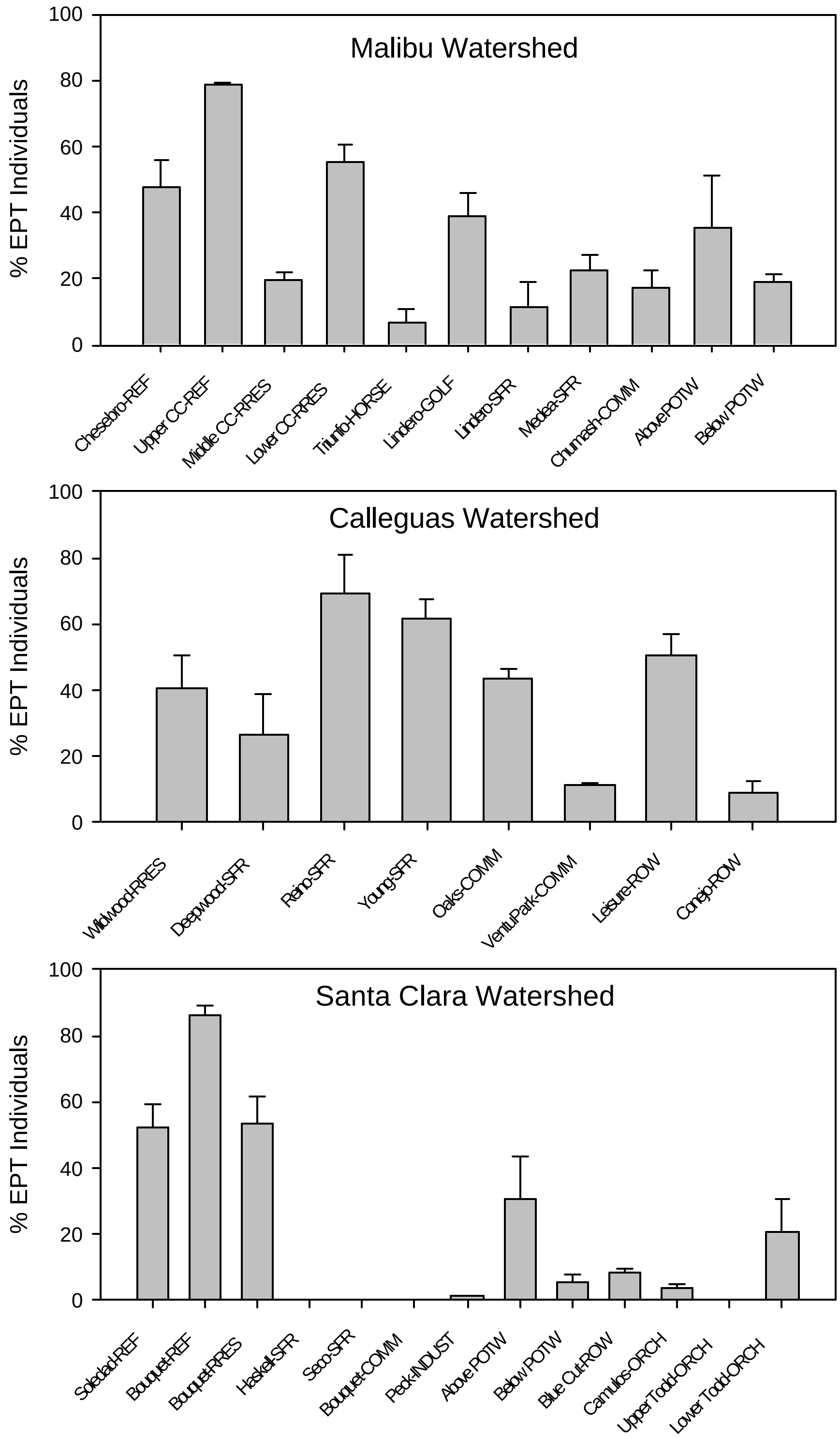


Figure 150. % EPT benthic macroinvertebrate individuals at all sites.

Benthic macroinvertebrates were sampled within three 1X2 ft plots at each riffle, using Dept. of Fish and Game methods.

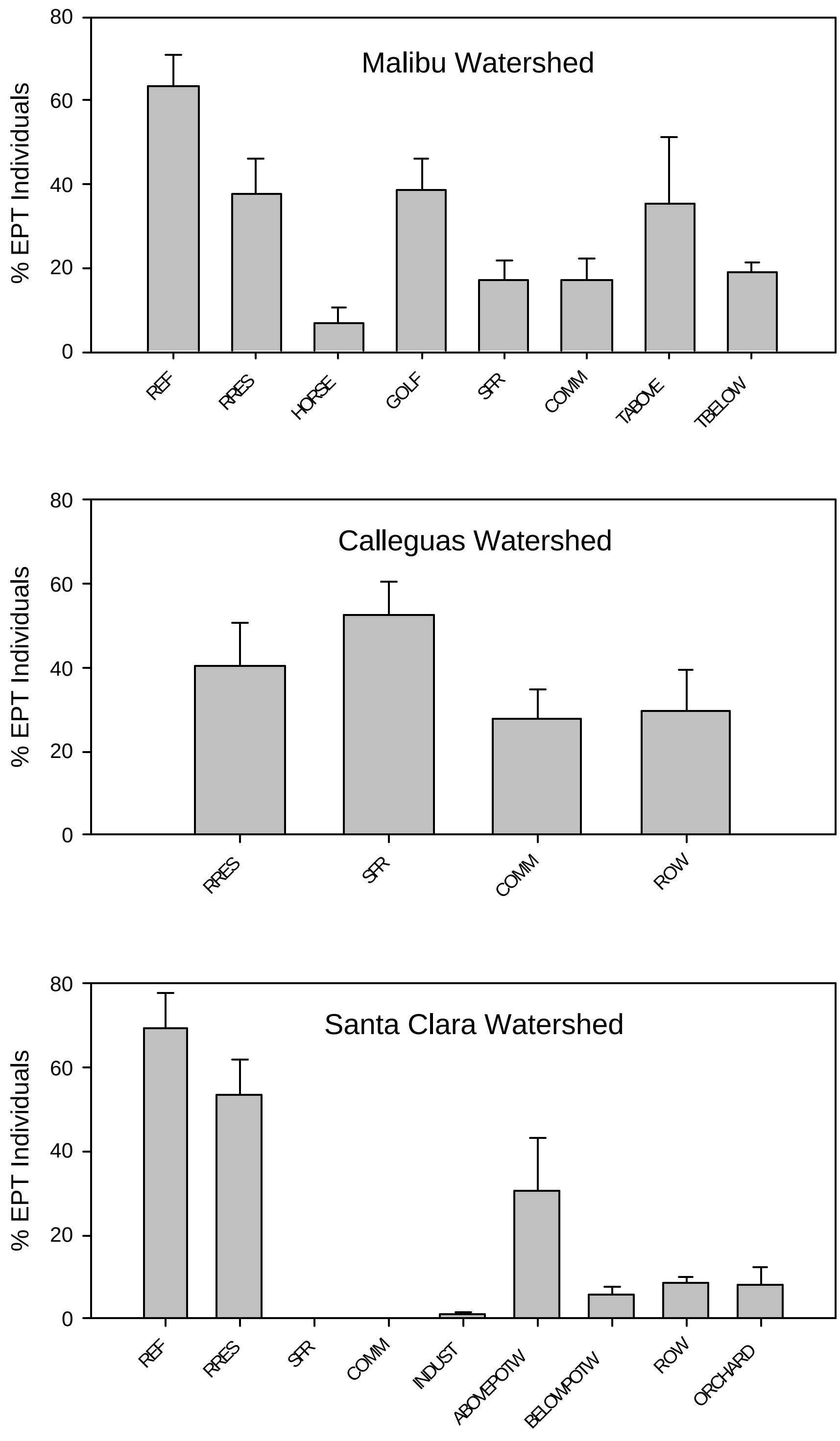


Figure 151. % EPT benthic macroinvertebrate individuals by land use within each watershed. Sites of similar land use were combined within each of the three watersheds.

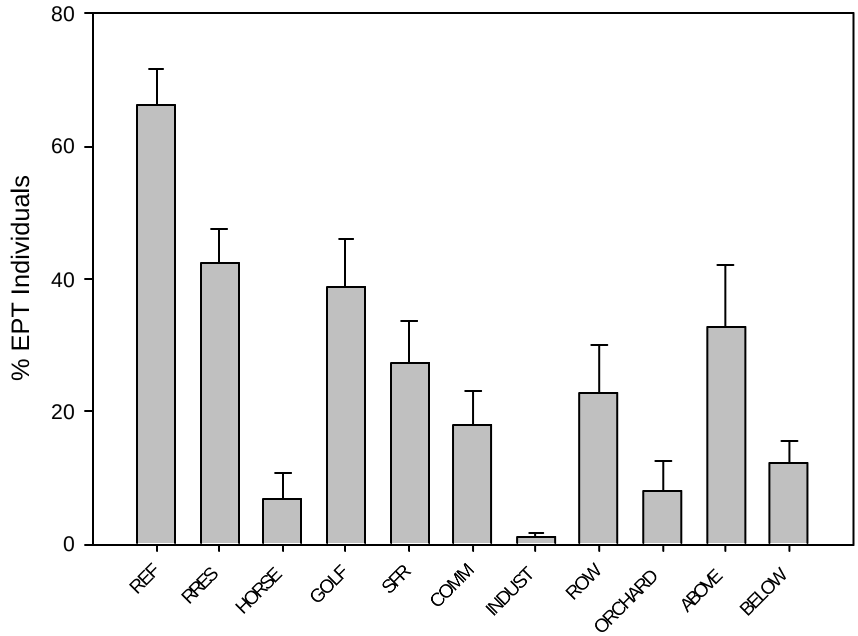


Figure 152. % EPT benthic macroinvertebrate individuals by land use among watersheds. Sites of similar land use were combined or averaged across all three watersheds.

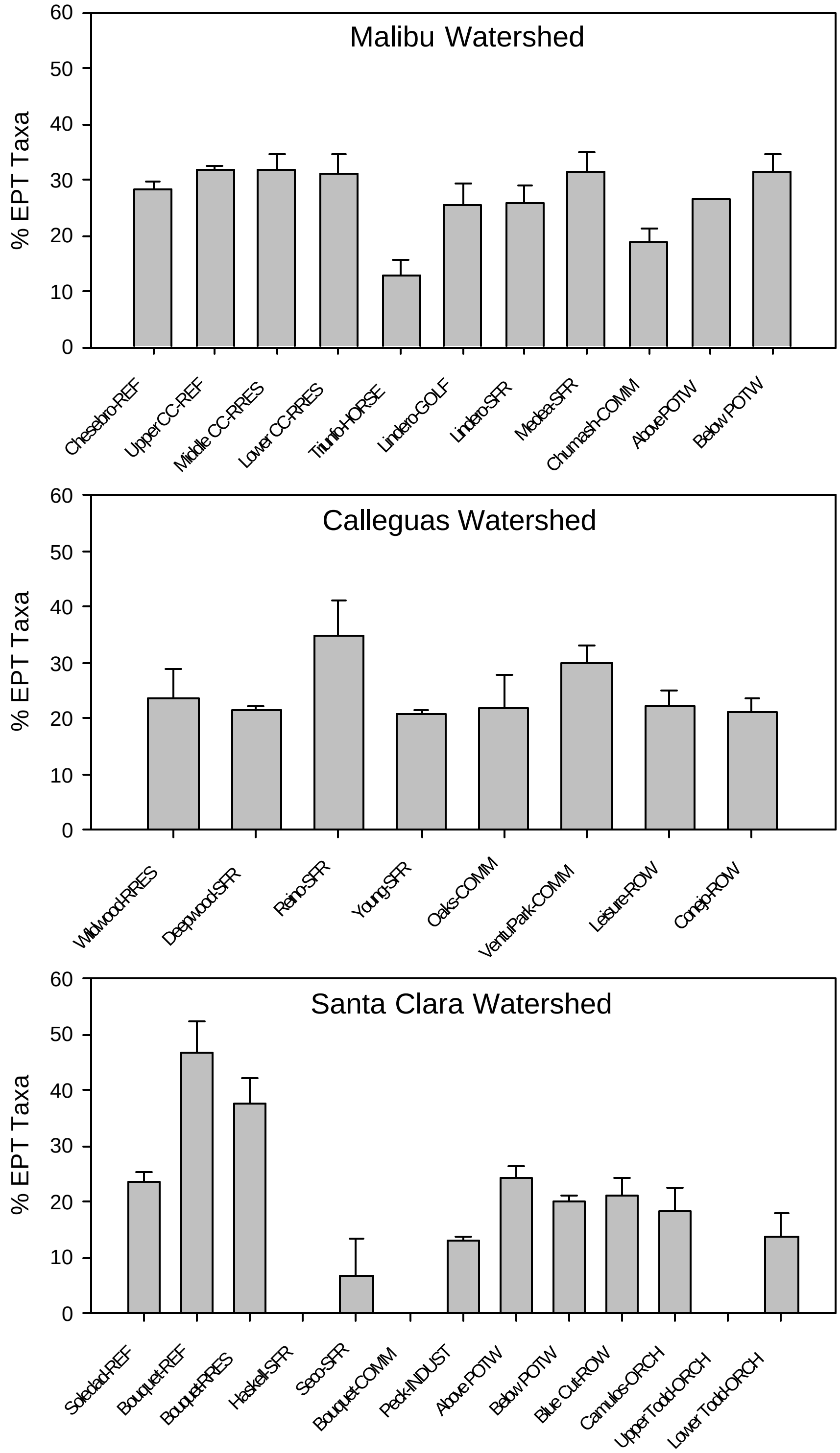


Figure 153. % EPT benthic macroinvertebrate taxa at all sites.

Benthic macroinvertebrates were sampled within three 1X2 ft plots at each riffle, using Dept. of Fish and Game methods.

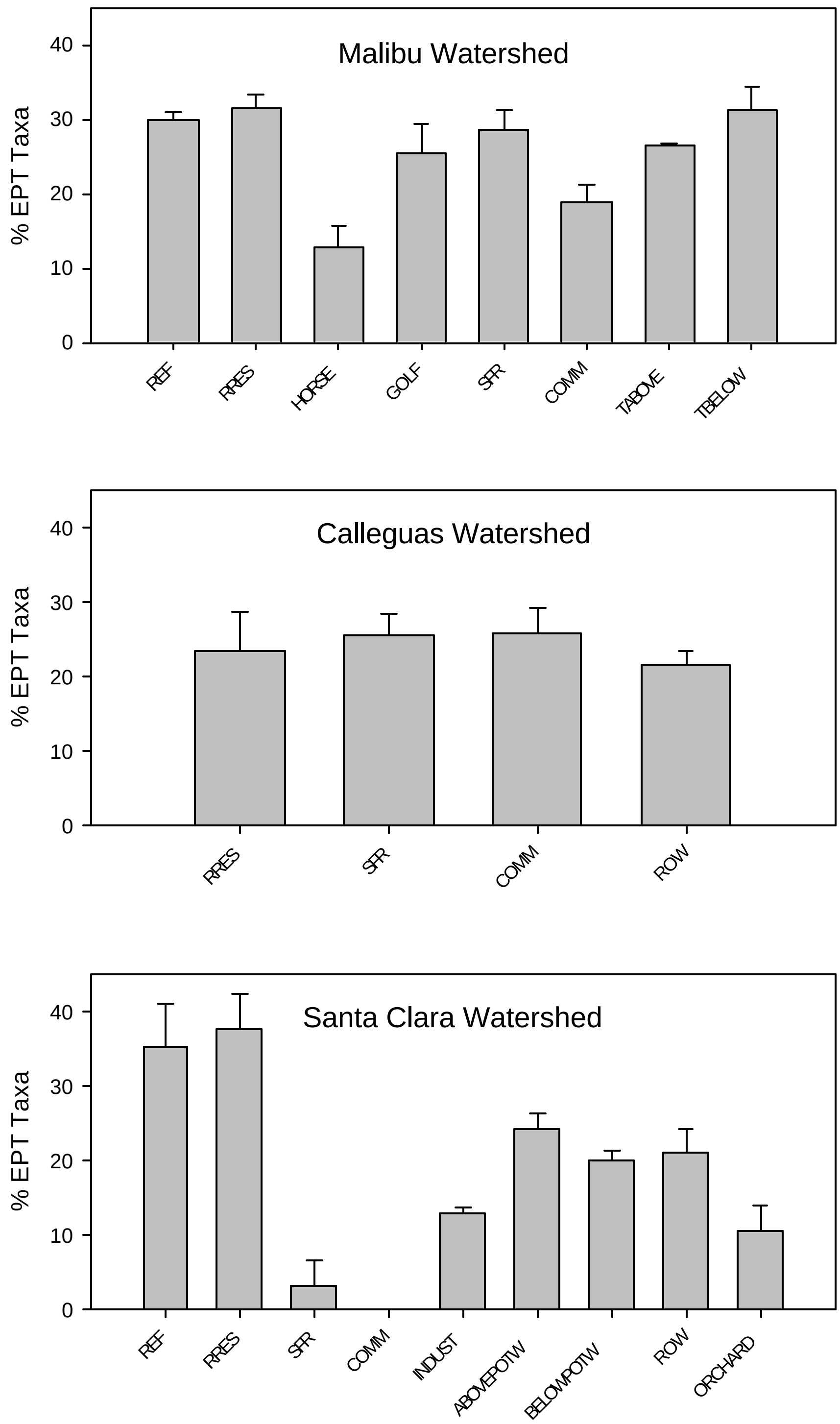


Figure 154. % EPT benthic macroinvertebrate taxa by land use within each watershed. Sites of similar land use were combined within each of the three watersheds.

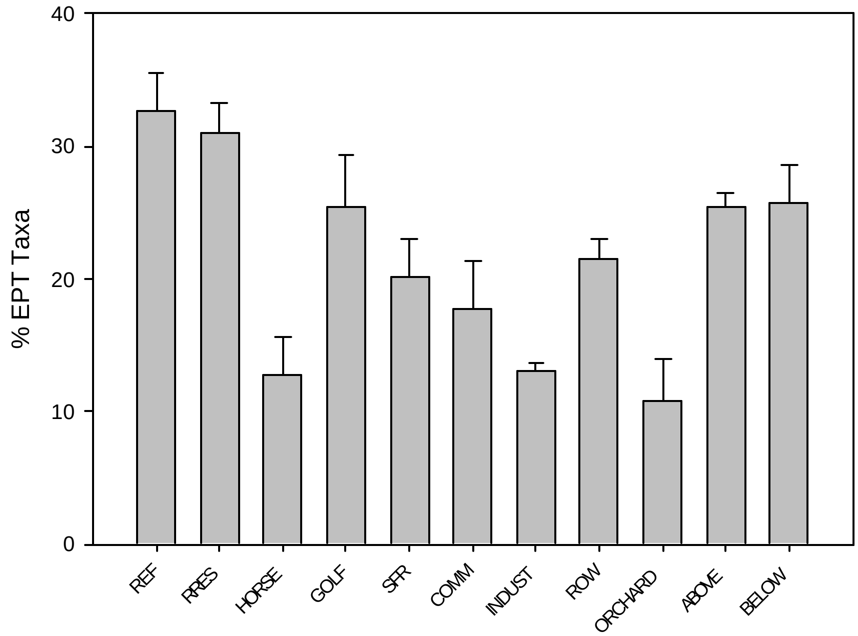


Figure 155. % EPT benthic macroinvertebrate taxa by land use among watersheds. Sites of similar land use were combined or averaged across all three watersheds.

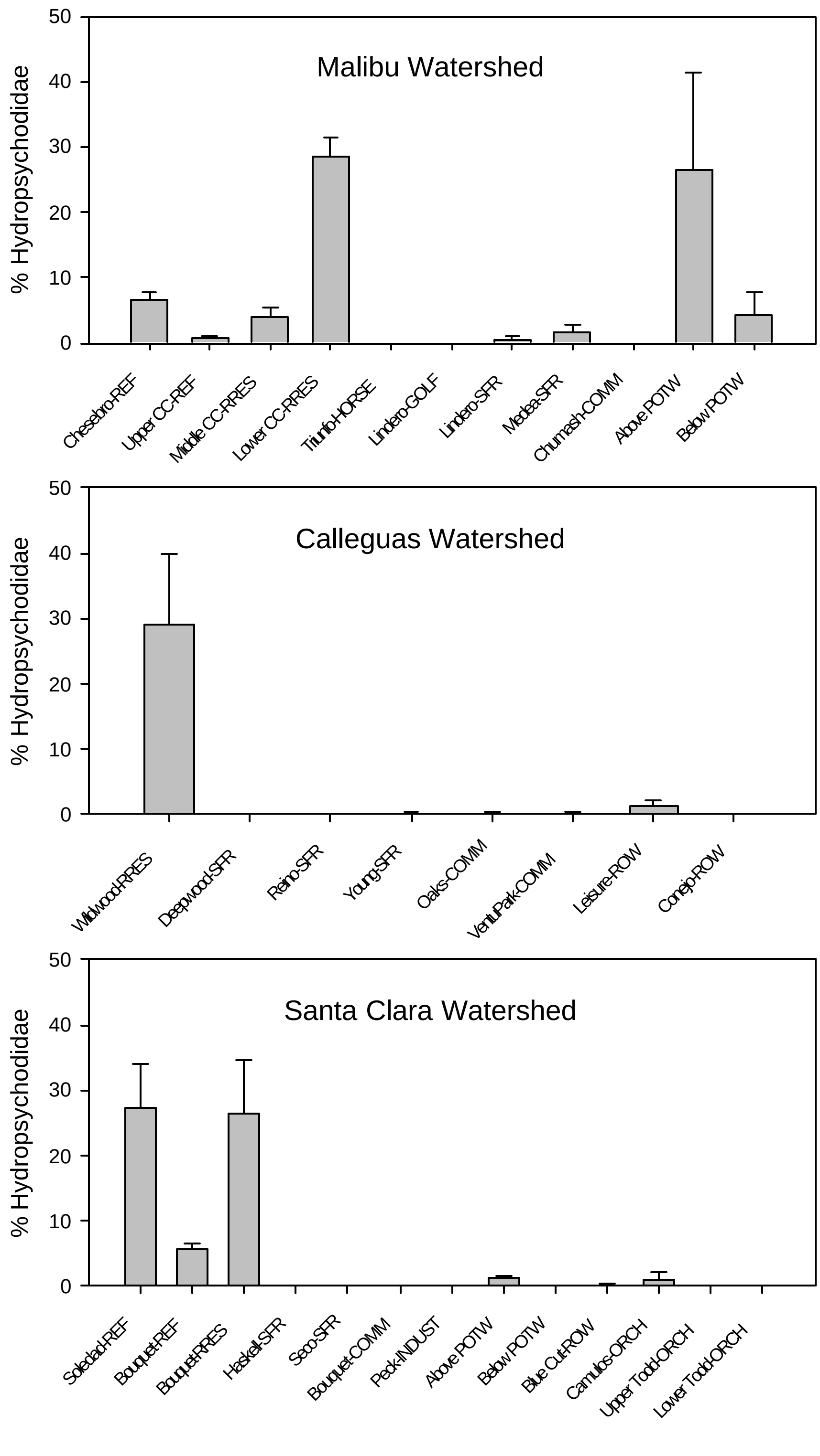


Figure 156. % Hydropsychodidae individuals at all sites.

Benthic macroinvertebrates were sampled within three 1X2 ft plots at each riffle, using Dept. of Fish and Game methods.

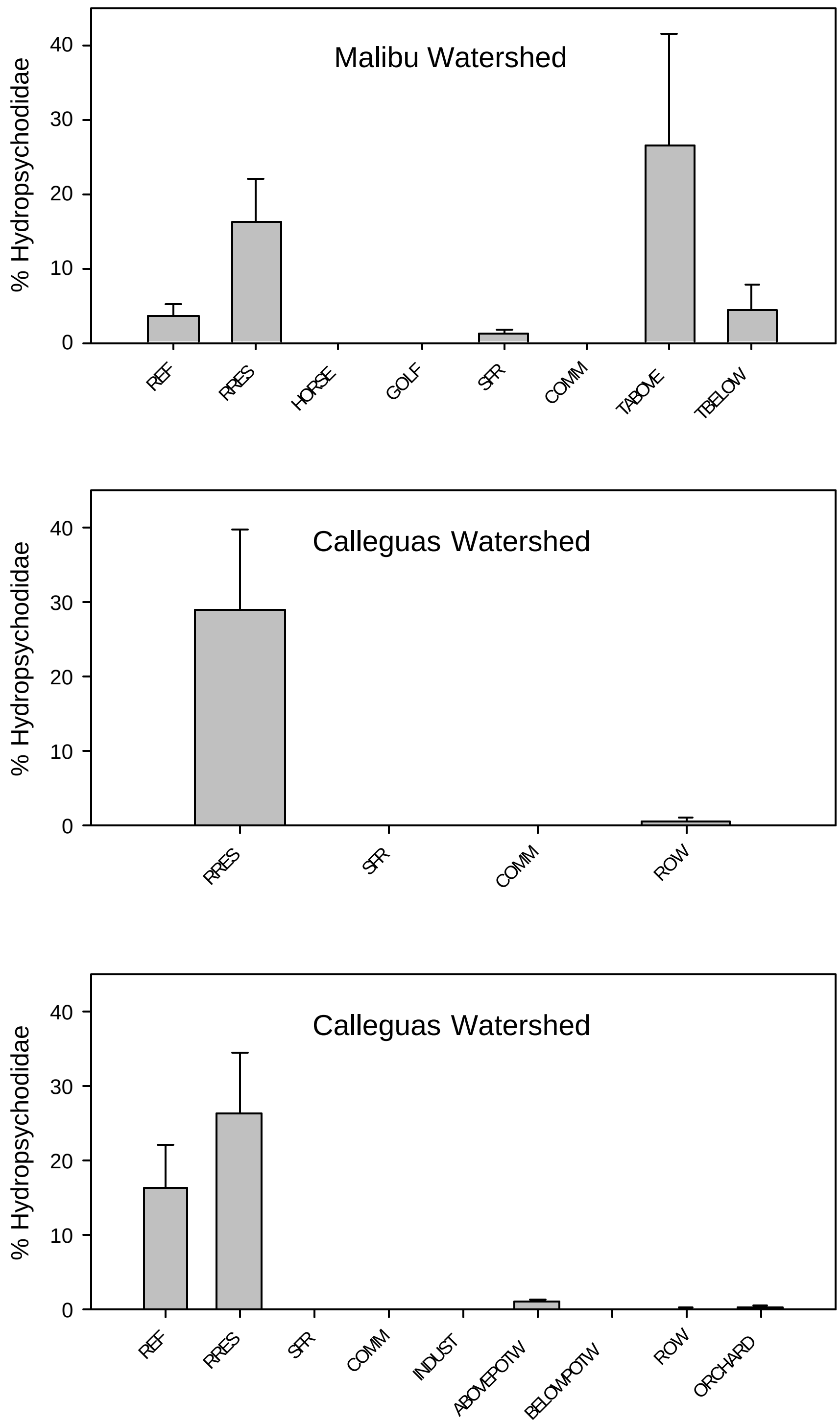


Figure 157. % Hydropsychodidae individuals by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

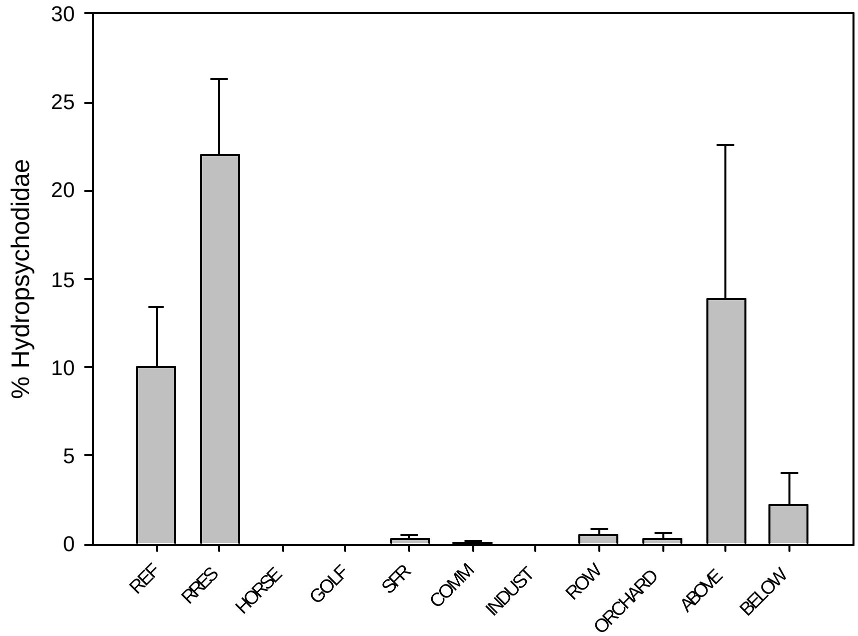


Figure 158. % Hydropsychodidae individuals by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

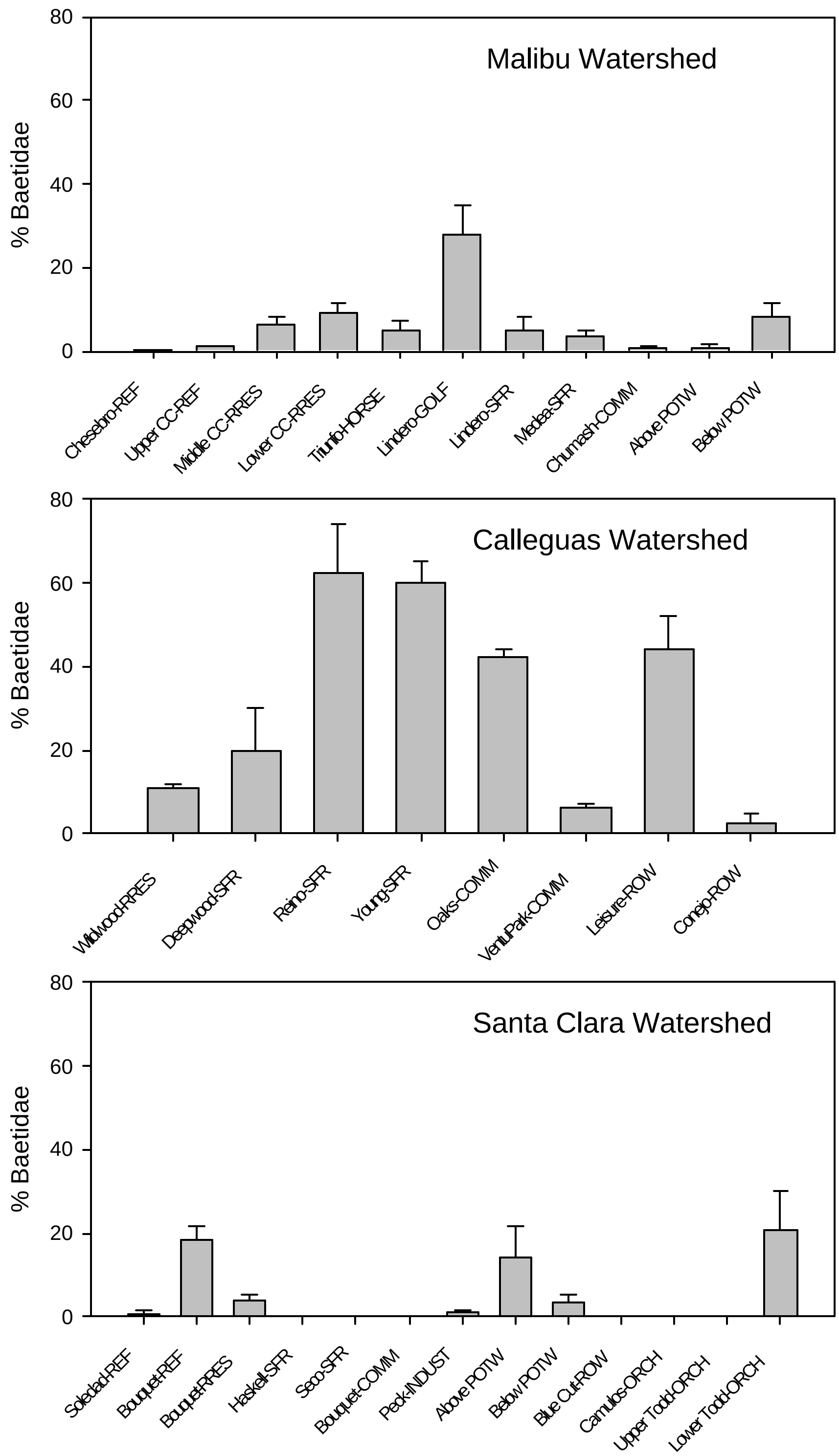


Figure 159. % Baetidae individuals at all sites.

Benthic macroinvertebrates were sampled within three 1X2 ft plots at each riffle, using Dept. of Fish and Game methods.

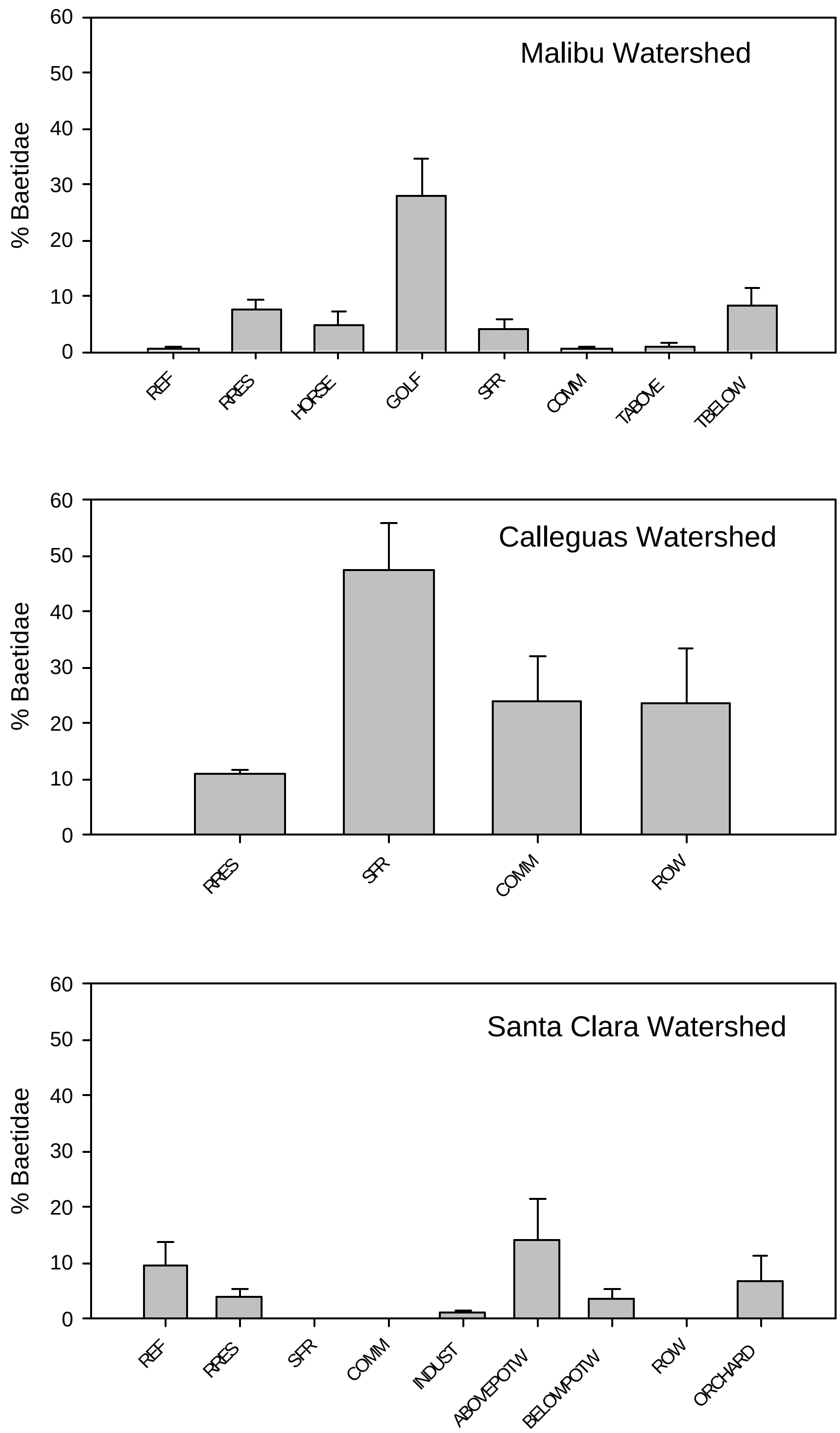


Figure 160. % Baetidae individuals by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

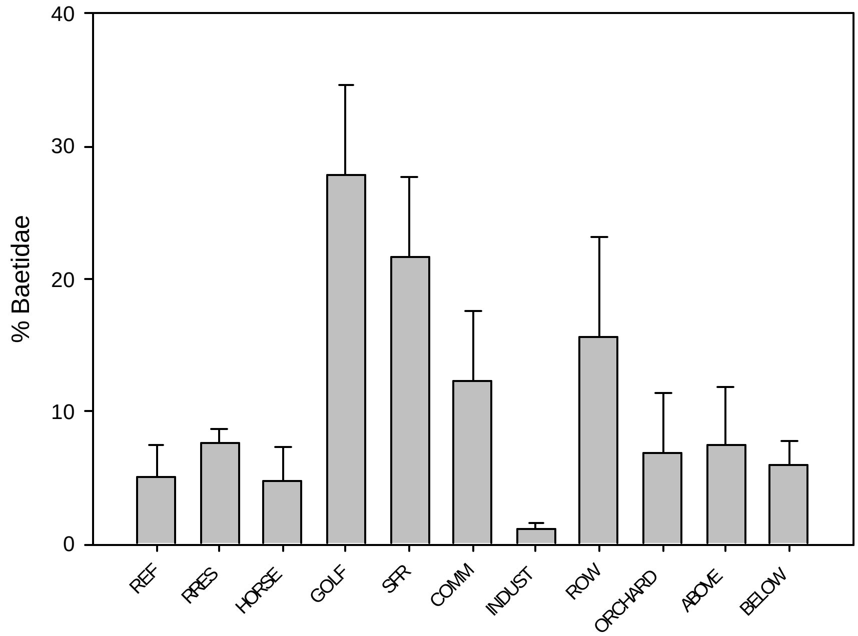


Figure 161. % Baetidae individuals by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

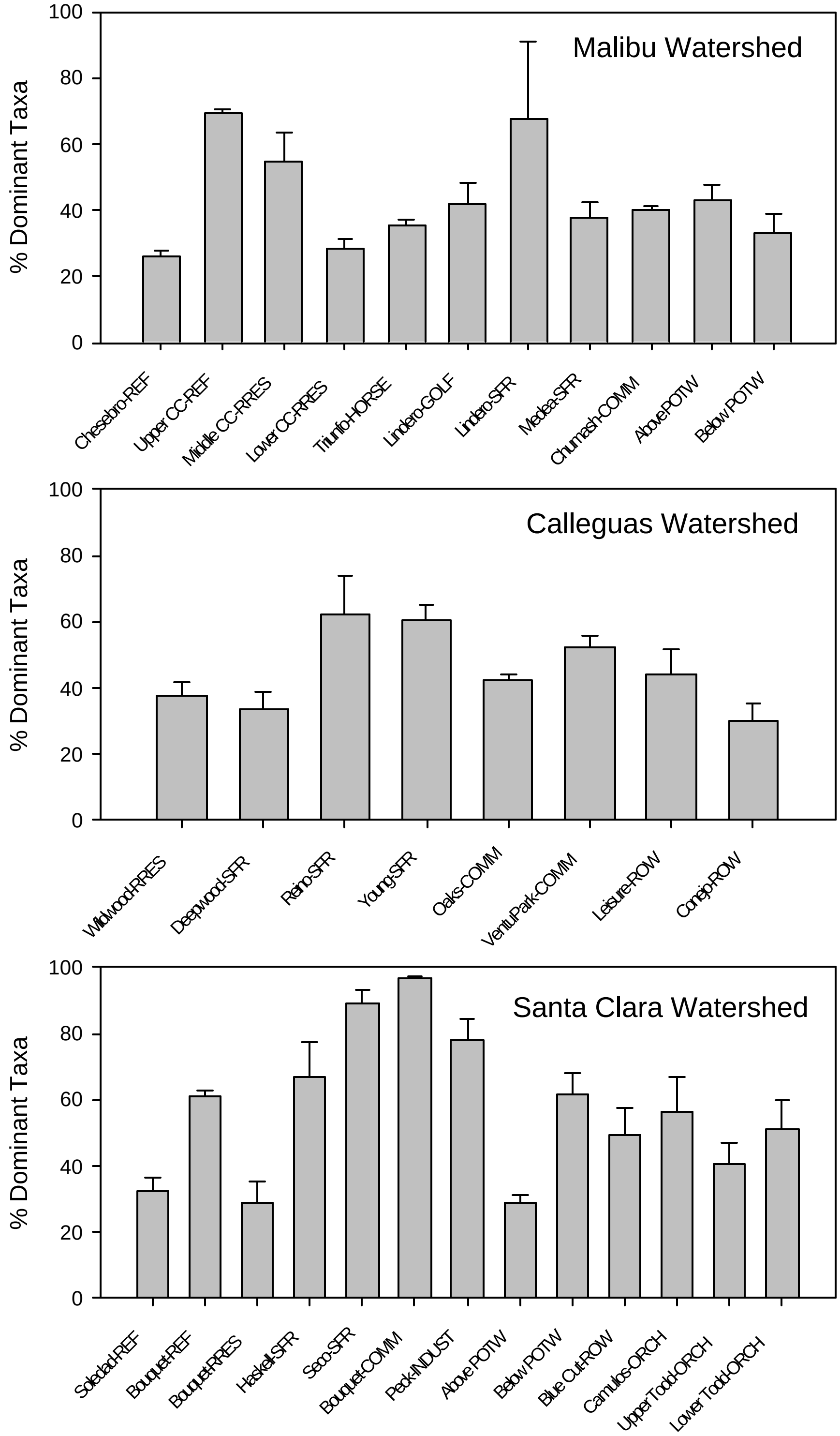


Figure 162. % dominant taxa individuals at all sites.

Benthic macroinvertebrates were sampled within three 1X2 ft plots at each riffle, using Dept. of Fish and Game methods.

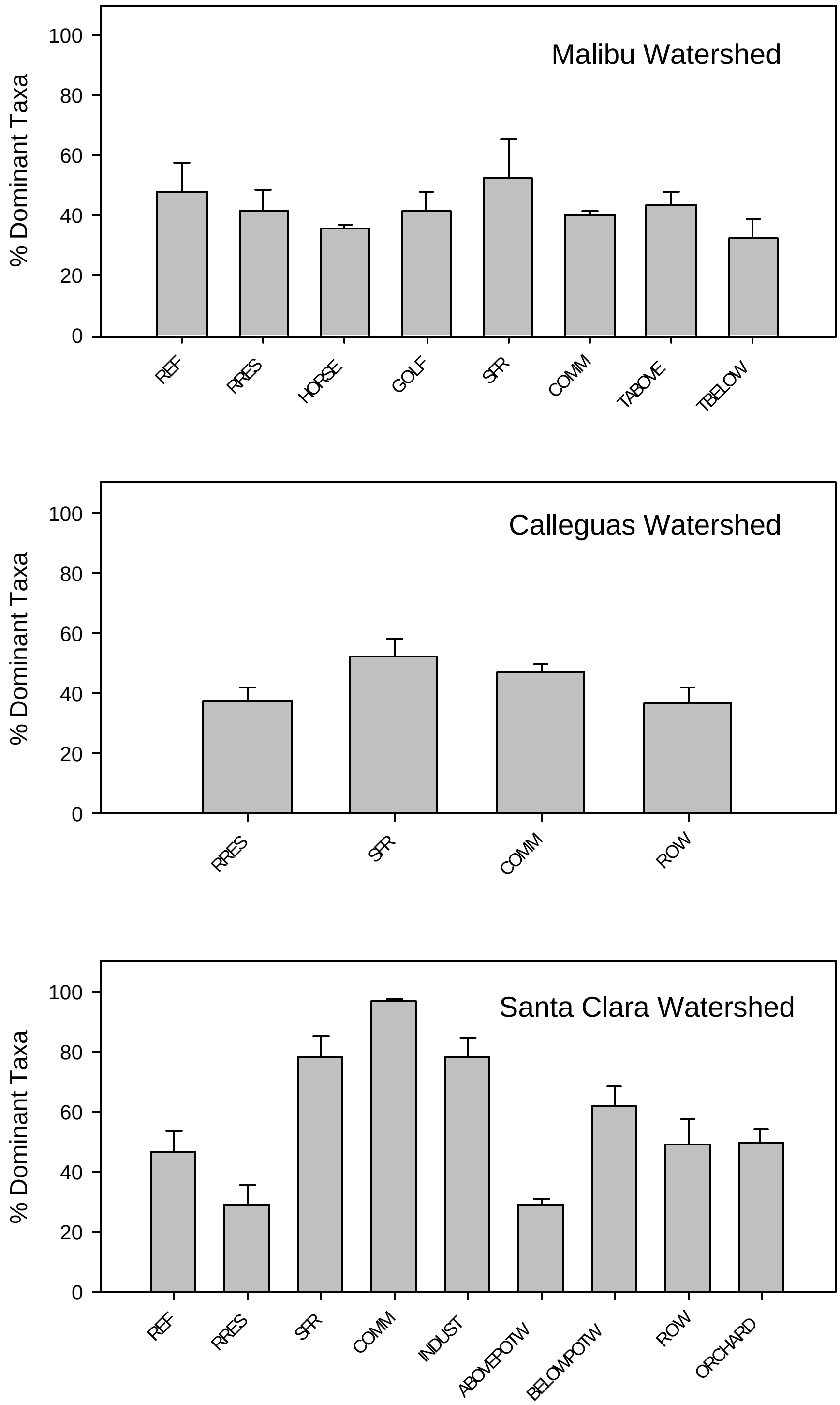


Figure 163. % dominant taxa individuals by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

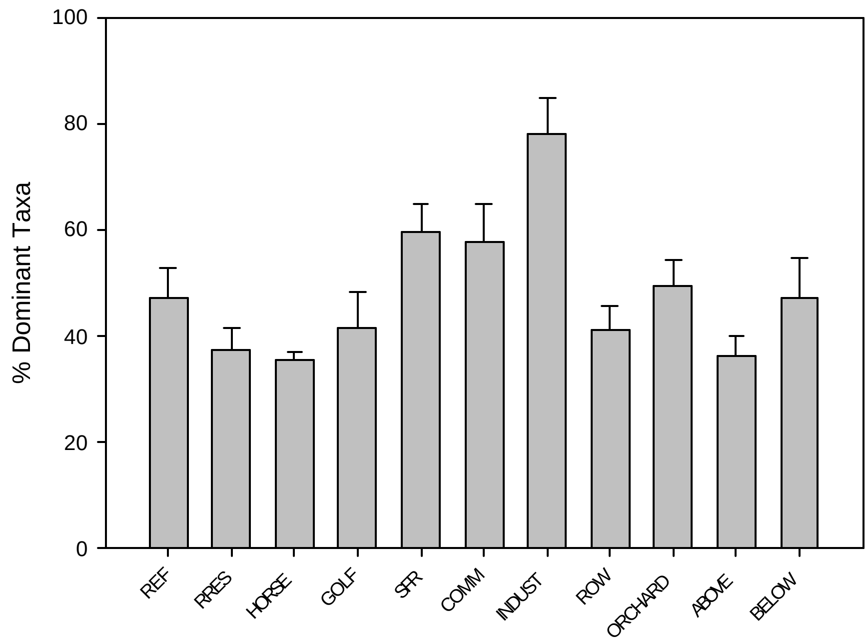


Figure 164. % dominant taxa individuals by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

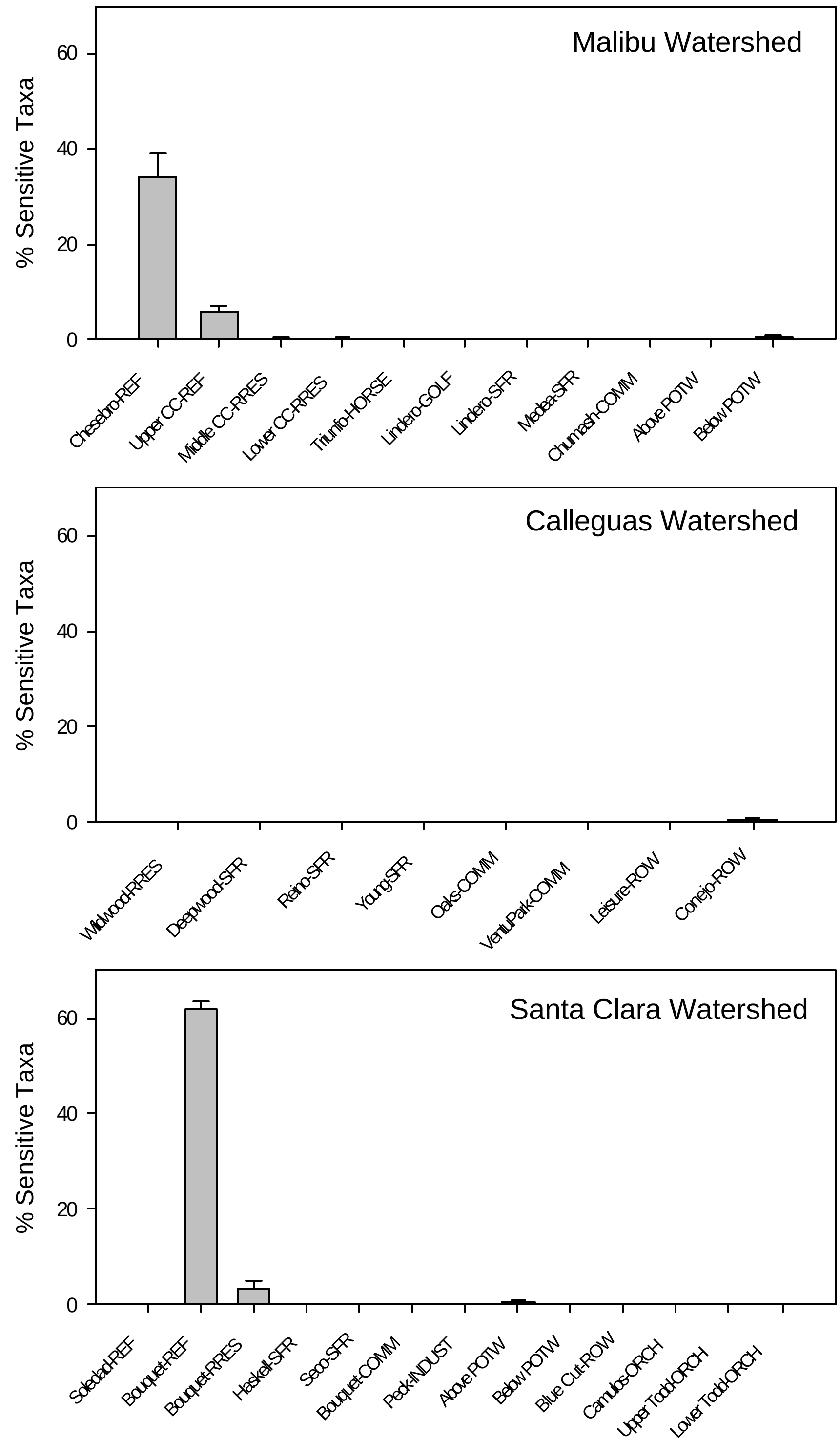


Figure 165. % sensitive taxa individuals at all sites.

Benthic macroinvertebrates were sampled within three 1X2 ft plots at each riffle, using Dept. of Fish and Game methods.

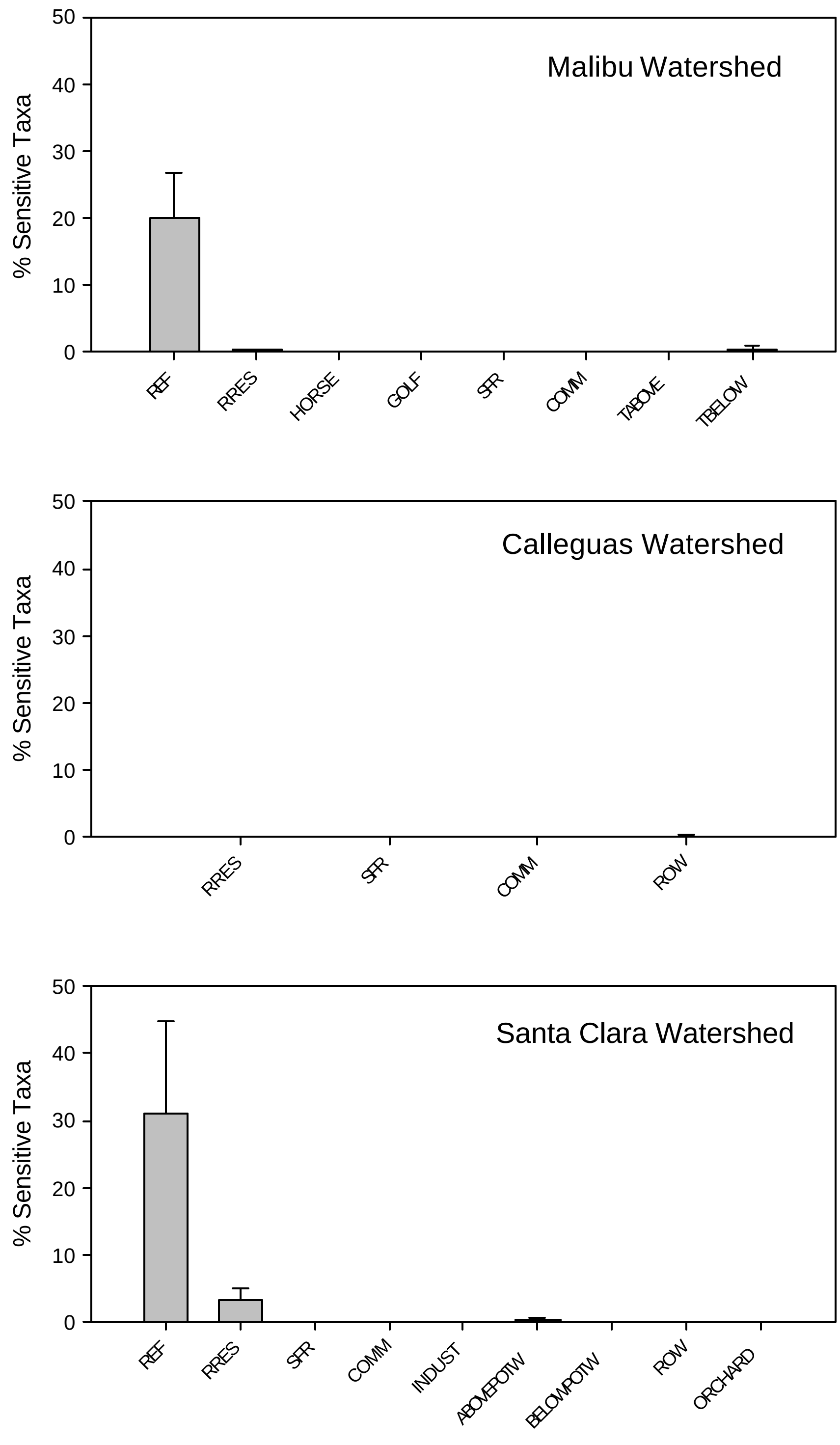


Figure 166. % sensitive taxa individuals by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

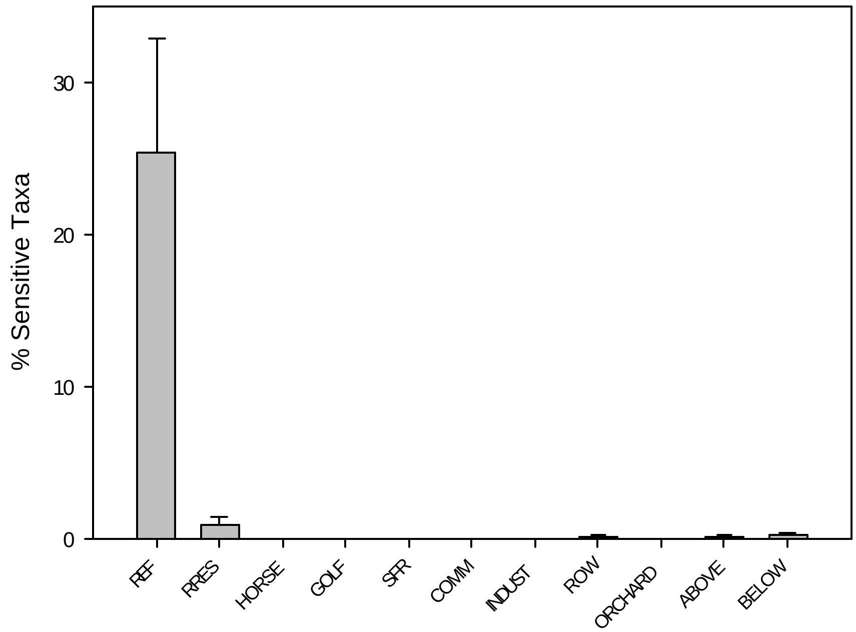


Figure 167. % sensitive taxa individuals by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.

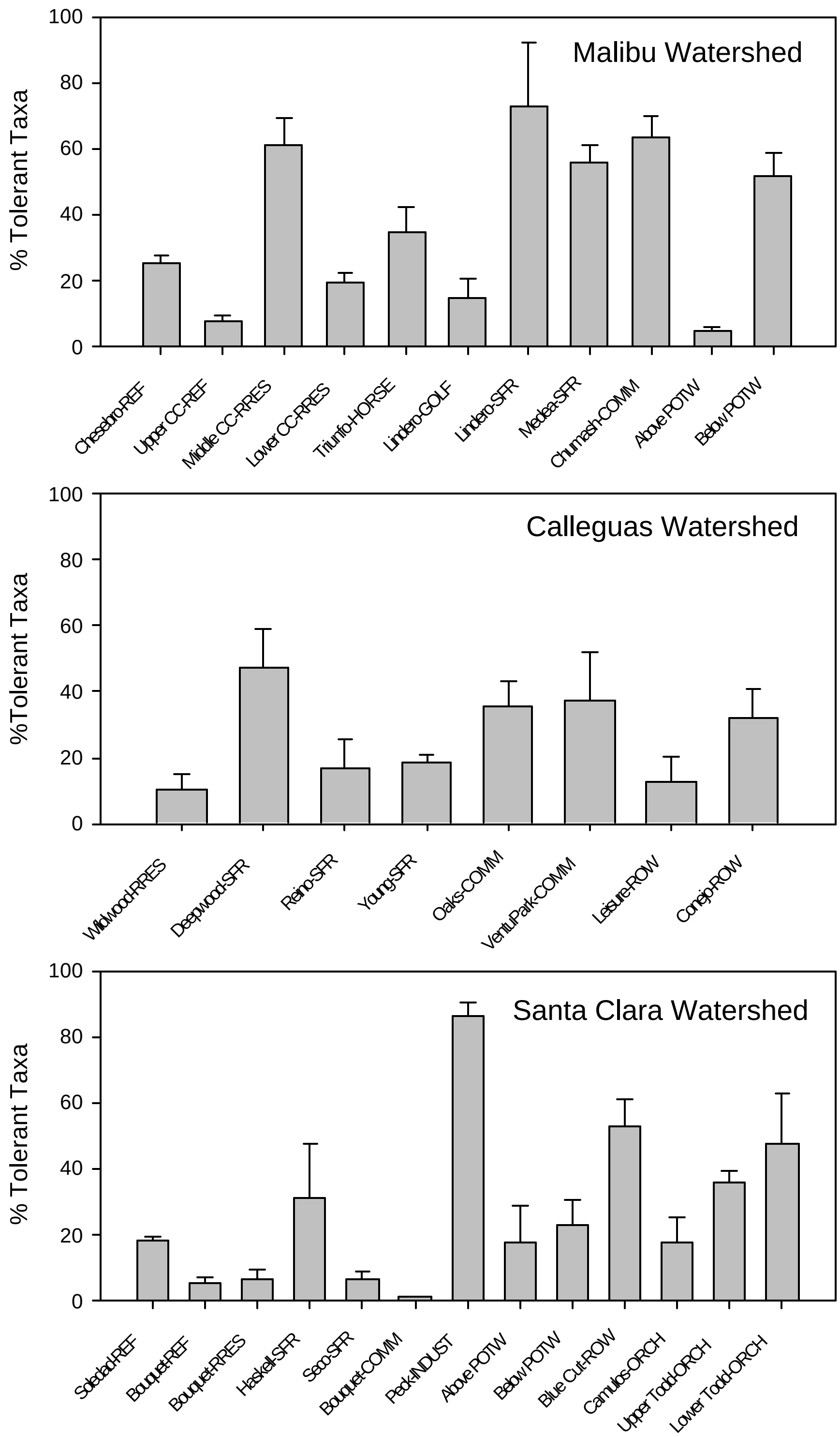


Figure 168. % tolerant taxa individuals at all sites.

Benthic macroinvertebrates were sampled within three 1X2 ft plots at each riffle, using Dept. of Fish and Game methods.

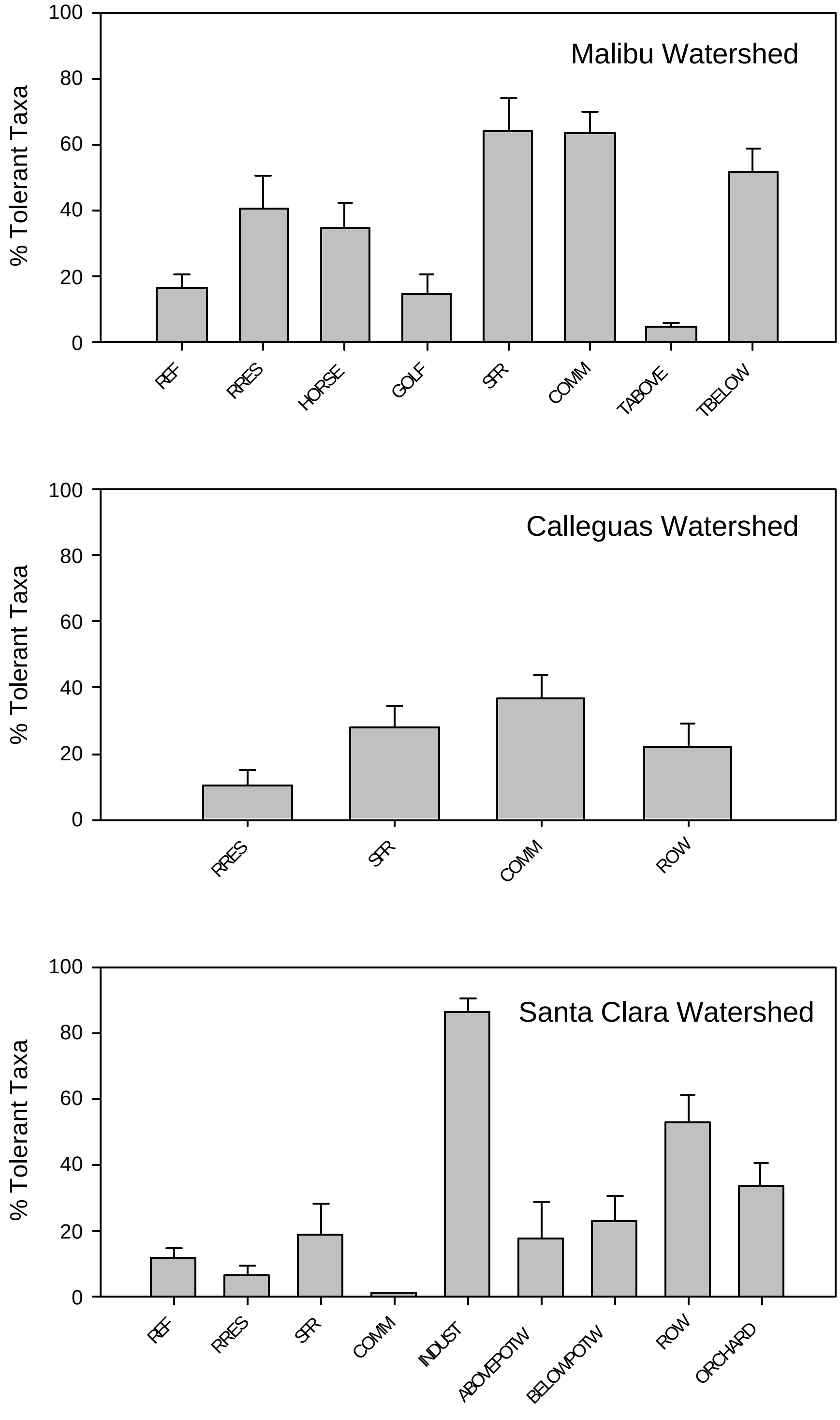


Figure 169. % tolerant taxa individuals by land use within each watershed.

Sites of similar land use were combined within each of the three watersheds.

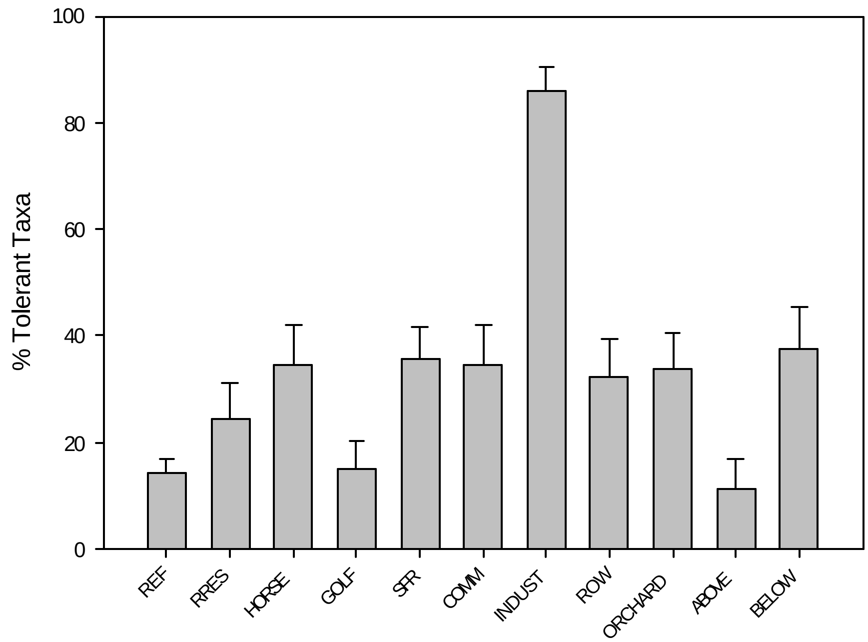


Figure 170. % tolerant taxa individuals by land use among watersheds.

Sites of similar land use were combined or averaged across all three watersheds.