Restoring Rocky Intertidal Habitats in Santa Monica Bay

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Executive Summary

The decline of flora and fauna of rocky intertidal habitats along wave-exposed coasts has been observed globally. Over the past ten years, researchers have showed links between organism population change and human visitation disturbance. The rocky intertidal zone in Los Angeles County, CA, is especially vulnerable to visitation disturbance due to its large human population coupled with the importance of the ocean as a recreation center. This study investigated recreational activity patterns and intensity of use by visitors along the rocky intertidal zone at ten sites in the Santa Monica Bay, Los Angeles County, California. Use varied from 0.4 visitors hr^{-1} to 42.7 visitors hr^{-1}. Estimates of use, conservatively extrapolated from samples taken at low tides during daylight hours, indicate that >20,000 people visited the most highly used sites each year. Surveys of visitor activities indicate that approximately 50% of the visitors walked at the site without engaging in more destructive activities. Fishers were infrequent at most of the surveyed sites. Collectors were most frequent at White's Point. The most commonly collected species included mussels, sea stars, owl limpets, urchins, snails, crabs, and sea slugs. Sitters/standers, walkers, and fishers tend to spend a majority of their time in one activity. Handlers and collectors, on the other hand, spend a relatively equal amount of time sitting/standing, walking, handling, and in the case of collectors, collecting. Intensity and patterns of human use can provide useful information required to design an effective management strategy to protect vulnerable species. Current management practices appear ineffective in protecting rocky intertidal flora and fauna from human disturbance since collecting, trampling, and handling occur intensively. In sites that are protected by law from collecting activities, enforcement was virtually absent. Enforcement may be more effective if concentrated on the most visited sites and on weekends when visitation is highest.

Human impacts on rocky intertidal ecosystems include disturbances from collecting, trampling, handling, and over turning of rocks. This study compared rocky intertidal flora and fauna populations at ten sites within the Santa Monica Bay in Los Angeles County, California differing in the amount and type of visitor use. Five of nine species expected to be impacted by collecting showed strong indications of a negative impact, with one other species having weak evidence of an impact. The densities of sea stars, sea urchins, sea hares, and rare/conspicuous invertebrates were lower at sites with high levels of human use; there was also some indication that hermit crabs occurred at lower densities at high-use sites. Owl limpet sizes were significantly smaller, with fewer large individuals at sites receiving a high number of visitors. Two of eight species expected to be impacted by collecting showed strong indications of a negative impact, with three more species having weak evidence of an impact. Anemones and tube-building worms and mollusks had lower cover at sites with high levels of human use. Limpets, articulated algae and blade algae also appeared to be influenced by human use. Seagrass cover, which was not predicted to be affected by human activities at a site, had lower cover at the sites with high levels of use (in the Malibu region, where seagrass was common). The higher proportion of impacts among species impacted by collecting may indicate that collecting is more detrimental to rocky intertidal organisms than trampling. However, our study may not have reflected the full impact of trampling. Considering that

even sites that we classified as low use were subjected to 1600 to 4300 visitors per year during low tides, our inability to detect differences in some species may reflect impacts to intertidal populations even at low use sites. If intertidal communities at these sites have also been affected by human activities, as seems likely, then we will underestimate the extent of human impacts.

Restoration of rocky intertidal habitats requires that the cause of degradation first be identified and eliminated or reduced. As we and others have demonstrated, the collection of organisms from Santa Monica Bay rocky intertidal habitats is widespread. The species most likely to be affected are the large invertebrates that are collected for food or curiosity, including sea urchins, octopuses, seastars, etc. Trampling has also been implicated in the degradation of rocky intertidal communities in Santa Monica Bay. Although we did not separate trampling and handling in our assessment of biological impacts, in general they will co-occur. There is also the possibility that poor water quality is degrading rocky intertidal communities. Little is known about the impact of current water quality conditions on rocky intertidal communities. The main concern about pollution is whether the coastal waters are so polluted that water quality would constrain any attempt at rocky intertidal habitat restoration. That is, even removing some sources of impacts (collecting and trampling) would not help the rocky intertidal biota if the water was too polluted. This seems unlikely. Thus, we have focused on assessment of restoration alternatives on techniques to reduce impacts from trampling, handling and collecting.

Once the cause of degradation has been identified, the first step in a habitat restoration is to remove the cause(s) of the degradation. There are then two possible courses of action: (1) allow recovery to take place on its own, without specific active restoration activities (passive restoration), or (2) actively manage the site by creating physical changes (such as altering topography or hydrology) or introducing organisms through planting or seeding (active restoration). In general, active restoration is more expensive and it is more difficult to achieve a fully functioning ecosystem. Luckily, rocky intertidal communities respond quickly to the cessation of human use impacts. Restoration has usually happened incidentally in response to the exclusion of either harvesting or all human use in an area. There is rarely the need to manipulate the physical aspects of the habitat (as is often needed for wetland restoration, for example), which greatly simplifies the restoration process and reduces costs. Although manipulation of the physical environment is generally not required for rocky intertidal restoration, active restoration to bring back target species might be necessary.

Four main classes of restoration alternatives are discussed: (1) reducing the trampling of intertidal organisms followed by passive recovery, (2) reducing the handling of intertidal organisms followed by passive recovery, (3) reducing the collection of intertidal organisms followed by passive recovery of the community, and (4) active restoration of target species (accompanied by the protection of these species from further impacts). Complete restoration of Santa Monica Bay intertidal habitats will likely require a suite of restoration efforts. Although collecting has a disproportionate impact on some target species, restrictions on collecting alone would not fully restore rocky intertidal communities. Simply walking in a rocky intertidal habitat seems to adversely impact the biota. A full restoration outcome will require a restriction of walking on intertidal rocks and handling of intertidal organisms as well as collection.

Our recommendations for approaches to be used for restoring Santa Monica Bay rocky intertidal habitats include:

- Establish or expand an education program
- Establish or expand docent programs
- Expand enforcement activities, including educating enforcement personnel
- Establish a pilot exclusion area
- Monitor trends in surfgrass abundance in Malibu

These five recommendations cover a suite of impacts. The pilot exclusion area is the most comprehensive restoration strategy, but we are recommending it first be implemented in a limited area, so the geographic scope of its benefits will be limited. The enforcement recommendation focuses solely on impacts from collecting; however, the species most affected by collecting were found to show the most consistent impacts from visitor use. The education and docent recommendations could help reduce impacts from collecting and handling. In addition, docents could help with enforcement and exclusion efforts. Finally, our data on biological impacts suggests the surfgrass is negatively affected by human use; we recommend that the status of surfgrass in the Malibu region be assessed, and restoration efforts be implemented only if they are deemed necessary.

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Acknowledgements

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Chapter 1. Introduction

California's coastal habitats support a productive and remarkably diverse biological community. Unfortunately, over the past century human activities, including fishing and pollution, have substantially reduced the abundances of many species. In California and elsewhere, these changes have been dramatic but not widely recognized (Jackson et al., 2001). Long-time observers of the California coast, however, frequently comment about the absence of once-common conspicuous species. Restoring the biodiversity of these habitats remains a major challenge to resource managers.

Although coastal habitats such as wetlands have an extensive history of 20 or more years of restoration efforts, there have been relatively few attempts to restore rocky intertidal habitats. As with all restoration efforts, the first step is to identify the cause(s) of degradation. Although there are some obvious possible impacts to the rocky intertidal habitats in Santa Monica Bay, including pollution, harvesting/collecting and trampling, no systematic study of the distribution and intensity of these factors has been conducted in the Santa Monica Bay region.

The ultimate goal of this project is to enhance the intertidal resources of Santa Monica Bay by restoring rocky intertidal habitats in the Bay. However, our understanding about the pre-impact rocky intertidal community, the causes of the degradation of this community, and the appropriate methods for restoring it, is not sufficient to support a direct restoration attempt at this time. Instead, this project proposes a phased approach to build the knowledge base necessary to support a scientifically based restoration project. Such a phased approach is needed to avoid expending funds on restoration efforts with poor chances for success.

The goal of this project is to provide the fundamental information necessary to design and implement successful rocky intertidal restoration efforts in Santa Monica Bay. The specific project objectives are:

1. To assess the potential sources of impacts to the rocky intertidal communities of Santa Monica Bay by reviewing existing information about the Bay and its resources.

2. To assess possible direct impacts to the rocky intertidal communities by human visitors.

   a) To assess patterns of visitor use and potentially impacting activities by surveying rocky intertidal habitats around the Bay.

   b) To assess the status of rocky intertidal communities, linked to the visitor use surveys, by surveying general biological communities as well as assessing the abundances of vulnerable species.

3. To identify and evaluate potential techniques for restoring rocky intertidal habitats in Santa Monica Bay.

Potential Sources of Impacts

There is little quantitative information about the status of rocky intertidal organisms for most of the history of Santa Monica Bay. The first human impacts were undoubtedly from collecting organisms for consumption, beginning with the indigenous Chumash and Gabrieleños-Tongva Indians. With, at least initially, relatively low population sizes, it is unclear how significant this source of impact was, but it certainly was a critical source of mortality in other areas, and likely affected species such as black abalone. Anecdotal evidence suggests it may have affected clams, octopuses, limpets, and other species. Harvesting for consumption continues today (*personal observations*), although present-day harvesting also focuses on species such as seastars collected for non-consumptive uses. Although it is difficult to assess the relative magnitude of harvesting pressure over the past 300 years, the sheer number and cultural diversity of people in the Los Angeles area suggests that rocky intertidal communities are experiencing an unprecedented level of collection pressure.

In the middle of the 20th century, the population of Los Angeles grew dramatically and industrial activities expanded (see Dojiri et al., 2003). With few environmental laws to protect water quality, water pollution became a significant problem. Although it has been suggested that water quality problems led to the decline of kelp beds around Palos Verdes kelp beds, we know little about the effects of pollution on rocky reef organisms in general, so it is difficult to determine whether pollution was impacting rocky intertidal communities. In any case, it is clear that water quality has improved dramatically in Santa Monica Bay. With conversion of sewage treatment plants to secondary treatment, the largest source of water pollutants was controlled, and there has been a steady decline in pollutant loads from wastewater facilities since 1971 (Santa Monica Bay Restoration Project, 1998). Presently, non-point sources contribute a substantial proportion of the pollutant loads to the Bay. Although this urban runoff has been shown to be toxic (Bay et al., 1996), it has not yet been linked to changes in benthic invertebrate communities (Schiff and Bay, 2003). Further, the spatial distribution of water-borne pollutants that could impact rocky intertidal communities is not known; presumably there is a gradient away from the major stormwater discharges such as Ballona Creek (which does not have any natural rocky intertidal communities nearby). Most rocky intertidal habitats are relatively distant from major stormwater discharges, though not from local stormwater discharge sources. Thus, the importance of water pollution to rocky intertidal communities today is uncertain, though it is most likely less important than it was 30-40 years ago.

In the meantime, the ever-increasing population put a new pressure on the rocky intertidal habitats: impacts of recreational visits. The beach in general has become a popular recreational destination, with more than 45 million visitors reported at Santa Monica Bay beaches each year (Schiff et al., 2001). The fraction of all beach visitors who visit rocky intertidal habitats is not known, but it is clear that the total number of visitors is substantial. Recent studies by Murray in Orange County (Murray, 1997; Murray et al.,

1999) and Tenera (2003) in the Monterey region have estimated visitor rates of up to 135,000 people per year at some locations. The Cabrillo Marine Aquarium receives approximately 140,000 visitors per year, with 5-6000 of these visitors being led to the intertidal by docents as part of organized, staff-led educational outings (L. Chilton, per. comm.). Walking in the rocky intertidal and handling rocky intertidal organisms have been demonstrated have negative impacts on rocky intertidal organisms (Addessi, 1994; Beauchamp and Gowing, 1982; Ghazanshahi et al., 1983; Keough and Quinn, 1998; Povey and Keough, 1991; Schiel and Taylor, 1999). However, little is known about the relationship between the intensity of visitor use and the magnitude and nature of impacts on intertidal organisms.

Although this general timeline of impacts is clear, there are remarkably few studies we can draw on to quantify changes in the rocky intertidal communities of Santa Monica Bay. We are most interested in accounts of the biota in the early decades of the 1900s, before most of the impacts from exploitation and pollution would have occurred. A thorough search for such information would be a research project in itself, and would examine accounts from early scientists, explorers, surveyors, and so forth. In the easily accessible literature, we found no information. The earliest information we found was from E.B. Dawson's surveys of intertidal algae in 1956-59 (Dawson, 1959, 1965), which was after many of the impacts would already have occurred, and even this was not quantitative in a way that would allow a simple comparison to today's biota. Dawson's surveys were repeated by Widdowson (1971), and then later by Thom 15 years after Dawson's original surveys (Thom, 1976, 1980; Thom and Widdowson, 1978). The first good quantitative information came from the Littler BLM surveys in the late 1970s (Littler 1978a, 1978b, 1979, 1980). Although these extensive surveys included both algae and invertebrates, by the time they occurred the rocky intertidal habitats had already experienced many impacts from different sources.

In the absence of clear quantitative studies, we can only speculate about the nature and magnitude of the changes that have occurred in Santa Monica Bay rocky intertidal habitats. It seems likely that large, conspicuous food items, such as abalone, would have had their populations depressed first, perhaps starting before European settlers arrived but certainly intensifying as the region's population grew. This conjecture is supported by long-term monitoring of black abalone on the Palos Verdes Peninsula, which has documented the virtual disappearance of abalone from that area (Miller and Lawrenz-Miller, 1993). There is abundant anecdotal evidence of much more extensive changes. For example, other food organisms have been reported to have experienced drastic declines at some sites (e.g., octopuses; B. Nelson, *personal communication*). The algal community has changed since even Dawson's surveys 45 years ago (Murray et al., 2001). It seems clear that there have been substantial changes, though the exact details remain undetermined.

Finally, we must consider the possibility that the rocky intertidal community has changed over the past 30-50 years, but that the cause of the change has been natural rather than anthropogenic. Some studies in the region have shown impacts from human use (Ghanzanshahi et al., 1983; Addessi, 1994). However, human use is but one potential driving force behind change in rocky intertidal communities. In the past few years, oceanographers and ecologists have become more aware of large-scale climatic shifts that occur on the scale of decades. One pattern has been termed the Pacific Decadal Oscillation (PDO). Whereas the more familiar El Niño events persists for 6 to 18 months and recurs every 6 to 8 years, the PDO persists for 20-30 years. It now appears that there were two full PDO cycles in the past century: the “cool” PDO regime prevailed from 1890-1924 and from 1947-76, while the “warm” regime occurred from 1925-46 and from 1977 to the mid-1990s (Figure 1). There are some indications that we are currently in the midst of another regime shift to cooler temperatures, but this has not yet been resolved.

The ecological consequences of these long-term climatic changes are not clear. Cool phases are associated with increased productivity off the west coast of the United States (including southern California), while warm phases are associated with lower productivity. Alterations in fish assemblages have been reported, but presumably such dramatic oceanographic conditions would result in extensive ecological changes, including changes to rocky intertidal communities. These climatic shifts certainly complicate the interpretation of changes in intertidal communities. For example, Dawson’s pioneering study of southern California intertidal algal communities occurred during the cool regime, Littler’s study occurred during a transition from cool to warm, and most recent studies have been conducted during a warm regime. Thus, a comparison of recent information on, say, algae, with Dawson’s initial surveys is complicated by the fact that recent data were collected in a warm regime while Dawson’s data were collected in a cool regime. Any conclusions about changes over time must take into account these long-term oceanographic cycles (as well as shorter-term oceanographic cycles such as El Niño). Our incomplete knowledge about the ecological consequences of the PDO cycles complicates any such interpretation – and even more so during transition periods, which may be the condition when the data reported in this report were collected. Furthermore, the presence of the PDO regimes complicates the interpretation of anecdotal observations, since the “normal” climate conditions vary over time periods comparable to the length of a human’s lifetime.

It is likely that changes in rocky intertidal communities in Santa Monica Bay over the past 50 years have reflected both important natural and anthropogenic factors. In part because of the difficulty of interpreting historic information in light of long-term oceanographic changes, and in part because of the paucity of such information, we have focused our attention in this study to contemporaneous comparisons of sites with minimal human use versus sites with high human use (see below). It may not be possible to identify how much of the past change was caused by human activities, but contemporaneous comparisons of low- and high-use sites allows us to assess some of the current impacts of human activities in rocky intertidal habitats.

Study region

The Santa Monica Bay region[1] is bracketed on the south by the rocky headland of Palos Verdes and on the north by the Malibu coastline (Figure 2). In between, the coastline is nearly completely sandy beach. The Palos Verdes peninsula consists largely of rocky habitat, both bedrock benches and boulder beaches, much of which is at the base of steep cliffs. In contrast, the Malibu coastline is a mixture of rocky reefs and sandy beaches, though it is predominantly sand; bedrock benches are much less common, and most rocky intertidal habitat is comprised of boulders. These different geomorphologies have important implications for the rocky intertidal communities in the Palos Verdes and Malibu regions; the Malibu rocky intertidal is much more influenced by sand, with intertidal rocks often covered with sand seasonally and sand scour much more pronounced. This difference complicates a comparison of intertidal communities, since we expect natural differences in the rocky intertidal biota between the regions.

Study design

Major objectives of this project include: (1) determining how many people visit rocky intertidal habitats in Santa Monica Bay, and what they do while in the intertidal, and (2) determining whether human use of the rocky intertidal habitats in Santa Monica Bay was affecting the rocky intertidal biota, and if so, how. There are a number of study designs that could be used to address these objectives. To assess human impacts, in theory we could use a before-after study design, comparing the present biota to its condition in the past. Unfortunately, there are no suitable data for past condition (see above). Another approach would be to assess use and biota in a range of habitats, comparing biota along a gradient of human use. Although we have adopted this approach to some extent, the natural differences between Palos Verdes and Malibu sites complicate its interpretation. In addition, a gradient design like this would require a large number of sites to overcome the large natural variability among different sites. The scope of this project would not allow a large number of sampling sites, so to minimize the effects of natural spatial variability, we adopted a modified matched-pairs design (Wiens and Parker 1995). For this design, we selected sites predicted to have high levels of human use, then matched them as best possible with a site predicted to have low use. The matched pairs were as close as possible geographically to minimize differences due to geomorphology, oceanography, exposure, etc.

Although the basic study design is a matched-pairs design, there were some complications that forced a modification of the design. Largely, the complications stemmed from the fact that, unlike an impact like an oil spill, the classification of sites as high use or low use was not clear before we actually collected data on use. Consequently, we discovered that some sites were not used to the degree originally assumed. In one case, use of Abalone Cove was not as high as expected, so we added White's Point as the high use comparison for Inspiration Point, and evaluate these as a trio of sites. However,

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[1] For the purposes of this study, the Santa Monica Bay region ranges from Pt. Fermin to the Los Angeles/Ventura County line.

White's Point was not as similar, physically, to the low use site (Inspiration Point) as Abalone Cove. In the second case, use of Point Dume was higher than expected, so we added Little Dume as the low use comparison site for Paradise Cove, and evaluate these as a trio of sites. Although these three sites are close together, there are some differences in exposure and geomorphology.

Organization of this report

This report has four chapters. This first chapter provides an overview of the project and relevant background information. Chapter 2 presents the information from the human use surveys. In this chapter, we estimate the amount of use each of our ten study sites receives as well as the different types of activities visitors to the rocky intertidal habitats at those sites engage in. Chapter 3 presents information from biological surveys at the ten study sites. The surveys provide a useful report of the status of rocky intertidal communities at each site. In addition, we related to communities at each site to the amount (and type) of human activity at the site in order to gain insight into the most important processes degrading the intertidal biota. The final chapter, Chapter 4, discusses possible approaches that could be used to restore the rocky intertidal habitats in Santa Monica Bay, and provides recommendations for some possible next steps.

There is one appendix to this report, a detailed description of the boundaries of the study areas as well as directions to each study site.

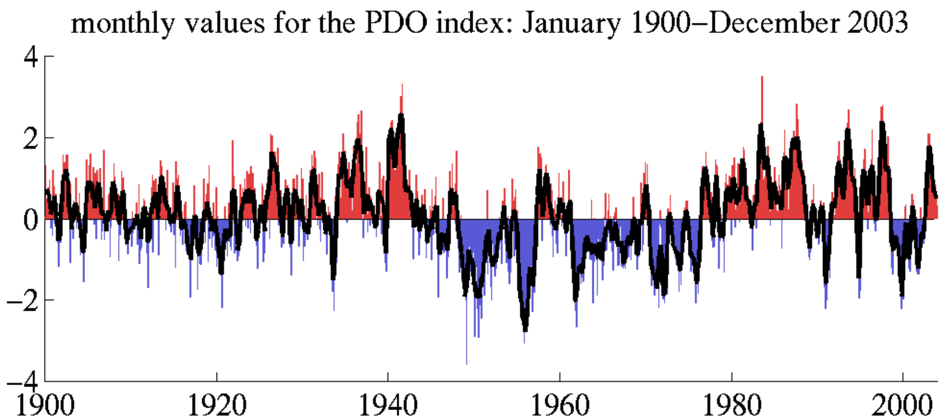

Figure 1. Pacific Decadal Oscillation (PDO) index values from 1900 to 2003.

Figure from http://tao.atmos.washington.edu/pdo/.

Chapter 2. Recreational activity patterns and intensity of use by human visitors to the rocky intertidal zone

Introduction

Changes in the natural flora and fauna of rocky intertidal habitats along wave-exposed coasts have been observed globally (Castilla and Duran, 1985; Griffiths et al., 1992; Addessi, 1994; Barry et al., 1995; Alstatt et al., 1996; Viejo, 1887; Kussakin and Tsurpalo, 1999; Sagarin et al., 1999; Murray et al., 2001). Some declines may be attributed to natural change in populations or environmental condition, but anthropogenic disturbances (including pollution, oils spills, and eutrophication) may also be a major factor in floral and faunal changes. Recently, there has been increased interest in understanding how rocky intertidal organisms are affected by human visitation and the resulting handling, trampling, and collecting of organisms (Lasiak, 1998; Murray et al., 1999; Crowe et al., 2000).

At low tide, organisms that are often submerged become available to the public to collect, handle, and trample. This type of public visitation of the rocky shore at low tide is commonly referred to as ‘tide-pooling’. Destructive activities, such as organism collection, can alter the ecosystem, as can less destructive activities, such as handling and trampling, when performed at greater intensities. Studies over the past decade have shown that, in some cases, a decrease in intertidal organisms is correlated to an increase in human pressures on the coast. Researchers have found rock-turning (Addessi, 1994), trampling (Brown and Taylor, 1999; Schiel and Taylor, 1999; Smith, 2002; Denis, 2003), subsistence farming (Lasiak and Field, 1995; Castilla and Bustamente, 1989; Duran and Castilla, 1989) and recreational collection (Murray et al., 1999; Keough and Quinn, 1991; Keough et al., 1993; Keough and Quinn, 2000; Smith, 2002) to be correlated with a change in community structure and a reduction in population densities and biomass. The human preference for collecting larger individuals of certain species is correlated to a change in size distribution (Ghazanshahi et al., 1983; Roy et al., 2003) and a possible disproportionate decrease in reproductive output as the reproductive potential (e.g. gonad volume) increases exponentially with size (Seapy, 1966; Branch, 1974; Levitan, 1991; Levitan et al., 1992; Tegner et al., 1996).

The rocky intertidal zone of Santa Monica Bay is an example of a habitat under persistent human pressure. Santa Monica Bay, in Los Angeles County, California, is adjacent to a dense urban center with a population of nearly 10 million people (http://www.losangelesalmanac.com/). Southern California enjoys mild weather year round, allowing beach visitation regardless of season, to a population that has social and cultural ties to the ocean. These factors define “human pressure” and may eventually cause irreversible damage to intertidal organisms if their populations become so low that they are unable to sustain themselves.

A common management tool for protecting coastal species is the establishment of a section of the coastline as a Marine Protected Area (MPA) with such designations as Marine Life Refuges, Ecological Reserves, and State or County Beaches/Parks. In these areas, law generally prohibits the collecting of flora, fauna, rocks, and shells. However, protection status does not limit the number of visitors in the rocky intertidal zone, so even where illegal collection may have halted, intense foot traffic and handling can continue to cause environmental decline. Moreover, MPAs may not have enforcement of existing regulations or proper signage to indicate to the public which activities may be unlawful, as has been reported nearby in Orange County, CA (Murray, 1997; Murray et al., 1999).

The successful management of a given natural resource is more likely to occur if it is first understood how humans affect that resource and in what capacity (Underwood and Kennelly, 1990). In this study, we assess: (1) the intensity of use by visitors in the rocky intertidal zone at different sites in Santa Monica Bay; (2) the enforcement of regulations prohibiting the collection of marine organisms in Marine Protected Areas, and (3) the influence of site characteristics, such as cost of parking and physical strain in reaching a site, on visitation. Recommendations for improved management of these habitats are discussed based on our results.

Methods

Study Sites

Five sites along the Palos Verdes peninsula and four sites along the Malibu coast were selected in Winter 2002. All sites were geographically located within Santa Monica Bay region in Los Angeles County (Figure 2). A tenth site in Malibu, Little Point Dume, was added to the study in Fall 2002 when one of the original sites thought to be low use (Point Dume) proved to be more visited than expected. In Santa Monica Bay, as with much of southern California, rocky headlands are separated by long stretches of sandy beach. Much of the area between Palos Verdes and Malibu is sandy beach and not suitable for this study. A majority of the study sites are afforded some type of legal protection from collecting (Table 1). Sites were grouped into sets of two or three based on similarities in location and physical characteristics. Within each group, sites differed in the level of human use. Use classifications were estimated prior to the study for each site based on access to coast, parking availability, parking costs, and estimated site popularity (Table 1).

Surveys

To quantify human activities, we used a protocol similar to that used by Murray et al. (1999) to survey human activity in the intertidal in Orange County, CA. Data collection occurred during daylight hours for 60 minutes before low tide and 70 minutes after low tide. Each survey included five 10-minute observation surveys and four 15-minute focal surveys conducted during a single low tide of 0.5 ft mean lower low water

(MLLW) or lower. Surveys were conducted several times (1-5) per season in Winter 2002, Spring 2002, Fall 2002, and Winter 2003, with roughly equal distribution between weekdays and weekends. No surveys were conducted during Summer 2002 because low tides during this period occur in very early mornings during darkness, when humans are unlikely to visit the shores.

Intensity of visitation was determined by counting the number of visitors who visited the site within the 130-minute sampling period. Only visitors within the rocky intertidal portion of the beach were counted; persons on the sandy beach above the intertidal zone were not counted. Every 30 minutes, all visitors on the site were observed for 10 minutes, providing five 10-minute observations in the 130-minute sampling period. The observed individuals were classified into one of eight categories. In order of decreasing destructiveness, they include: collecting live organisms, collecting shells, rock turning, fishing with collected bait, fishing with non-collected bait, handling, walking, or sitting/standing. If an individual was engaged in more than one activity during the observation period, the most destructive activity was assigned to that individual. The intertidal zone (splash, high, middle, and low) in which the visitor spent the most time was also recorded.

Focal surveys were conducted to assess the activity patterns of individual users. An individual falling into the most destructive category from the previous 10-minute observation survey was randomly selected and monitored for 15 minutes. To ensure the full range of activity categories was included, the next focal survey used an individual from the next most destructive category. For the focal survey, each activity and its duration were recorded. This time-budget provides the number of seconds an individual engaged in each activity, as well as information on the activities engaged by certain categories, collectively. All of the focal survey results were combined to obtain a summary of the amount of time spent in each activity according to the use category (collector, walker, etc.) assigned to the person during the preceding 10-minute use surveys. An "unknown" classification was used for individuals who came onto the site during the focal survey when no one else was present; the activities of these individuals were recorded, but their use category could not be determine prior to the focal survey.

Several site characteristics, including cost of parking, physical effort required to reach the site, nearby human population, other attractions near the site, and popularity of site with educational field trips, were assessed to determine their influence on the number of visitors a site receives. Cost of parking was estimated based on the availability of free parking and the cost of nearby pay parking lots. Physical effort was estimated on a scale of 1 to 10 based on proximity of the parking lot to the site, the terrain to be crossed, and general physical exertion required to get to the site. Nearby population was scaled from 1 to 5 based on degree of urbanization near the site. The influence of other site attractions such as surfing and swimming, or in the case of Point Fermin, the presence of a marine museum, was ranked on a scale of 1 to 5, with 5 being the most attractive. The same scale was used for popularity of a site with school groups, with 1 being the least used site(s), based on observations made during human use surveys.

Analyses

Data sets were analyzed using analysis of variance for univariate data (ANOVA). Data were log-transformed as necessary to meet the assumption of normality. Statistical analyses were conducted using Minitab 13.32 software. Site and day type (weekday or weekend) were considered fixed factors. The five 10-minute surveys provided a total of 50 minutes of observation per low-tide visit for each site. A single day of observation was treated as one independent sample; all activities occurring in the five samples within that day were averaged, to yield a single mean number of people in each activity for a specific day. Although eight categories were recorded during the actual surveys, categories were condensed to five for analysis; sitting and standing, fishers with and without bait, and rock turners and handlers were combined.

Although our data provide direct estimates of number of visitors per hour of observation, we can calculate rough estimates of use at a site over the entire year. We considered visitation only on days with tides below 0.5 feet during daylight hours; this is a conservative estimate, since extensive areas of intertidal can be exposed at higher tides, so there is undoubtedly some visitation on other days. We considered use during a 4-hour period for each low tide. To estimate the number of people visiting a site during a low tide period, we multiplied the average number of visitors per hour times four hours; we used separate estimates for weekends and weekdays because visitation use was different for these day types. Again, this is a conservative estimate; although the best tide-pooling occurs during an approximately 4-hour period, it is often possible to tide-pool for a longer period, especially during extreme low tides. To estimate use over an entire year, we counted the total number of weekend and weekday days of low tides below 0.5 feet during daylight hours over a year, and multiplied these by the average number of visitors on these day types over a complete low tide. Unlike estimates reported by other researchers, our estimates include only visitors to the rocky intertidal habitat, and do not include visitors to the sandy beach above rocky areas.

To determine the influence of factors such as cost of parking and strain in reaching the site on visitor use, a multiple regression was used with site characteristic data and the number of visitors per hour from the human use surveys.

Results

Visitor intensity differed significantly among sites (ANOVA, $p<0.001$; Figure 3). The highest level of use was found at Leo Carrillo High Use (42 visitors hr^{-1}) and Point Fermin High Use (37 visitors hr^{-1}), while the lowest use was found at Inspiration Point (0.4 visitors hr^{-1}). The highest number of visitors found in one day was at Leo Carrillo High Use, where 115 visitors hr^{-1} were observed. Five sites (Point Fermin High Use, White's Point, Paradise Cove, Point Dume, and Leo Carrillo High Use) with a visitor use of >20 visitors hr^{-1} were not significantly different from each other and were considered high use. The other five sites (Point Fermin Low Use, Inspiration Point, Abalone Cove, Little Dume, and Leo Carrillo Low Use) were considered low use. Use at Inspiration Point was significantly lower than all sites except Little Dume (Tukey's multiple comparison, Figure 3); use at Point Fermin Low Use, Abalone Cove, Little Dume, and Leo Carrillo Low Use did not differ significantly. Use at Point Dume was actually intermediate, not differing significantly from the other high use sites, but also not differing significantly from Abalone Cove and Leo Carrillo Low Use. The high use sites received an average of 33 visitors per hour during low tide periods, while the low use sites received an average of 5.1 visitors.

The number of visitors was higher on weekends than weekdays (Two Factor ANOVA, site $p<0.001$, day type $p<0.001$, site x day type $p=0.081$; Figure 4). An average of 32.2 people hr^{-1} visited all sites combined on weekends compared to 9.3 people hr^{-1}on weekdays. The difference between weekday and weekend was not as great at low use sites compared to high use sites, as indicated by the nearly significant interaction term.

There were few differences in visitation among the seasons (Figure 5). Because there was no consistent effect, season was not included as a factor in the analyses.

The Leo Carrillo High Use study area had the highest estimated use per year, with more than 23,000 visitors to the rocky intertidal study site (Table 2). When normalized to shore length, Leo Carrillo High had an estimated 49,054 visitors per year per 100 m of shoreline. The Point Fermin High Use area had a slightly higher normalized of 51,795 visitors per year per 100 m of shoreline. Use of the five "high use" areas ranged from 30,000 to 50,000 visitors per year per 100 m of shoreline. Use of the "low use" areas was substantially lower. However, except for Inspiration Point, which is estimated to receive only 428 visitors per year per 100 m of shoreline, visitation at the "low use" areas was actually substantial, ranging from 5,000 to 12,000 visitors per year per 100 m of shoreline.

Walkers were the most common type of user considering all sites together, comprising 51 % of the rocky intertidal visitors. Handlers were also common (33 %), followed by sitters/standers (8%), collectors (6%), and fishers (2%). For most sites individually, a majority of the visitors were walkers, with an average as high as 15.6 walkers/10 min at Point Fermin High Use on weekends (Figure 6). The highest number of collectors was found on weekends at White's Point (3.1 collectors/10 min). Fishers were infrequent at most sites except at White's Point, a popular fishing spot, where the number of fishers averaged 2.3/10 minutes on weekends. With two exceptions, the number of people observed/10 min for each of the five activities (sitting/standing, walking, handling, collecting, and fishing) was higher in the high use site compared to the low use sites. The exceptions, involving relatively few people, were for collectors and fishers at Point Fermin on weekends. In addition, for almost all use categories, the number of people was higher on the weekends as compared to weekdays; exceptions included collectors and handlers at Inspiration Point and fishers at Leo Carrillo High Use. Differences in the number of people observed per 10 minutes between low use and high use sites within site groupings was also consistent among weekend and weekdays for each category. One exception occurred with collectors at Point Fermin Low Use, where collecting was found to higher than Point Fermin High Use on weekends but declined to zero collectors on weekdays even though the number of collectors remained the same at the high use site. There was a significant interaction between site and day type for handling, collecting and fishing (Table 3); for sitting/standing and walking, the main effects of site and day type were significant.

The frequency of visitors falling into each category varied substantially among sites (Figure 7). At Little Dume, which occurs along a popular walking route between Paradise Cove and Point Dume, walkers made up over 80 % of the visitors; many of the visitors at Little Dume simply made a slight detour from the sandy beach to walk through the rocky intertidal zone. In contrast, Point Fermin Low Use is difficult to get to and has no adjacent sandy beach, and a high proportion of the visitors to this site handled or collected organisms in the rocky intertidal zone. The frequency of collectors was lowest at Point Fermin High Use and Point Dume, with just over 2%, and highest at Inspiration Point and Point Fermin Low Use, with over 20% of the visitors collecting.

Across all categories, more people were found in the middle intertidal zone (0.73 visitors/10 min) than the splash, high, or low zones (0.28, 0.43, and 0.38 visitors/10 min, respectively). The percent of persons found in the four zones varied among the five use categories (Figure 8). Sitters/standers were observed equally among all zones. Walkers, handlers, and collectors were observed mostly in the middle intertidal zone. Fishers were most frequently found in the low intertidal zone.

Additional details were collected about three of the five activity categories: collectors were observed to determine if they were collecting live organisms or shells and rocks; fishers were observed to determine if they collected bait on site; and handlers who overturned rocks where observed to determine whether the rocks were placed back into their original position. The most commonly collected live species included mussels (*Mytilus californianus*) and sea stars (*Pisaster ochraceus*), and to a lesser extent owl limpets (*Lottia gigantea*), sea urchins (*Strongylocentrotus purpuratus* and *S. franciscanus*), snails (*Tegula* spp.), crabs (*Pachygrapsus crassipes*), hermit crabs (*Pagurus* spp.), and sea hares (*Aplysia californica*). Collectors were observed collecting live material 54% of the time while they collected shells (mostly urchin tests) and rocks 46 % of the time. The percentage of collectors collecting live organisms differed among sites (Figure 9). Interestingly, it appears that most collectors at low use sites collected shells and rocks, while collectors at high use sites collected more live specimens. Across all low use sites, 10% of collectors collected live material, while in high use sites >65% collected live plants and animals. The vast majority of fishers (87%) collected bait on site. On all occasions where the organism collected for bait was noted, the mussel *Mytilus californianus* was collected. For those visitors who turned over and handled rocks, only

20% of the individuals returned the rocks to their original location. Rocks were often left up-side down or were thrown some distance, ending up in a different intertidal zone, often in the subtidal zone.

The focal surveys showed that individuals classified as sitters/stander, walkers and fishers tend to spend a majority of their time doing activities in their category (Figure 10). Handlers spent relatively equal amounts of time looking, walking around the site, and handling organisms or rocks, but only rarely collecting items. Collectors spent 20% of their time actually collecting and were often walking around the site, looking, and picking up organisms and rocks.

The physical effort spent reaching a site and the popularity of a site for school-led education field trips were found to have the most influence on the number of visitors (Multiple regression, R^2=0.918, $p<0.05$; Table 4), indicating that visitor use decreased as the effort to reach a site increased and as the number of educational field trips to a site decreased. Cost of parking, nearby human population, and other site attractions were not found to have a significant influence on visitation.

Discussion

Human visitors and their activities in the rocky intertidal zone can change densities, biomass, size structures, and the composition of the rocky intertidal community (Ghazanshahi, et al., 1983; Duran and Castilla, 1989, Lasiak and Field, 1985; Schiel and Taylor, 1999). Similar changes have been reported to the Santa Monica Bay rocky intertidal habitats, including declines in abalone (Miller and Lawrenz-Miller, 1993; Alstatt et al., 1996), mussels (J. Smith, unpublished data), and macrophytes (Murray et al., 2001). These declines may be due in part to natural fluctuations, but the high degree of urbanization of the surrounding area and the intense use of the rocky intertidal suggest that human activities have played an important role. In spite of the potential for impacts due to tide-pooling activities, no previous study has characterized the activities and number of people that visit rocky intertidal habitats in the Santa Monica Bay region.

The number of people visiting rocky intertidal habitats was quite high relative to other areas of California, especially for our “high use” sites (Figure 11). Annual use at the high-use Santa Monica Bay sites was higher than use at the James V. Fitzgerald Reserve in San Mateo County, CA, reported by Tenera (2003) to be the most visited beach in California for which they had data. The Fitzgerald Reserve had an estimated 110,000-135,000 visitors per year (22,000 per year per 100 m shoreline), mostly from organized educational field trips (Smith, 1993). In contrast, Point Pinos in Monterey CA (Tenera, 2003) and Cabrillo National Monument in San Diego CA (Engle and Davis, 2000) reported visitation levels less than 4,000 and 10,000 visitors per 100 m shoreline, respectively. The estimate for Point Pinos assumes a 6-hour period of low tide (compared to our assumption of 4 hours) and includes visitors using the sandy beach. The estimate for Cabrillo was made during minus tides when daily visitor use was probably highest, but extrapolated to the entire year, which has a variety of tides, which probably results in an overestimate. Point Pinos and Cabrillo are considered to be heavily used sites but have levels of use comparable to our low use sites (except Inspiration Point).

The maximum number of people observed at any site on a given day was 115 visitors per hour at Leo Carrillo High Use. Extrapolated to a four-hour low tide period, the total number of visitors on that day is estimated to be 460 visitors. This number is lower than the maximum number of visitors reported at Dana Point, where 1,443 people visited during a low tide period (Murray et al., 1999), but Dana Point has a shoreline length of 1.2 km compared to 48 m at Leo Carrillo High Use. Therefore, the maximum intensity of use on one day appears to be higher at Leo Carrillo High Use (958 visitors/day/100 m of shoreline) compared to Dana Point (120 visitors/day/100 m of shoreline). (It is important to normalize for shoreline length because different sites have dissimilar sizes, and our study areas did not necessarily incorporate all rocky intertidal habitat at a location.) In 288 surveys conducted from 1990-95 at the Cabrillo National Monument in San Diego, CA, a maximum of 327 visitors was observed in the highest use area during instantaneous surveys 30-minutes before low tide (Engle and Davis, 2000), or approximately 100 visitors on 100 m of shoreline; averaged over the 12 seasons surveyed, the highest value per season was 148, or 45 visitors/100 m of shoreline. By comparison, maximum recorded visitation at Leo Carrillo High Use was 240 visitors/hour/100 m of shoreline. At Yaquima Head, Oregon, a maximum of 155 visitors per hour were observed, with an average of 77 visitors per hour (Crumrine, 1992); it is unclear how large the intertidal site is and whether this estimate included visitors only within both the rocky intertidal and sandy beach. These studies indicate that the Santa Monica Bay sites are among the most intensely used site along the West Coast.

As expected, there were more visitors on weekends compared to weekdays. Keough et al. (1993) also found more visitors to the rocky intertidal in Australia on weekends than weekdays, with holiday weekends having the greatest number of visitors. For sites with relatively low use, there was little difference between weekend and weekday. Little Dume had the smallest difference by day of the week (2.1 visitors/hour on weekdays vs. 2.9 on weekends); this site has no nearby parking available and stands out as being visited largely by local residents. For most sites, there were 2-3 times more visitors on weekends compared to weekdays. Two high-use sites, Paradise Cove and White's Point, had nearly 5 times higher use on weekends. Abalone Cove had the greatest difference, with only 2.0 visitors/hour during weekdays but 17.9 visitors/hour during weekends, a nine-fold difference.

With so many people visiting rocky intertidal habitats, managing these areas to protect natural resources is a challenge. Current management focuses on regulating harvesting. Many of our study areas are located within an established Marine Protected Area. However, even though law forbids collecting at these sites, we regularly observed the harvesting of live organisms. Murray et al. (1999) also regularly observed instances of collecting within Marine Life Refuges in Orange County, CA, with little or no enforcement. At our sites, enforcement of collecting laws was rarely observed (and only at Leo Carrillo High Use, Leo Carrillo Low Use, and White's Point) and, in those cases where enforcement occurred, only warnings were given out. For a majority of these instances, "enforcement" consisted of a lifeguard's presence, often perched on a cliff or briefly driving by the site but rarely enforcing any collecting laws. On three occasions out of 140 surveys, rangers were present for a short time at the sites, warning a handful of people that collecting was not allowed.

Although increased enforcement is one obvious way to reduce illegal collecting, greater awareness of the regulations and reasons behind the regulations might also be effective. Murray et al. (1999) noted the inadequate signage at Orange County MPAs. The Santa Monica Bay sites also have minimal signage, usually only at the entrance to the site (which can be some distance from the rocky intertidal habitat), and collecting regulations are not prominent among the list of regulations. With regulations against collecting being poorly disseminated, it is likely that many collectors are simply ignorant of the laws. More direct forms of education could also be effective. For example, Point Fermin is adjacent to the Cabrillo Marine Aquarium and regularly receives elementary school children on educational field trips. The aquarium receives approximately 140,000 visitors per year, with 5-6000 of these visitors being led to the intertidal by informative docents as part of organized, staff-led educational outings (L. Chilton, per. comm.). At Point Fermin High Use, docents encourage gentle handling of organisms while explaining the importance of returning the organism to its original location. In addition, docents are regularly present and actively educating visitors about collecting. Perhaps as a result, Point Fermin High Use had the lowest percentage of visitors who were collectors (2.2%) of all sites surveyed.

Whether by enforcement of regulations or education, some effort to reduce collecting is clearly needed to protect resources at these sites. Up to 1.75 collectors were found per 10-minute survey at some sites. This value is similar to the maximum number of collectors found (1.1 per 10 minutes) in Orange County (Murray et al., 1999), although lower than what Keough et al. (1993) found at several sites in Australia (3-4 collectors observed in 5-minute surveys). We estimate that about 4500 people were collecting at White's Point over a year (based on the number of collectors in the 10 minute surveys on weekends and weekdays, adjusted to the number per low tide, and multiplied by the number of weekend and weekday low tides). Considering that people usually collect more than one individual organism at a time, sometimes hundreds, many thousands of organisms are being removed from these sites every year. In fact, this may be an underestimate, since there are also occasional large-scale collecting events not included in this study but seen at other times. During these large-scale events, collectors illegally remove literally buckets, and in one observed case a pick-up truck, full of organisms at one time.

Although controlling direct impacts from collecting is important, half of the people surveyed in the rocky intertidal were merely walking, with another 8% sitting or standing. Although these visitors were actively visiting the rocky intertidal habitat, their activities were less interactive than other visitors and they did not directly handle or harm intertidal organisms. One-third of the visitors handled organisms, and though this is could be more damaging to some organisms, it is legal at all sites, even the marine protected areas. In most cases, handling has relatively little impact, especially when one is just proding or picking up an organism for a short period and placing it back into its original location. On the other hand, handling can affect the health of organisms if, for instance, one individual is persistently handled on several occasions over time, or if an individual is handled by one person for an extended period, or if the organism is especially delicate (e.g., octopuses and sea hares). Furthermore, handling can have detrimental affects on organisms if they are picked up and displaced into habitats not suitable to their survival. On several occasions, sea stars were removed from their habitat and placed (or thrown, in some cases) in the high intertidal zone, where their survival was unlikely.

Although legal, walking in the rocky intertidal and handling rocky intertidal organisms have been demonstrated to have an impact on rocky intertidal organisms (Addessi, 1994; Beauchamp and Gowing, 1982; Ghazanshahi et al., 1983; Keough and Quinn, 1998; Povey and Keough, 1991; Schiel and Taylor, 1999). The traditional management approach of establishing Marine Protected Areas does nothing to limit this impact. Moreover, the California Coastal Act explicitly encourages use of the coast, stating that "maximum access, which shall be conspicuously posted, and recreational opportunities shall be provided for all the people…" (California Public Resources Code §30210). It is clear that the Coastal Act encourages access to the rocky intertidal, although the same Section goes on to state that access should be consistent with the need to protect natural resource areas from overuse. Thus, management of coastal resources in California must balance ready access with resource protection, and this balance is exceedingly difficult to achieve in the face of the high visitation rates demonstrated in this study.

Protection of rocky intertidal resources from trampling and handling will require the exclusion of visitors from some areas. To some extent, this occurs naturally in sites that are difficult to access, as indicated by our multiple regression results. For example, Inspiration Point required the longest and most strenuous hike to visit and was the least popular site of all our study sites, with only 428 visitors per year per 100 m of shoreline. However, there are few places in the Santa Monica Bay region that inaccessible; our least accessible site along the Malibu coastline (Little Dume) had an estimated 2,500 visitors per year per 100 m of shoreline. Consequently, human activities impinge on rocky intertidal communities throughout the entire region.

Table 1. Characteristics of the ten sites sampled.

Sites were placed into groupings based on similarities in location and habitat type. The Marine Life Refuge prohibits taking of nearly all rocky intertidal invertebrates; the Ecological Reserve prohibits taking of all invertebrates; the State Beach prohibits taking of all animals and plants; the County Park and Area of Special Biological Significance do not have regulations prohibiting collections, although there is a sign posted at Paradise Cove stating that collecting is prohibited.

Site	Site Code	Groupings	Location	Lat/Long	Shoreline Length (m)	Area (m^2)	Protection Status	Access
Point Fermin (High Use)	PTFH	1	Palos Verdes Peninsula	33 42' 29" 118 17' 04"	39	1431.1	Marine Life Refuge	Minimal free parking available on the street with additional pay parking lot ($7.00) located nearby. This site is located adjacent to the Cabrillo Marine Aquarium and is often a stopping point for public visitors and educational field trips when visiting the aquarium. The walk to the intertidal is short and undemanding.
Point Fermin (Low Use)	PTFL	1	Palos Verdes Peninsula	33 42' 22" 118 17' 11"	36	1111.6	Marine Life Refuge	Minimal free parking available on the street with additional pay parking lot ($7.00) located nearby. This site is located further upcoast than the high use site and requires a longer, more strenuous walk.
White's Point	WHT	2	Palos Verdes Peninsula	33 42' 49" 118 18' 59"	60	3877.2	County Park	Minimal free parking is available on the cliff top with additional pay parking lot ($5.00) located adjacent to the intertidal zone. Because of its physically undemanding access, this site is a popular place for educational field trips.
Inspiration Point	INSP	2	Palos Verdes Peninsula	33 44' 12" 118 22' 08"	65	1941.4	Ecological Reserve	Pay parking ($5.00) is available during restricted hours. However, the parking lot is approximately a 15 minute walk away and access to the site includes a strenuous hike down a steep hill.
Abalone Cove	ABAL	2	Palos Verdes Peninsula	33 44' 17" 118 22' 27"	36	1826.1	Ecological Reserve	Pay parking ($5.00) is available during restricted hours. However, the parking lot is approximately a 10 minute walk away and access to the site includes a strenuous hike down a steep hill.
Paradise Cove	PARA	3	Malibu Coastline	34 01' 10" 118 47' 10"	32	948.2	Area of Special Biological Significance	Free parking is available to those dining at the restaurant located adjacent to the site. For those not dining at the restaurant, pay parking is available ($20.00). The site is located just a short, undemanding walk away from the lot.
Little Point Dume	LDUME	3	Malibu Coastline	34 00' 27" 118 47' 36"	63	885.4	Area of Special Biological Significance	Parking for this site is limited mostly to the same lots as Paradise Cove and Point Dume. From these lots, there is a 15 minute walk along a sandy beach to reach the site.
Point Dume	DUME	3	Malibu Coastline	34 00' 09" 118 48' 12"	31	767.1	State Beach	Limited free 2 hour parking is available on the cliff top with additional pay parking ($5.00) located on the opposite side of a peninsula. Access from the cliff includes a short but somewhat strenuous walk down a staircase. Access from the pay lot is longer and more strenuous.
Leo Carrillo (Low Use)	LEOL	4	Malibu Coastline	34 02' 45" 118 55' 42"	32	837.4	State Beach	Free parking is available along the street with additional pay parking ($3.00) located nearby. Access to the site includes a short walk along a sandy beach.
Leo Carrillo (High Use)	LEOH	4	Malibu Coastline	34 02' 41" 118 55' 57"	48	3152.5	State Beach	Free parking is available along the street with additional pay parking ($3.00) located nearby. Access to the site is very close to parking.

Table 2. Total number of visitors per year at rocky intertidal sites.

Estimates based on mean visitor per hour for weekdays and weekends separately, a 4 hour low tide period, and the number of weekend and weekday days with tides below 0.5 ft. during daylight hours. Data are also standardized per 100 m of shoreline.

Site	Visitors per hour weekday	Visitors per hour weekend	Estimated total visitors per year	Visitors per year per 100 m shoreline
PTFL	3.1	7.4	2,899	5,177
PTFH	20.1	55.6	20,200	51,795
INSP	0.3	0.7	278	428
ABAL	2.0	17.9	4,287	11,908
WHT	12.1	59.7	16,987	28,312
LDUME	2.1	2.9	1,575	2,500
PARA	11.4	51.7	15,167	47,397
DUME	13.2	28.3	11,754	37,916
LEOL	2.9	11.3	3,518	10,994
LEOH	20.8	71.9	23,546	49,054

Table 3. Summary of Two-Way ANOVA with site pair and day type as fixed factors for 10-min use surveys.

Analyses were conducted on each category in which a visitor was assigned based on the most destructive activity conducted over a 10 minute survey.

Category	Site	Day Type	Site x Day Type
Sitting/Standing	P<0.001	P<0.001	P=0.453
Walking	P<0.001	P<0.001	P=0.273
Handling	P<0.001	P<0.001	P=0.010
Collecting	P<0.001	P<0.001	P=0.005
Fishing	P<0.001	P=0.001	P<0.001

Table 4. Results from multiple regression analysis with R^2=0.918.

Factor	Standardized Coefficient	P value
Use by school groups	0.578	0.032
Effort spent reaching site	-0.491	0.048
Cost of parking	0.221	0.382
Nearby population	0.055	0.803
Other site attractions	-0.004	0.986

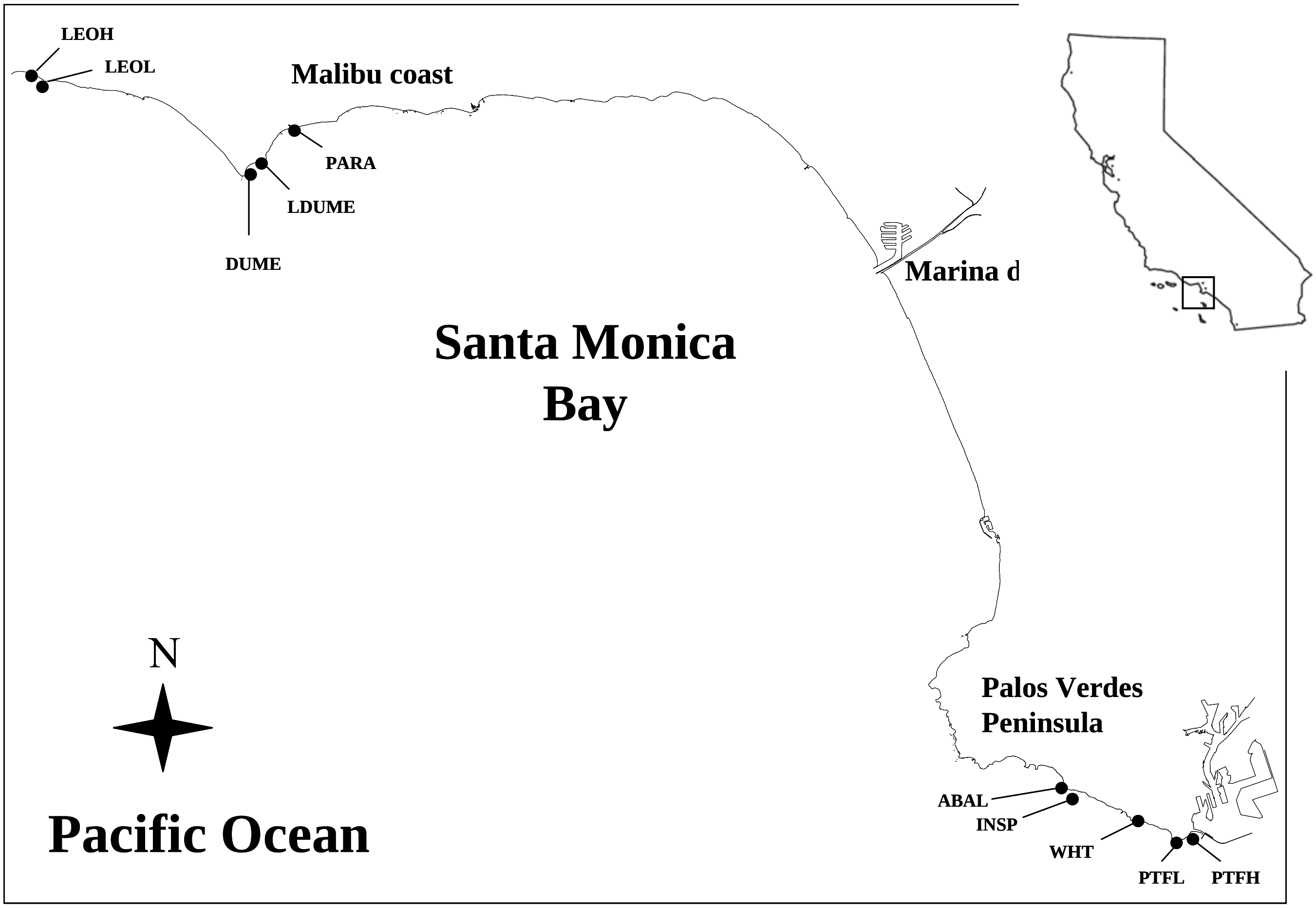

Figure 2. Map of ten sites located within the Santa Monica Bay, Los Angeles County, California.

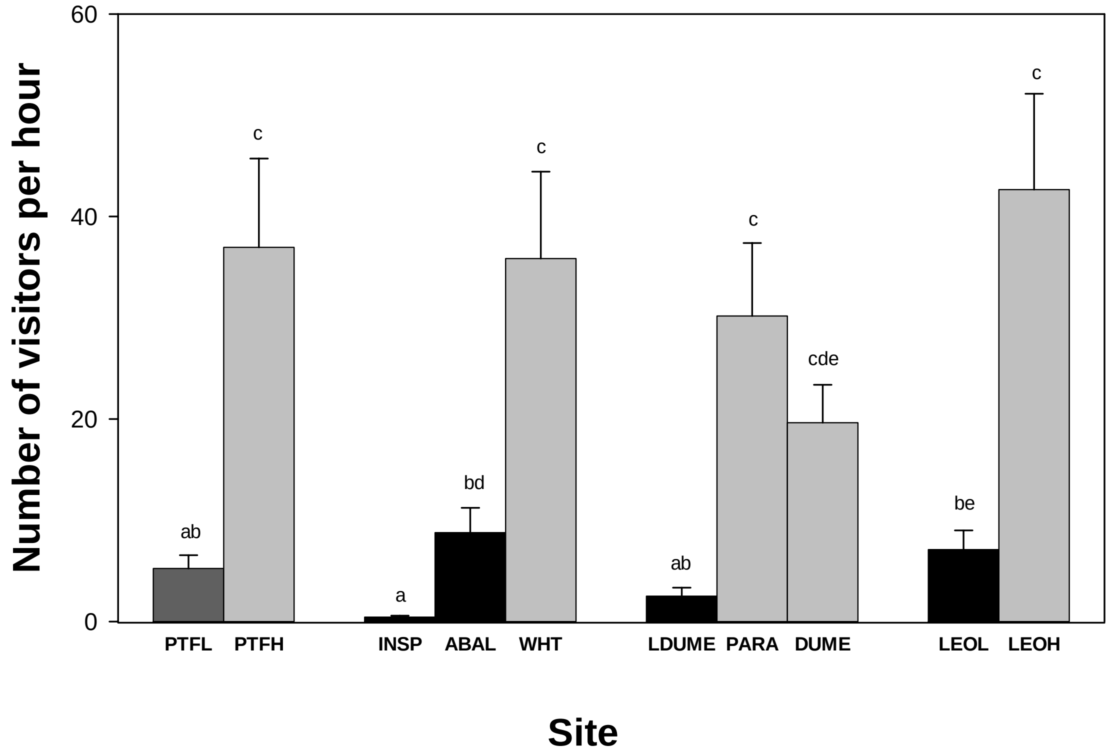

Figure 3. Number of visitors (Mean ± SE) found at each of the ten sites.

Differences among sites were assessed with a one-way ANOVA ($p<0.001$); for presentation purposes, sites are grouped based on similar locations and site characteristics. Sites with the same letter were not significantly different based on Tukey's multiple comparison.

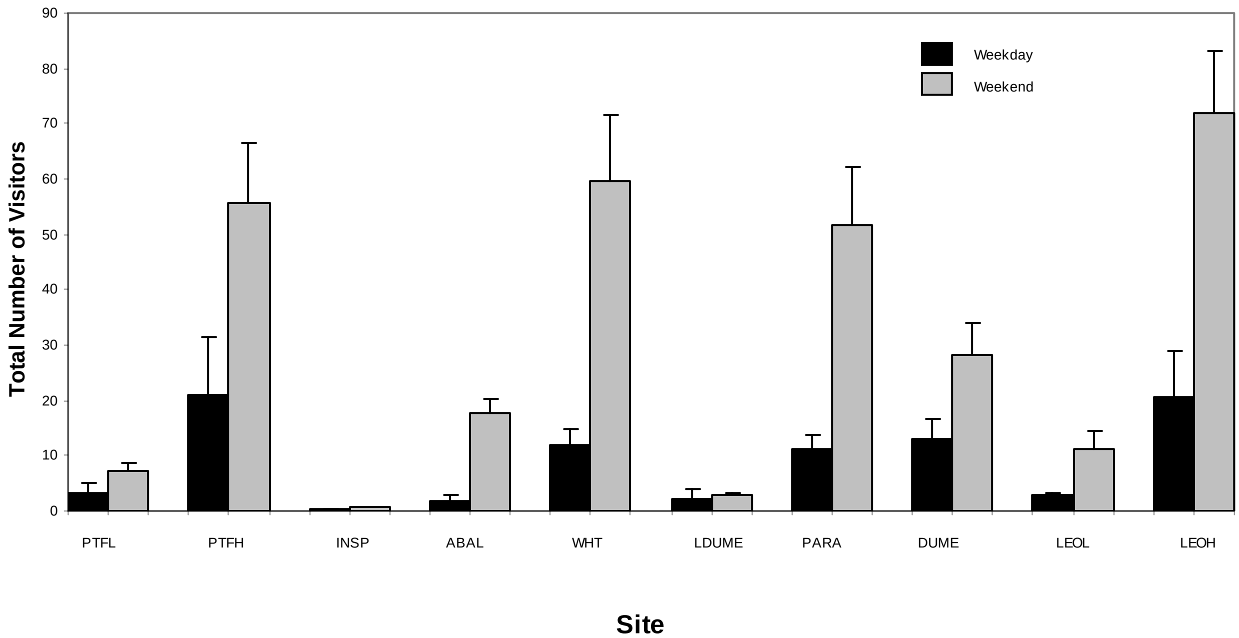

Figure 4. Number of visitors (Mean ± SE) found within each of the ten sites on either weekends or weekdays.

A Two-Way ANOVA revealed significant differences among sites and day type.

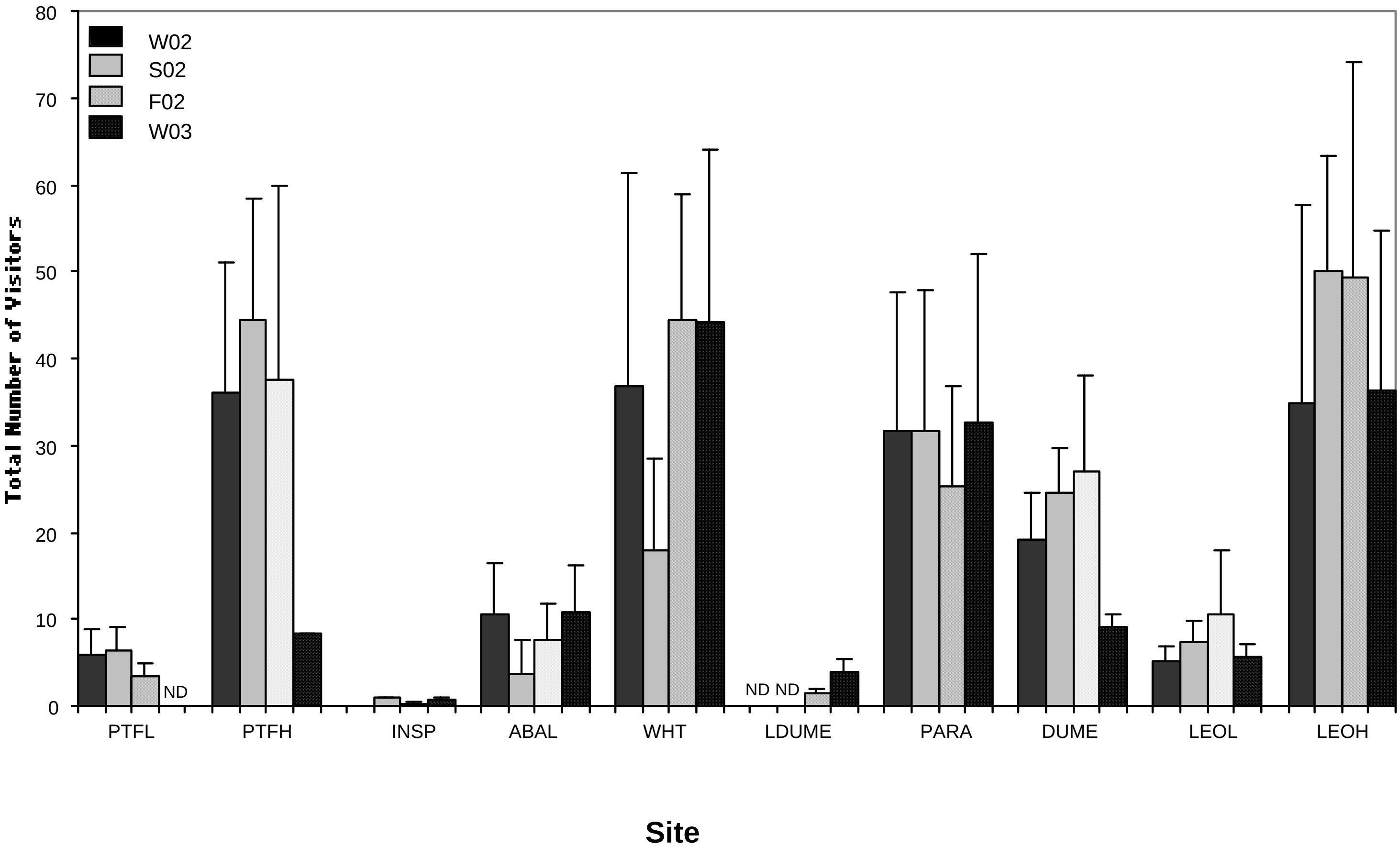

Figure 5. Number of visitors (Mean ± SE) found within each of the ten sites in four sampled seasons.

Summer 2002 was not sampled because low tides during this period fall within darkness when people visiting the sites are unlikely. During some seasons, a few sites were only visited on one occasion (no SE) or not at all (ND)

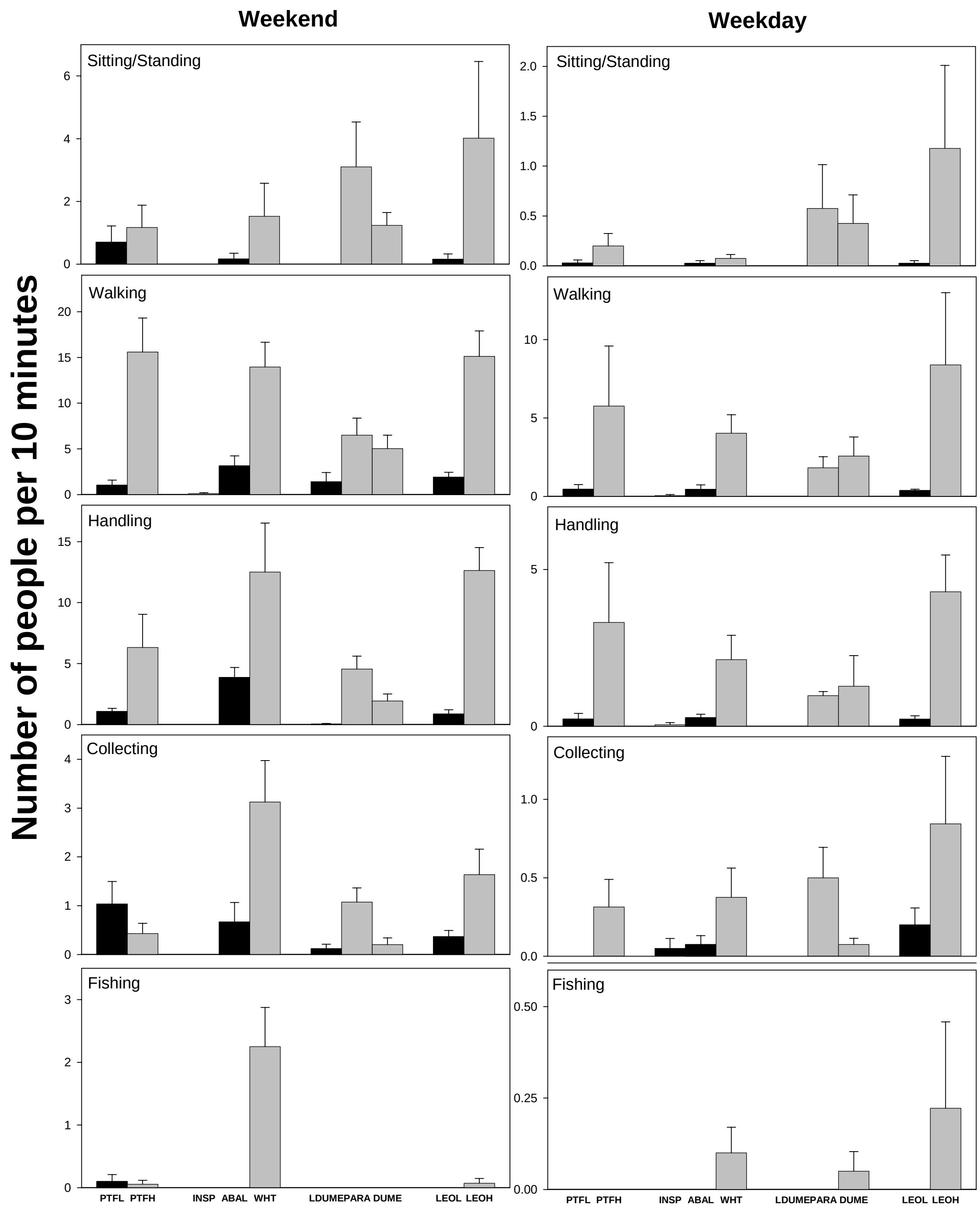

Figure 6. Number of people per 10 minutes (Mean ± SE) performing one of five activities (sitting/standing, walking, handling, collecting, and fishing).

Visitors were assigned to categories based on the most destructive activity conducted over a 10-min survey. Data are based on the mean number of visitors observed at one site per day. Note different scales for individual panels.

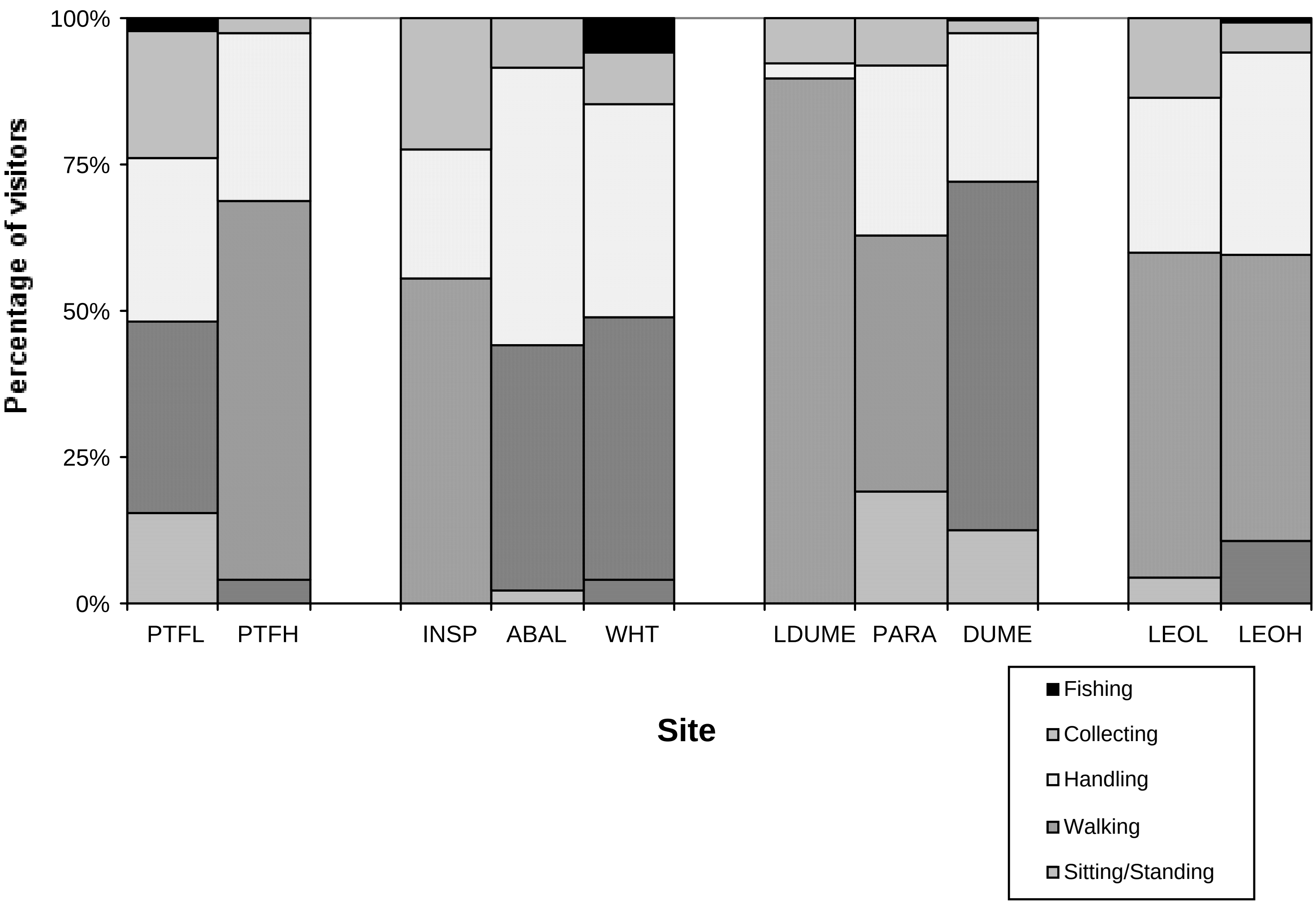

Figure 7. The frequency of visitors assigned into one of five categories during 10-minute surveys at all ten sites.

The category assigned was the most destructive activity conducted over the 10-minute survey.

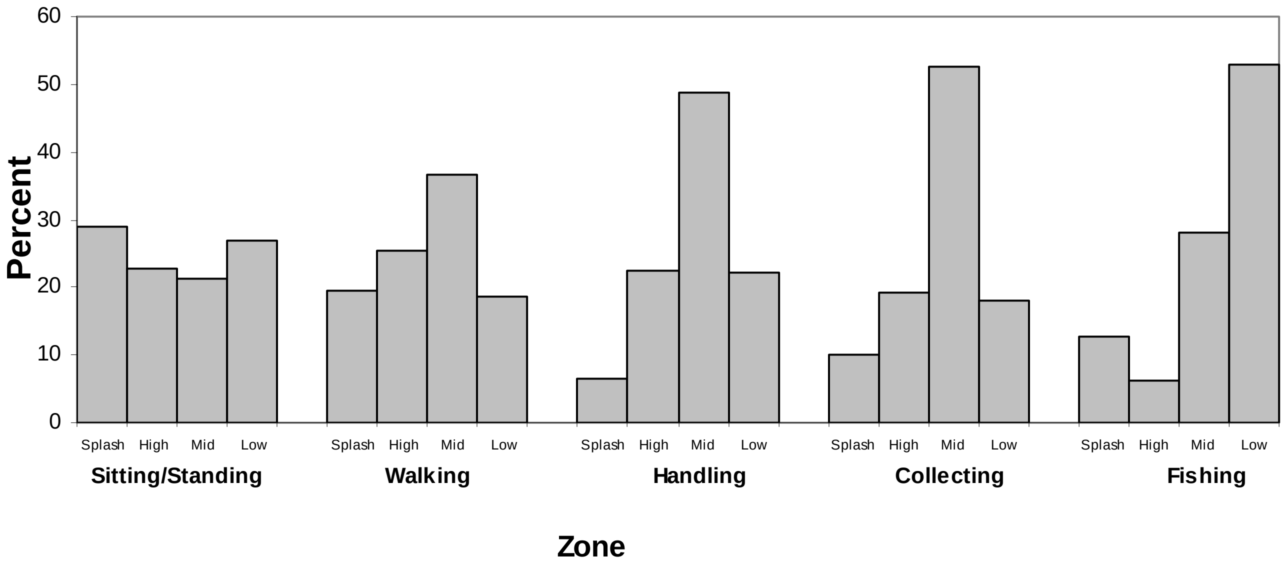

Figure 8. The percent of people within five use categories occupying four intertidal zones.

Percentages are based on observation made during 10-minute surveys. The zones inhabited are based on the time in which a person sitting/standing, walking, handling, collecting, or fishing spent the most during the 10 minutes surveyed.

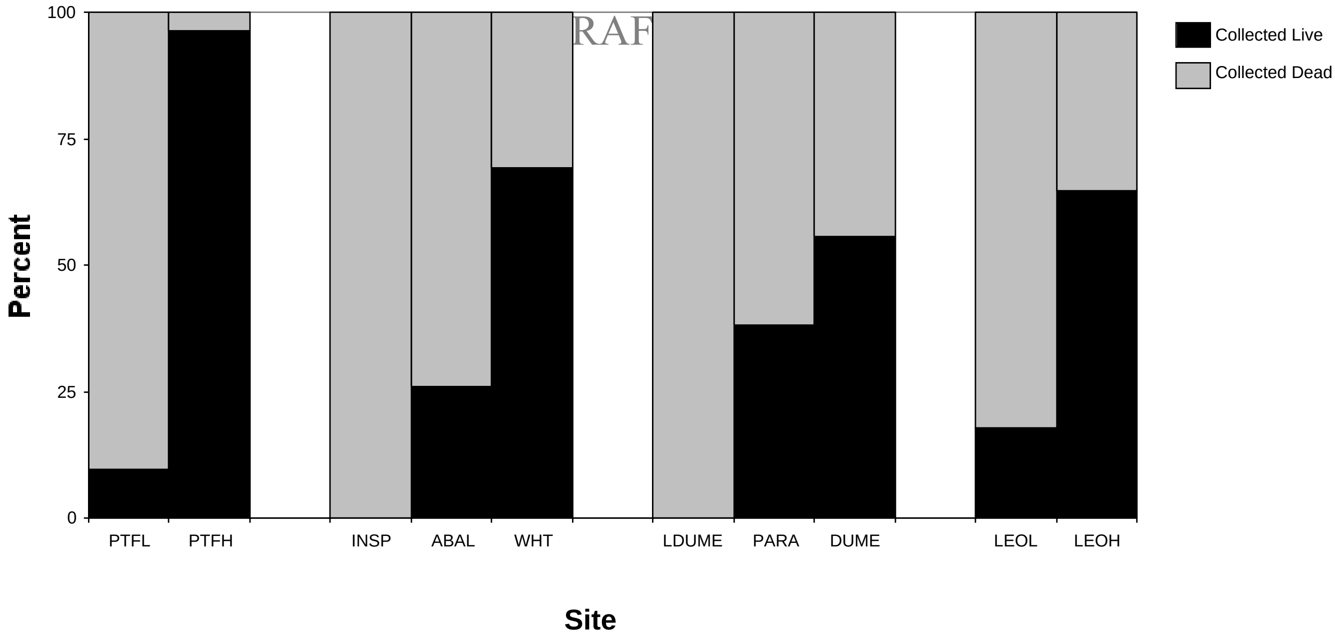

Figure 9. The percentage of collectors that collected live organisms and those that collected rocks and shells (dead).

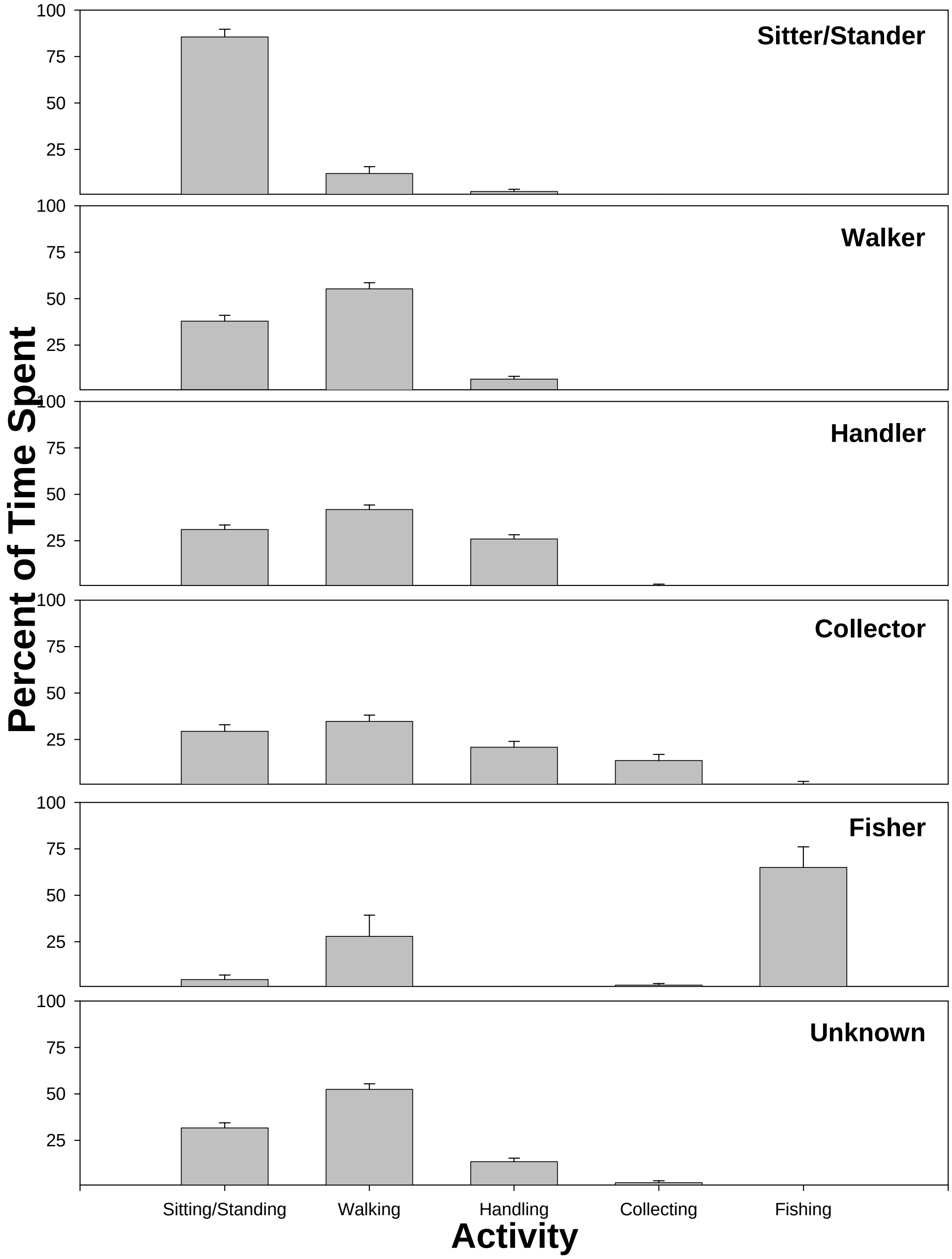

Figure 10. Mean percentage of time spent (± SE) in five activities.

The five activities (sitting/standing, walking, handling, collecting, and fishing) were compiled for persons identified as falling into one of six categories based on 10-minute surveys taken before each focal survey. Those who arrived on site during the focal survey, after the 10-minute surveys were finished, fell into an "unknown" category.

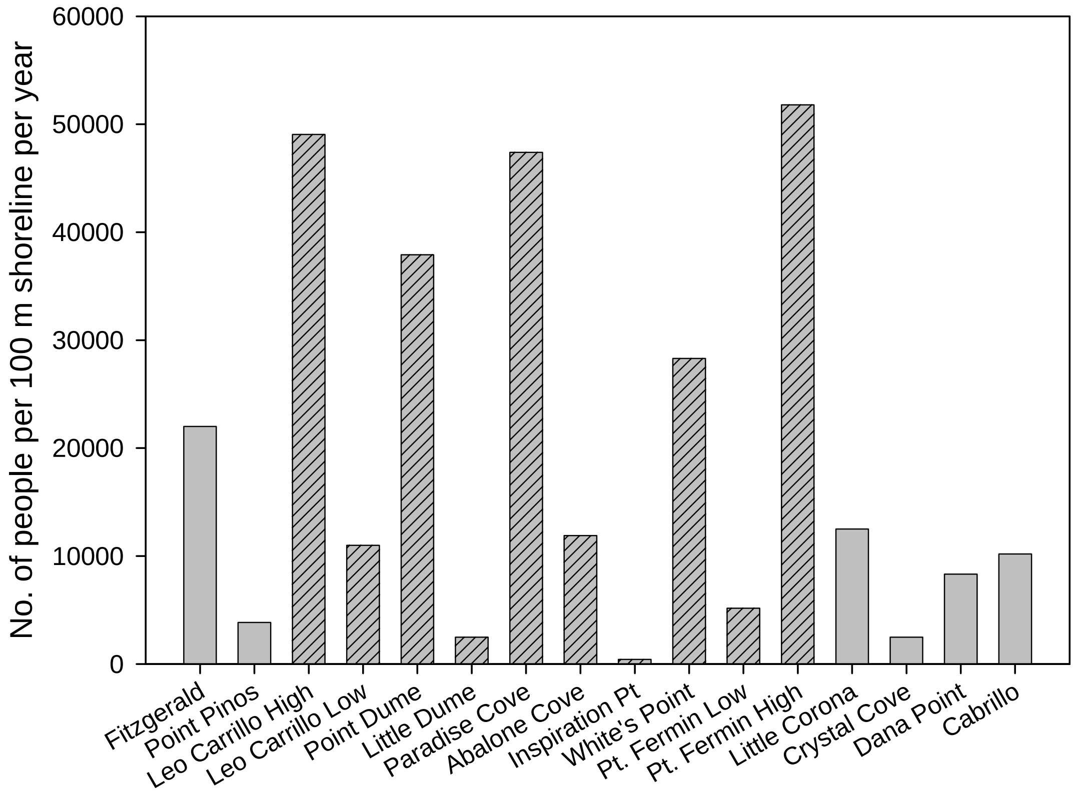

Figure 11. Annual visitation estimates at rocky intertidal sites in California.

Sites are arranged from north to south; sites in Santa Monica Bay denoted by hatched bars. Estimates derived using different methods; the estimate for Cabrillo may be an overestimate, and the estimates for Little Corona, Crystal Cove and Dana Point are not based on quantitative observations of actual use of the rocky intertidal habitat but a general estimate of 100,000 visitors per area; this estimate and shoreline lengths from Tenera (2003). Data from various sources as summarized in Tenera (2003).

Chapter 3. Condition of rocky intertidal populations and relationship to levels of human use

Introduction

Coastal ecosystems, some of the most productive and diverse of all systems, are impacted by humans in several ways, including habitat loss and degradation, pollution, overexploitation, species introductions, and global climatic change (Suchanek, 1994). With 60% of the world's population living within 100 km of the coast (Vitousek et al., 1997), coastal ecosystems are exposed to a particularly large degree of anthropogenic disturbances. In California, where more than 20 million humans live near the coast (Lindberg, et al., 1998), the coast is a popular destination for recreational activity.

The rocky intertidal zone is a diverse coastal ecosystem that is exposed to several types of human perturbations, including pollution, oil spills, and recreational activities. Recreational activities in the rocky intertidal zone including activities such as fishing; tidepooling; collecting organisms for food, fish bait, home aquaria, or research; educational field trips; seaside strolling; and photography. The resulting trampling, handling and collecting of organisms, and overturning of rocks can directly impact intertidal populations.

Collecting of organisms is likely the most damaging of activities conducted by humans visiting rocky shores as it results in the direct removal of organisms. Human exploitation of the rocky intertidal in many parts of the world has been occurring for thousands of years (Vedder and Norris, 1963; Speed, 1969; Abbot and Haderlie, 1980; Dillehaye, 1984; Lindberg et al., 1998). Extraction of individuals decreases abundances and often alters the size structure of a population because humans are size-selective towards the largest specimens (Branch, 1975; McLachlan and Lombard, 1981; Moreno et al, 1984; Hockey and Bosman, 1986; Ortega, 1987; Lasiak and Dye, 1989, Lasiak, 1991). Removal of larger individuals may result in a disproportionate decrease in the reproductive ability of the population because the reproductive potential (e.g. gonad volume) increases exponentially with size (Seapy, 1966; Branch, 1974, 1975; Parry, 1977; Creese, 1980; Levitan, 1991; Levitan et al., 1992; Tegner et al., 1996). In addition, for species such as *Lottia gigantea* that are protandrous (i.e., change from male to female with age), the extraction of larger (and thus older) individuals may decrease the reproductive potential of a population by decreasing the number of females. Removal of organisms may also cause changes in community structure and further cascading effects on other intertidal populations (Moreno et al., 1984; Duran and Castilla, 1989; Kingsford et al., 1991).

In contrast to the obvious effects of collecting, trampling in the rocky intertidal zone is a common but often unnoticed disturbance. Several studies have assessed the impacts of trampling on flora and fauna of the rocky intertidal, most of which have shown deleterious effects (see references in Table 5). If trampling does not immediately dislodge organisms, it can weaken attachment strengths, making them more susceptible to loss from wave activity (Brosnan and Crumrine, 1994; Smith, 2002). Trampling can also cause morphological damage that may have an effect on other physiological or reproductive processes. For instance, trampling on the rockweed *Silvetia compressa* resulted in damage to the frond tips that hold the receptacles for reproduction (Murray, 1997; Denis and Murray, 2001). The brown alga *Hormosira* sustained a loss of its vesicles or air bladders when trampled (Keough and Quinn, 1998; Schiel and Taylor, 1999), affecting how it competes for light and withstands heat stress (Schiel and Taylor, 1999).

Few studies have documented the effects of humans turning over intertidal rocks. Some impacts are obvious, since many organisms living on the undersides of rocks cannot survive extended exposure to light and desiccation. In fact, frequently visited intertidal sites are often characterized by conspicuous rocks with exposed bleached and dead organisms that normally occur on the undersides of rocks. Similarly, seaweeds that live on the tops of rocks may bleach and die when light is restricted after the rock is turned over. However, rocks are also turned by natural processes; for example, Sousa (1979) showed that diversity was actually highest on medium-sized boulders that were flipped occasionally by waves.

The purpose of this study was to investigate how human visitation to rocky intertidal habitats might alter the invertebrate and algal populations occurring there. We examined rocky intertidal populations at several sites in the Santa Monica Bay, Los Angeles County, California. Rocky intertidal locations within the Santa Monica Bay are all open to human access and have likely been subjected to human visitation for many years. Some harvesting has likely occurred for centuries, but impacts presumably increased markedly in the 1950s and 1960s as the population of Los Angeles grew substantially. Unfortunately, although there are anecdotal reports of much richer intertidal habitats in the past, there are no relevant quantitative studies against which today's intertidal communities could be compared. Therefore, instead of a before-after study design, we utilized a gradient impact design (Wiens and Parker, 1995) in which rocky intertidal populations were compared among sites exposed to differing levels of human visitation.

We hypothesized that most, but not all, species or flora/fauna groupings would be negatively associated with human visitation. Table 5 presents the expected impacts for the major species/species groups in southern California rocky intertidal habitats. Table 5 also indicates which mechanism (collecting and/or trampling) we expect to cause damage to intertidal populations. Predicted impacts were based on previous studies (see references in Table 5) or, where no previous research could serve as a guide, considerations of species morphologies or harvesting.

Methods

Ten sites were sampled in Santa Monica Bay in Los Angeles County, California (Figure 12). Five sites were chosen along the Palos Verdes Peninsula and five sites in the Malibu region; these two areas are the only rocky sections of the Bay, with the intervening region consisting mainly of sandy beaches not suitable for this study. All sites were within 60 km and were subjected to relatively similar oceanographic conditions such as salinity and sea surface temperatures. Sites differed in the degree of human use based on surveys conducted from winter 2002 to winter 2003 (Chapter 2) and were categorized into high and low levels of human visitation based on the total number of visitors per hour a site received (Table 6). Sites were placed into matched pairs or groups with at least one low and one high use site within a group (Table 6). Sites were matched based on similarities in habitat and location to account for habitat differences along the PV and Malibu coasts. However, due to difficulties in finding sites within Santa Monica Bay with low levels of human visitation, sites could not be matched perfectly. Leo Carrillo High Use and Leo Carrillo Low Use was the best matched pair, since the habitat was very similar and exposed to very similar physical conditions. Because of the imperfect matching, site pairs were not analyzed statistically, but instead are used to illustrate trends where applicable.

Biological communities at each site were sampled using the biodiversity survey protocol established by the Multi-Agency Rocky Intertidal Network (MARINe) for surveying sites throughout the west coast of North America. Sessile organisms were sampled using a point-contact method. At each site, a 30-m transect line was placed in the upper limit of the splash intertidal zone, parallel with the shore. Eleven transects were then placed perpendicularly every 3 m along that transect, so that these transects ran from the high zone into the low intertidal zone. The length of the transects varied from 25 to 40 m depending on the site but all 11 transects within a site were of equal length. Along each transect, 100 uniformly spaced points were chosen and each species found directly below that point was recorded. The percent cover of each species along each transect was calculated based on the number of hits out of 100 possible points. Species richness and diversity (Shannon-Wiener Diversity and Pielou's Evenness; Pielou, 1975) were calculated for each site using percent cover data. To simplify analyses, cover data for similar species were grouped. Seven groups of algae were analyzed, including filamentous or filamentous-like algae (*Ceramium*, *Centrocerus*, *Polysiphonia*), encrusting algae (*Ralfsia*, *Psuedolithoderma*, *Lithophyllum*), blade algae (*Ulva*, *Enteromorpha*, *Smithora*, *Pophyra, Cryptopleura, Endarachne*), articulated corallines (*Corallina*, *Lithothrix*, *Bossiella, Calliarthron*), fleshy algae (various fleshy reds such as *Prionitis*, *Gelidium*, *Mazzaella*, *Chondrocanthus*, *Pterocladiella* and browns such as *Colpomenia, Scytosiphon*), rockweed (*Silvetia*), tough and leathery algae (*Sargassum*, *Egregia*, *Halidrys, Zonaria, Dictyota, Pachydictyon*), and seagrass (*Phyllospadix*). The total cover of all seaweeds and seagrasses was also analyzed. For sessile invertebrates, barnacles (*Chthamalus*, *Balanus*), anemones (*Anthopleura*), bivalves (*Mytilus*, *Septifer*, *Psuedochama*), tube-building worms and molluscs (*Phragmatopoma*, *Spirorbis*, *Serpulorbis*), and total invertebrates (sessile and motile) were analyzed.

Motile invertebrate densities were sampled using 0.5 m^2 quadrats randomly placed along each transect in the high, middle, and low intertidal zones. One quadrat was placed in each zone on each transect, for a total of 33 quadrats per site. All motile invertebrates within each quadrat were identified to species and counted. To simplify analysis, some species were combined into similar groups such as limpets (*Lottia*, *MacClintockia*), chitons (*Lepidochitona*, *Lepidozona*, *Mopalia*), and snails (*Littorina*, *Acanthina*, *Nucella*, *Epitonium*). In addition, species richness and diversity (Shannon-Wiener Diversity and Pielou's Evenness) of motile invertebrates were calculated for each site.

For rare, large invertebrate species, such as *Pisaster, Aplysia, Megathura,* and *Parastichopus,* we counted all individuals within 2 m (1 m on each side) along each of the eleven transects. Additionally, we measured the shell lengths of owl limpets, *Lottia gigantea*, by haphazardly placing 0.5 m^2 plots within owl limpet habitat and measuring all owl limpets within the plots.

Analyses

Statistical analyses were conducted using Minitab 13.32 software. Data were tested for statistical assumptions; to meet the assumption of normality, percent cover of several sessile species were arcsine transformed and densities of several motile invertebrate were log x+1 transformed.

Because the study design was not a perfect matched-pairs design (i.e., some site groups had two sites while others had three) and there was a gradient of human use included in the study sites, there was no single statistical analysis that would indicate whether species were impacted by human activities. For this reason, we used five analytical approaches to assess impact. The first approach was based on a visual assessment of a trend in cover or density from a graph with sites arranged from lowest to highest use. This qualitative assessment was supported by a one-factor ANOVA with site as the main factor. When the overall ANOVA was significant, Tukey's multiple comparisons tests were performed to determine which sites were significantly different from one another. Although percent cover and motile invertebrate density was measured for all species encountered at a site, only a few species where abundant enough for analysis. In many cases, species were combined into groups for analysis.

The second approach also depended on comparison of sites along a gradient of human use, but the comparison was limited to sites within a group. In other words, for each group of matched sites, we assessed whether the high(er) use site(s) had lower cover or density than the low(er) use site(s). This approach takes advantage of the site-matching used in selecting the study sites, which we did because of the great variability in physical conditions between rocky intertidal habitats. Patterns were based on nominal differences between low and high use sites within a site group. The one-factor ANOVAs and Tukey's multiple comparisons tests were used as supplemental information. Evidence of impact was based on an assessment of how many out of the four site groups exhibited a particular trend.

The third and fourth approaches were based on t-tests. T-tests were used to analyze population differences among all low compared to all high use sites. In addition, a t-test was used to compare intertidal populations among the best-matched pair of sites at Leo Carrillo (Low and High use sites).

For the fifth and final approach, a regression was used with log (x+1) transformed visitor data (number of human visitors per hour; Chapter 2) and biological data (mean percent cover (arcsine transformed) or invertebrate density (log x+1 transformed)) to evaluate the relationship between use and intertidal populations.

Lottia gigantea differed from other taxa in that sizes rather than densities were measured. Differences among sites in mean size of *L. gigantea* were analyzed using a one-factor analysis of variance (ANOVA) with site as the main factor. Size frequency distributions of *L. gigantea* were compared using Kolmogorov-Smirnov tests for each site pair.

Results

Lottia gigantea ***shell length***

The mean size of *L. gigantea* varied significantly among sites (Figure 13; log transformed data, ANOVA, $p<0.001$) and was generally larger in the low use site compared to the high use site within its matched group. The mean size at all low use sites combined (39.8 mm) was significantly larger than at all high use sites combined (27.6 mm, t-test, $p<0.001$). Mean size at a site was negatively associated with the number of visitors per hour at that site (Regression, $p=0.023$, $R^2=0.55$).

At low use sites (excluding Leo Carrillo Low Use, with only two limpets), the maximum owl limpet lengths were 75, 66, 77 and 62 mm while at high use sites, the maximum lengths were 64, 48, 51, and 44 mm. Only 6 of the 148 largest limpets measured (> 45 mm) were found at high use sites. The limpet size distributions of the low use sites differed from the high use sites among site pairings (Figure 14; Kolmogorov-Smirnov, $p<0.001$), except for the pairings with Leo Carrillo Low, where only 2 limpets were found, and Paradise Cove, where only 10 limpets were found. In all cases, the distributions differed by the absence of larger *Lottia gigantea* at the high-use sites.

Percent Cover

Each of the analyzed algae groups was found to vary significantly among sites (Figure 15; ANOVA, $p<0.001$). Four groups, articulated algae, blade algae, fleshy algae, and rockweeds, were predicted to experience declines due to human use (Table 5). Articulated algae ranged from 12.8% at Point Fermin Low Use to 3.1% at White's Point. Although the highest covers were at relatively low use areas and the lowest cover was at a high use area, overall there was no clear pattern with respect to human use. Blade algae cover was similar at all sites except Little Dume (a low-use area), which had a significantly higher cover than all other sites. Fleshy algae cover was highest at Little Dume (10.5) and lowest at Point Dume (1.0). Again, the highest cover was at a low-use site and the lowest cover at a high-use site. Although overall there was no clear pattern with respect to human use, cover at the high use site within the pair or group was often lower than the low use site. Rockweed was found at only three sites and constituted less than 2% of the cover at those sites. Three algal groups, encrusting algae, seagrass, and tough and leathery algae, were predicted to show no effects of human use. Encrusting algae cover varied among sites, with no pattern with respect to human use, as expected. The pattern for tough and leathery algae was also as expected, with low cover at all sites except Leo Carrillo High Use. In contrast, seagrass showed a relationship with human use. Seagrass was mostly absent at sites in Palos Verdes, but in Malibu, seagrass cover was higher at the low use sites compared to their paired high use sites. Filamentous algal cover, which was predicted to be either unaffected or positively affected by human, was significantly higher at Point Dume (28%) than all other sites, but there was no clear pattern with human use. Total plant cover reached almost 60% at Little Dume, a low-use site, while cover at White's Point, a high-use site, was only 17%. In spite of a correspondence between use and total algal cover at the extremes, the no overall pattern between total algal cover and level of use was apparent.

The slope of the regression between cover at a site and the number of human visitors per hour at that site was negative for six of the eight algal groups, but none of these regressions was significant (Table 7). Although not significant, the slopes of the regressions were generally consistent with predicted effects. Within the Malibu region, which is mainly where seagrass was found, seagrass showed a significantly negative relationship with visitors (Table 7). When looking at the best matched pair sites at Leo Carrillo, blade algae and seagrass cover was significantly lower at the high use site (t-test; $p=0.054$, $p<0.001$), tough and leathery algal cover was significantly higher (t-test; $p=0.006$), while encrusting algae was nearly significantly higher (t-test; $p=0.083$).

Considering all analytical approaches, none of the algal groups had good evidence for an impact of human use (Table 8). However, for articulated algae and blade algae there were indications of a negative effect for two of the five approaches we used. In addition, there was strong evidence that seagrass was negatively associated with level of human use.

The cover of sessile invertebrate groups and total invertebrates (sessile and motile) varied significantly among sites (Figure 16, ANOVA, anemones p=0.045, all others p <0.001). Three groups, bivalves, anemones and tube-building worms/molluscs, were predicted to experience declines due to human use (Table 5). Bivalve cover was similar among all sites except at White's Point, a high-use site with significantly higher bivalve cover than the other sites, so there was no indication that bivalve cover was related to use. Anemone cover ranged from 3.5% at Leo Carrillo Low Use to 0.9% at Point Fermin High, with the highest use sites having relatively low cover, consistent with the predicted effect of human use. Tube-building worm and mollusc cover was highest at Leo Carrillo Low Use (16%). Although the overall cover of tube-building worms and mollusks did not show a clear relationship to level of use, their cover was generally lower in the high use site within a site grouping. In contrast to these taxa, barnacle cover was predicted to be unaffected by use level. Barnacle cover was highest at White's Point, a high-use site, and next highest at low-use sites, consistent with the prediction of no relationship to level of use. Total invertebrate cover varied from 35% at White's Point to less than 1% at Point Dume.

None of the invertebrate groups was found to have a significant relationship with visitor use (Table 7). The regression with anemones and tube-building worms had a negative slope, as expected, but the relationship was weak, and the relationship with bivalves was positive rather than negative. Barnacle, anemone, tube-building worm/mollusc, and total invertebrate cover were significantly lower at the high use portion of Leo Carrillo compared to the low use portion (t-test p=0.047, 0.010, <0.001, and <0.001, respectively); bivalves were nearly significant lower (p=0.067).

Considering all analytical approaches, two of the invertebrate groups, anemones and tube-building worms and mollusks, had good evidence for an impact of human use (Table 8).

Bare rock was a major constituent of cover at all sites and differed significantly among sites (Figure 16, ANOVA, P<0.001). Contrary to expectations, overall the cover of bare rock did not increase with higher use. Instead, there was a significant effect of region, with bare rock cover being higher at sites on the Palos Verdes Peninsula. Within the two regions (Malibu and Palos Verdes), there was no relationship between the cover of bare rock and level of use. However, at the best matched pair of sites, Leo Carrillo, bare rock cover was significantly higher at the high use site (t-test, p<0.001).

Across all sites, 84 different species of algae and invertebrates were recorded. Species diversity measurements calculated using percent cover data (richness, Shannon-Wiener Diversity Index, Pielou's Evenness) were found to vary significantly among sites (Figure 16, ANOVA, p<0.001). Diversity was relatively similar among sites except at Point Dume, where diversity was always significantly lower. No trends were observed among site pairs for species diversity although Pielou's Evenness was significantly higher at Leo Carrillo High Use than Leo Carrillo Low Use (t-test, p<0.001). All three diversity indices showed a pattern of having a negative relationship with human visitation but none was significant (Table 7).

Motile Invertebrate Density

All motile invertebrate species and groups varied significantly among sites (Figure 17, ANOVA, p<0.001). Five groups, *Pachygrapsis crassipes*, *Pagurus* spp., *Strongylocentrotus purpuratus*, *Tegula* spp., and total limpets, were predicted to experience declines due to human use (Table 5). *Pachygrapsus crassipes* density was similar at all sites except White's Point, a high-use site. The density of hermit crabs (*Pagurus* spp.) ranged from 35 individuals m^{-2} at Inspiration Point to less than 2 individuals m^{-2} at Point Dume. Although the pattern was not consistent across all site groups, for the site group with the highest hermit crab densities, densities were lower at the sites with higher use. *Pagurus* was nearly significantly lower in all high use sites combined than low use sites (t-test p=0.056). Urchin density was low at most high use sites (except Point Fermin High Use) and reached up to 51 individuals m^{-2} at Point Fermin Low Use. *Strongylocentrotus purpuratus* densities were always lower in the high use sites and was nearly significantly lower in all high use sites combined as compared to all low use sites combined (t-test p=0.061). *Tegula* spp. density was high at the two Leo Carrillo sites. There was little difference between high and low use sites within site groups. Limpets (*Lottia* spp., *MacClinockia scabra*) were abundant at most sites. At two site groups, Leo Carrillo and Point Dume, limpets occurred at lower densities at the high-use site, but there was no pattern at the other site groups. Two taxa, littorines and chitons, were predicted to be unaffected by human use (Table 5). *Littorina* spp. occurred in very large numbers at White's Point (about 2500 individuals m^{-2}), significantly higher than all other sites, with no apparent relationship to level of use. Chiton density was highest at Point Fermin, again with no apparent relationship to level of use.

The large, conspicuous and relatively rare invertebrate species and groups varied significantly among sites (Figure 18, ANOVA, p<0.001). *Pisaster* density was higher at low use sites than high use sites within two of the site groups. The density of *Aplysia* was significantly higher at Leo Carrillo Low Use than all other sites. In addition, *Aplysia* densities were low or zero at all high use sites. The density of all rare and conspicuous invertebrates was significantly higher at Inspiration Point and Leo Carrillo Low Use, two low-use sites, compared to the remaining sites. *Aplysia californica* and rare, conspicuous invertebrate densities were also found to be mostly lower in the high use site of the site groupings. *Aplysia* was found at all low use sites and only at three of the five high use sites. In addition, *Aplysia* was nearly significantly lower in all high use site combined than at low use sites (t-test p=0.063). Since *Pisaster* and rare, conspicuous invertebrates are known to be frequently collected, we found that sites where collecting is relatively low (Inspiration Point, Little Dume, Point Dume, Leo Carrillo Low Use, and Abalone Cove; see Chapter 2), *Pisaster* and conspicuous invertebrate densities were higher than at sites were collecting is common.

Eight of the nine motile invertebrate species predicted to be impacted by human use had negative slopes in the regression of density versus level of use, although only the regression for large, conspicuous invertebrate group (i.e., *Cypraea*, *Parastichopus*, *Navanax*, *Pisaster*, *Aplysia*, etc.) was significant. An unusually high density of urchins at Point Fermin High Use likely resulted in a non-significant regression even though urchin density at Point Fermin Low Use was higher. Point Fermin may have afforded a habitat particularly suitable for urchin populations. If Point Fermin High Use is removed from the regression analysis, we find a significantly negative relationship with visitor use (p=0.038, R^2=0.48). At Leo Carrillo, the best-matched pair of sites, there were significantly lower densities of *Strongylocentrotus* (p=0.073), total limpets (p=0.026), *Pisaster* (p=0.004), *Aplysia* (p<0.001), and all rare, conspicuous invertebrates (p<0.001) at the high use site.

Considering all analytical approaches, four of the invertebrate groups we examined had good evidence for an impact of human use (Table 8). *Pisaster*, *Strongylocentrotus*, *Aplysia*, and rare/conspicuous invertebrates were all predicted to be affected by collecting. In addition, there were indications of a negative effect for two of the five approaches we used for *Pagurus* and limpets.

At all sites, a total of 44 different motile invertebrate species were identified from plot measurements while an additional six rare, large, conspicuous species were found during transect swaths. Species diversity measurements calculated using motile invertebrate densities (richness, Shannon-Wiener Diversity Index, Pielou's Evenness) were found to vary significantly among sites (Figure 17, ANOVA, p<0.001). Diversity was relatively equal at most sites except Point Dume which had significantly lower biodiversity than the other sites. Among site groupings, richness and Shannon-Wiener Diversity were found to be mostly lower in the high use site (with the exception of Leo Carrillo for Shannon-Wiener diversity). Pielou's evenness was significantly higher in the high use site of the Leo Carrillo matched pair (t-test, p=0.007). All three diversity measures had a negative relationship with human visitation but no regressions were significant (Table 7).

Discussion

There are significant challenges associated with detecting the impacts of human activities on rocky intertidal communities. The most significant obstacle is determining the appropriate reference condition against which current conditions can be compared. Rocky intertidal communities are extremely variable over space, making a simple comparison of two sites, as in a control-impact design (Wiens and Parker 1995) problematic. We have tried to minimize the effect of this spatial variability by matching high-use sites to low-use sites (similar to Wiens and Parker's matched-pairs design), but natural spatial differences are still expected, and this variability will reduce the power of statistical tests to detect differences among sites. In addition, human activities in the rocky intertidal are "press" disturbances that have extended over many decades, so we have inadequate information on the nature of these communities before they were impacted by humans, further complicating any search for evidence of human impacts. Finally, human impacts in an urban area such as Santa Monica Bay are diffuse and pervasive; as shown in Chapter 2, the pervasive use of rocky intertidal habitats in Santa Monica Bay means there are few (if any) truly low-use sites in the region. As a consequence of these challenges, we expect to be able to detect only substantial impacts on species that can tolerate some anthropogenic disturbances, and hence still occur in the region. Our data do not include information on black abalone, for example, since they are virtually absent from the entire region. We have employed a weight of evidence approach for deciding if a taxon has been affected by human use, synthesizing the results of the different analyses we used (summarized in Table 8).

The human activities likely to most directly impact rocky intertidal organisms in Santa Monica Bay are (1) collecting and (2) trampling and other general wear-and-tear of organisms from handling, turning of rocks, etc. The effects of collecting are easy to understand, and collecting has been shown to impact rocky intertidal organisms throughout the world. In this study, the species predicted to be affected by collecting (Table 5) showed the clearest effects of anthropogenic impact (Table 8). The strongest indications of human impacts on collected species occurred in owl limpets, rare and conspicuous invertebrates, *Pisaster*, sea urchins, and *Aplysia*, with *Pagurus* also having some indications of impacts.

The owl limpet is a commonly collected species (Murray et al., 1999; Chapter 2) and showed clear signs of negative impacts by human use in Santa Monica Bay. Humans are known to select the larger owl limpets for collection (Ghazanshahi, et al., 1983; Duran and Castilla, 1989, Lasiak and Field, 1995). Our results support this as *L. gigantea* populations were found to have a smaller mean size and a high frequency of small individuals at high-use sites compared to low-use sites. Our results are consistent with other studies conducted along the local coastline (Pombo and Escofet, 1996; Roy et al., 2003; Kido and Murray, 2003). Very few large limpets (>45 mm) were found at high use sites; even the largest limpet found at low use sites (77 mm) was well below the *L. gigantea* maximum size (>100 mm; Lindberg et al., 1998), perhaps suggesting that there may be some exploitation of *L. gigantea* at low use sites (see below). Results for high use sites were comparable to that of Kido and Murray (2003) who studied owl limpet sizes at 8 sites in Orange County, CA with differing levels of human use. At higher use sites, they found a mean size range of 26.2-28.5 mm while size ranged from 29.1-35.2 in lower use sites, compared to 25.3-31.6 mm at our high use sites and 28-45.2 mm at our low use sites. Low use sites in Orange County had smaller mean sizes than most of the low use sites in this study. The mean sizes at most sites in Santa Monica are much smaller than the mean size found at sites protected from human collecting in San Diego (~ 45 mm; Roy et al., 2003) and on one of the Channel Islands (49.0 mm, Pombo and Escofet, 1996).

Large, conspicuous invertebrate species such as *Pisaster*, *Aplysia*, and *Parastichopus* are particularly vulnerable to human activities and, as a group, had a significant negative relationship with human visitation. Conspicuous invertebrates, in particular *Pisaster,* were observed to be frequently collected (Chapter 2). *Pisaster* was previously found to be heavily impacted by human use and was completely absent at high use sites (Ghazanshahi, et al., 1983). Because they are easily spotted and occur in such low numbers, one individual conspicuous invertebrate is likely to be handled and molested more than individuals in higher densities would be. One species within this group, the sea slug *Aplysia californica*, is afforded little protection from trampling or handling as it is a soft-bodied organism. In addition, *Aplysia* secretes a red ink-like substance when molested and visitors to the intertidal often attempt to cause these animals to secrete their ink by squeezing them. Repeated molesting and displacement of individuals into unsuitable intertidal zones (also observed frequently during human use surveys, Chapter 2) will result in death and decreased densities.

Another commonly collected, large invertebrate, the purple sea urchin (*Strongylocentrotus purpuratus*), was consistently found at lower densities at the high use sites. *Strongylocentrotus purpuratus* is likely heavily impacted by collectors but may also be damaged from trampling or rock turning, since urchins can be easily crushed underfoot or under rocks. Although this study did not measure urchin sizes, previous studies have shown that urchins in high use sites were smaller than those in low use sites (Addessi, 1994), indicative of population changes from overexploitation.

Hermit crabs were another commonly collected species in which we expected to see declines with increased visitor intensity. In addition to people collecting live crabs, humans often collect shells that are potential homes for hermit crabs, which could also lead to decreased abundances at heavily use sites. In some places, many of the shells collected may contain hermit crabs, although the collectors may believe they are empty because the hermit crabs have retracted so far within the shell, they can not be seen. Contrary to our expectations, hermit crab abundance was at best weakly associated with visitor intensity. At most sites, hermit crab abundance was relatively equal except for the site grouping including Inspiration Point, Abalone Cove, and White's Point. Within this grouping, hermit crab densities were much higher than the other sites and were found to be higher in the two low use sites (Inspiration Point and Abalone Cove) as compared to the high use site (White's Point). Although there was a marginally significant overall t-test and a non-significant negative slope in the regression, the evidence for a human impact on hermit crab densities is not strong, perhaps because most sites had hermit crab abundances that were too low to indicate impacts sustained from human activities.

The most commonly collected snail in southern California is the turban snail (*Tegula* spp.). The regression indicated that *Tegula* densities were negatively associated with visitor use, significantly so if Leo Carrillo High Use is removed from the analysis (Regression, $p=0.049$, $R^2=0.45$). At other sites in southern California, *Tegula* sizes have been found to be smaller at sites where use intensities are higher suggesting perturbations from over collecting (Roy et al., 203; Sato and Murray, unpublished data). In spite of the regression results, the other indicators of human use did not show a strong impact on *Tegula* in Santa Monica Bay.

Bivalves, mainly mussels (*Mytilus* spp.), were expected to be impacted from both trampling and collecting (primarily for bait). Brosnan and Crumrine (1994) demonstrated the susceptibility of mussels to trampling, and Smith (2002; unpublished data) and Zedler (1978) have shown an association between lower mussel cover or biomass and high use sites in southern California. At our Santa Monica Bay study sites, however, there was little evidence of an impact of human use on mussels. The high mussel cover at White's Point, a high use site, disrupted any relationship with use. White's Point supports an extensive mussel bed in spite of regular collections for bait; however, that bed is situated in an area that is frequented by few intertidal visitors, so trampling impacts would be much smaller than indicated by the overall site usage estimates.

Studies in Orange County have shown that the shore crab *Pachygrapsus* is negatively associated with human use (Murray et al., 1999). We also observed them to be occasionally collected by humans (Chapter 2). Therefore, we expected crab densities to decrease with level of use. However, we found little indication that *Pachygrapsus* was impacted by human use at the high-use sites we studied. Because *Pachygrapsus* are fast motile species, unlike all other species we studied, our sampling method was not optimal for assessing their densities, so definitive conclusions cannot be made until a more appropriate sampling method is used.

Although the strongest effects were generally seen for species that are collected (some of which may also be affected by trampling), several species expected to be affected primarily by trampling also appeared to be impacted by human use in Santa Monica Bay rocky intertidal habitats. The affected species include anemones, tube-building worms and mollusks, and seagrass. Limpets, articulated algae, and blade algae also showed some indications of having been negatively affected by human activities.

Anemones are likely damaged by trampling as they are soft bodied organisms and are often poked and prodded by visitors. Tube-building species, mostly the sandcastle worm

Phragmatopoma californica, are particularly vulnerable to damage from trampling. Large colonies of *Phragmatopoma* can be broken in half by a single step (pers. obs.) and have been observed to be less common in higher use sites in other studies for the same reasons (Zedler, 1978, Ghazanshahi et al., 1983). Both of these taxa showed strong indications of negative impacts by human use, with four of the five analytical approaches indicating an impact.

We expected trampling to result in damage to articulated algae, blade algae, fleshy algae, and rockweeds. There was at best weak evidence of an impact to these taxa (except for rockweeds, which occurred at too few sites to be assessed well). Because we only measured percent cover, we could not detect morphological damage, decreased biomass, or changes in algae heights that may have been incurred by trampling damage but not resulting in cover change. Some studies investigating trampling impacts on algae, especially articulated corallines, have shown reduced height of the turf but not a large change in the area occupied by the algae (Zedler, 1978; Povey and Keough, 1991; Brown and Taylor, 1999). It is possible that our methodology was not able to completely detect impacts caused by trampling.

Although filamentous algae are likely easily damaged from trampling because of their weak structure, a pattern of cover increase with increasing level of use was observed. Filamentous algae may be taking advantage of newly opened space as a result of removal of other space occupiers from trampling, collecting, or turning over of rocks. Since filamentous algae are opportunistic species (Littler and Littler, 1980), they may be growing fast enough to take advantage of open space and withstand repeated loss from trampling. In addition, declines in herbivores that feed on filamentous algae at high use sites may be resulting in an increase of filamentous algae.

Except for owl limpets, whose density was only a small portion of the group, limpets are not collected frequently, but they may be damaged by trampling and handling. Zedler (1978) noted that visitors often will pry off limpets for examination. Jiggling of some limpets will increase mortality and that those limpets that were removed and replaced sustained an even higher mortality rate (Zedler, 1978). Limpets might also be affected by trampling. Limpets were found to have only a weak association with visitation. In spite of the potential sources of impacts, our data provide only weak evidence of a negative effect of visitor use on limpets.

As predicted, barnacles and encrusting algae did not appear to be affected by human use. Although other studies have observed that trampling of *Chthamalus* resulted in decreased cover of barnacles (Zedler, 1978) and that *Balanus* barnacle cover was lower at high use sites (Ghanzanshahi, et al., 1983), we did not find any association with use. It is not clear why we did not find effects on barnacles when other studies have seen negative impacts. Barnacles do have hard shells that can resist trampling effects, they occur in the high intertidal where trampling may occur at a lower intensity, and they occur on the sides of rocks (as well as the tops), where they would not be as susceptible to trampling effects.

Although not significant, the snails *Littorina* spp. were found to have densities that increased with increasing human visitation. Littorine snail density was very high at White's Point (over 2500 snails m^{-2}), likely driving the positive relationship observed with visitor use intensity. Again, this may be attributable to habitat differences. However, littorine snails feed on microalgae that may be growing into newly opened space as a result of increase human disturbance. Therefore, littorines may increase with increased usage because of indirect impacts on their food source.

Considering that seagrass is often found in the low intertidal zone and may not be exposed to human disturbance very often, as compared to flora in the high or mid intertidal, we did not expect seagrass to be impacted by use intensity. Furthermore, seagrass is very slippery and is unlikely to be trampled on very often. However, seagrass was found to have a significant, negative regression with visitor use within Malibu. Seagrass must be particularly vulnerable to human activities, with only a small degree of trampling causing significant damage. Zedler (1978) noted similar results in San Diego, where a lower cover of *Phyllospadix scouleri* was observed in areas where visitor use was high. Trampling has been show to result in decreased biomass of the seagrass *Thalassia testudinum* in the tropics (Eckrich and Holmquist, 2000). However, since *Thalassia* thrives in a soft bottom habitat, trampling may not be directly causing damage to the plant itself but instead disturbing the soft substrate in which it is buried. Trampling in the rocky intertidal is not likely to be subject to the same mechanical disturbance.

Similarly to seagrass, tough and leathery algae (mostly *Egregia*, *Sargassum*, *Zonaria*) tend to be located in the low intertidal zone or in pools. These species are likely not trampled on often because of their location; moreover, they can be extremely slippery, so intertidal walkers are likely to completely avoided them. We found not evidence that these algae were affected by human use.

Conclusions

Five of nine species expected to be impacted by collecting showed strong indications of a negative impact, with one other species having weak evidence of an impact. Two of eight species expected to be impacted by collected showed strong indications of a negative impact, with three more species having weak evidence of an impact. In addition, one species (seagrass) not expected to be impacted showed strong evidence of an impact by trampling. The higher proportion of impacts among species impacted by collecting may indicate that collecting is more detrimental to rocky intertidal organisms than trampling. However, our study may not have reflected the full impact of trampling. For example, within the morphological groupings we used, there will be species that are sensitive to trampling and species that are less sensitive, so there may have been community shifts that we have not detected. We also did not investigate changes in size structure of organisms (besides owl limpets). A comparison of current algal specimens with herbarium specimens from 40 years ago suggests that the thalli of many algae are considerably smaller now (S. Murray, *personal communication*). Thus, there may be important population and community changes that we did not detect.

Our study design uses “low use” sites to define the reference condition for rocky intertidal communities in Santa Monica Bay. If intertidal communities at these sites have also been affected by human activities, then we will underestimate the extent of human impacts. In fact, we think it likely that even the low use sites in our study have been negatively impacted by human use. Considering that, other than Inspiration Point, the low use sites received between 2 and 8 visitors per hour, or 1600 to 4300 visitors per year (Chapter 2), the degree of human impacts at low use sites may be quite high. These sites have been subjected to human perturbations for many years and the damage incurred during this time may obscure differences between low and high use sites. A similar study conducted in Palos Verdes in the early 1980s showed that the abundances of many species were high at sites subjected to very low levels of use but decreased quickly as use intensity increased (Ghazanshahi et al., 1983). Sites with use intensities above a certain threshold were found to have equally low abundances of these species. Abundances decreased rapidly in sites receiving over 2 persons per 100 m of shoreline measured during four instantaneous observations over 6 hours. Sites receiving over 2 persons per 100 m of shoreline included what appear to be Point Fermin High Use, Point Fermin Low Use, and White's Point. Abalone Cover had a use level below 2 persons per 100 m of shoreline, although in our study Abalone Cove had a higher number of visitors than Point Fermin Low Use. Our sites may have visitor use intensities above a threshold where impacts can be detected. Other studies that compared low and high use sites to demonstrate obvious impacts of human use on intertidal populations have surveyed low use sites where humans were completely excluded (Moreno et al., 1984; Oliva and Castilla, 1986; Castilla and Bustamente, 1989). We suspect that the evidence for human impacts in Santa Monica Bay would be much stronger and show more extensive impacts if there had been a true reference site available for inclusion in our study.

A majority of the sites sampled in this study are protected by law from collecting of flora and fauna as a State Park, Ecological Reserve, or Marine Life Refuge. However, damage from illegal collecting continues to occur on a regular basis (Chapter 2). Furthermore, even if collecting was stopped, trampling and handling will continue to occur. Although our data indicate that collecting may be causing more serious impacts to target organisms than trampling, trampling affects a more extensive set of species and our study design has probably underestimated trampling effects. Limiting or restricting access to rocky intertidal locations may alleviate human pressures on the coast and allow greater recovery time to the impacted organisms.

Table 5. A list of species or flora/fauna grouping with the expected impact from increased human use and the mechanisms by which it may be damaged.

Previous studies investigating the impacts of human use on these species are also reported.

Species or grouping	Expected: +,-, or none	Expected impact	Mechanisms for impact	References
Lottia gigantea	-	Collecting will cause a decrease in size.	Collecting	Decreased size observed[1,2,3,4]. Densities also higher in low use sites[1].
Rare inverts (i.e. *Pisaster*, *Parastichopus*,etc.)	-	Collecting and handling (and habitat displacement) will result in a decrease in density.	Collecting	Ophiurids and octopus densities lower at high use sites[6].
Pisaster	-	Collecting and handling (and habitat displacement) will result in decreased densities.	Collecting	*Pisaster* density lower at high use sites[9].
Strongylocentrotus purpuratus	-	Collecting will cause a decrease in density.	Collecting	Smaller sized urchins observed at high use sites[6].
Tegula spp.	-	Collecting will cause a decrease in density.	Collecting	Smaller sized snails observed at high use sites[3,7]. Smaller sizes snails of several other gastropods also observed in high use sites[3,8].
Pachygrapsus crassipes	-	Collecting will cause a decrease in density.	Collecting	Crab densities low at high use sites[5].
Pagurus spp	-	Collecting of live crabs and empty (or thought to be empty) shells will cause a decreased in density.	Collecting	None
Aplysia	-	Easily damaged by trampling and molestation, and often collected resulting in decreased densities	Trampling and Collecting	None
Bivalves	-	Collecting of mussels, clams will cause a decrease, trampling will dislodge mussels.	Trampling and Collecting	Experimental trampling resulted in decreased cover, biomass of mussels [10,11]. Mussel cover, bed thickness, and biomass found to be lower at high use sites (cover only[1]; all data[12]).
Total limpets	-	Trampling or handling will dislodge limpets from rock resulting in mortality.	Trampling	*Lottia digitalis* density lower at high use sites[1] and found to have increased mortality when jiggled[1]. *Lottia paradigitalis* densities lower at high use sites[9]. *Fissurella* spp. found to have decreased size and density at high use sites[3,17,18].
Anemones	-	Trampling will crush and dislodge soft bodied organism.	Trampling	None
Tube-building worms	-	Trampling damages weak structure of *Phragmatopoma* colonies.	Trampling	*Phragmatopoma* cover lower at high use sites[9].
Articulated algae	-	Trampling will cause a decrease in. cover	Trampling	Experimental trampling resulted in decreased biomass, size, cover[13,14]. Articulated algae cover higher in low use areas[1].
Blade algae	-	Trampling will damage most blades, especially *Ulva*, *Enteromorpha*, causing cover	Trampling	*Ulva* found to decrease with experimental trampling[15].

		decreases.		
Fleshy algae	-	Trampling will cause a decrease in cover.	Trampling	No cover change observed when *Gigartina* trampled[1,16].
Rockweeds	-	Trampling will cause a decrease in cover.	Trampling	Experimental trampling resulted in decreased cover and size of *Silvetia*[16,19], and *Hormosira*[13,20,21].
Bare rock	+	Trampling will cause a decrease in algae and inverts resulting in increased bare rock.	Trampling	None
Encrusting algae	None	Should not be affected by trampling, may increase if more open rock available.		None
Tough and leathery algae	None	Too low in intertidal zone and too slippery to be affected by trampling.		Commonly collected *Durvillea* was found to be higher in areas where humans excluded[22].
Seagrass	None	Too low in intertidal zone and too slippery to be affected by trampling.		Seagrass cover lower in high use areas[1].
Barnacles	None	Not likely to be damaged by trampling, although some studies have shown effects.		*Balanus* cover lower at high use sites[9]. Experimental trampling resulted in decreased cover of *Chthamalus*[1].
Littorina spp.	None	Not likely to be damaged by trampling, not collected.		None
Total chitons	None	Not likely to be damaged by trampling, not collected.		None
Filamentous algae	None or +	Trampling will cause decreases and damage to its weak structure but is fast growing and may not be affected, and could increase in response to effects on other species.	Trampling	None
Diversity	Undetermined	Intermediate disturbance may increase diversity but diversity will likely decrease at the highest use sites.		No change observed[9].
Total plant cover	Undetermined	Possible shift in composition although total cover may not change.		None
Total invertebrate density	Undetermined	Possible shift in composition although total cover may not change.		None
Total snail density	Undetermined	Possible shift in composition although total densities may not change.		None

[1] Zedler, 1978; [2]Kido and Murray, 2003; [3]Roy et al., 2003; [4] Pombo and Escofet, 1996; [5]Murray, et al., 1999; [6]Addessi, 1994; [7]Sato and Murray, unpublished; [8]Keough et al., 1993; [9]Ghazanshahi, et al., 1983; [10]Brosnan and Crumrine, 1994; [11]Smith, 2002; [12]Smith, unpublished data; [13]Povey and Keough, 1991; [14]Brown and Taylor, 1999; [15]Bally and Griffiths, 1989 [16]Brosnan et al., 1996; [17]Moreno et al., 1984; [18]Oliva and Castilla, 1986; [19]Denis and Murray, in prep; [20]Keough and Quinn, 1998; [21]Schiel and Taylor, 1999; [22]Castilla and Bustamente, 1989

Table 6. Characteristics of the ten sites sampled.

The number of visitors per hour was obtained from observations during low tide hours on weekday and weekends (Chapter 2).

Site	Site Code	Pairing	Location	Lat/Long	Visitors per hour
Point Fermin (High Use)	PTFH	1	Palos Verdes Peninsula	33 42' 29" 118 17' 04"	37.0
Point Fermin (Low Use)	PTFL	1	Palos Verdes Peninsula	33 42' 22" 118 17' 11"	5.2
White's Point	WHT	2	Palos Verdes Peninsula	33 42' 49" 118 18' 59"	35.9
Inspiration Point	INSP	2	Palos Verdes Peninsula	33 44' 12" 118 22' 08"	0.4
Abalone Cove	ABAL	2	Palos Verdes Peninsula	33 44' 17" 118 22' 27"	8.8
Paradise Cove	PARA	3	Malibu Coastline	34 01' 10" 118 47' 10"	30.2
Little Point Dume	LDUME	3	Malibu Coastline	34 00' 27" 118 47' 36"	2.5
Point Dume	DUME	3	Malibu Coastline	34 00' 09" 118 48' 12"	19.5
Leo Carrillo (Low Use)	LEOL	4	Malibu Coastline	34 02' 45" 118 55' 42"	7.1
Leo Carrillo (High Use)	LEOH	4	Malibu Coastline	34 02' 41" 118 55' 57"	42.7

Table 7. Relationship between human use and population abundance for intertidal organisms.

Regression analyses were conducted on mean biological data (transformed where indicated) at each site with visitors per hour (log transformed) recorded at each site during previous human use surveys (see Chapter 2). *arcsine transformed data; **log (X+1) transformed data

		Regression analyses results		
		R^2	Slope	P value
Percent Cover:	Rock*	0.01	-	0.771
	Algae:			
	Filamentous*	0.04	+	0.581
	Encrusting*	0.10	-	0.365
	Articulated*	0.10	-	0.373
	Blade*	0.12	-	0.331
	Fleshy*	0.29	-	0.111
	Rockweed	0.00	-	0.900
	Tough and Leathery*	0.07	+	0.473
	Seagrass*	0.06	-	0.511
	Seagrass (Malibu only)*	0.79	-	0.045
	Total Plant*	0.06	-	0.500
	Invertebrates:			
	Barnacles*	0.02	+	0.714
	Anemones*	0.10	-	0.383
	Bivalves*	0.09	+	0.400
	Tube-building worms*	0.07	-	0.457
	Total Invertebrate*	0.01	-	0.790
	Richness	0.07	-	0.455
	Shannon Wiener Diversity Index	0.34	-	0.076
	Pielous Evenness	0.32	-	0.088
Densities:	*Aplysia californica***	0.06	-	0.486
	Littorina spp.**	0.07	+	0.463
	*Pachygrapsus crassipes***	0.00	+	0.832
	Pagurus spp.**	0.29	-	0.108
	*Pisaster ochraceus***	0.17	-	0.232
	*Strongylocentrotus purpuratus***	0.27	-	0.126
	Tegula spp.**	0.14	-	0.283
	Total chiton**	0.00	-	0.896
	Total limpet**	0.07	-	0.470
	Total snail**	0.07	+	0.257
	Total snail (without littorines)**	0.03	-	0.624
	Large conspicuous spp.**	0.41	-	0.045
	Richness	0.07	-	0.459
	Shannon Wiener Diversity Index	0.11	-	0.361
	Pielou's Evenness	0.20	-	0.201

Table 8. Summary of analyses of effects of human use.

– indicates lower values at high use sites, + indicates higher values at high use sites, and 0 indicates no clear pattern. Overall pattern was assessed qualitatively as a relationship between cover or density and level of use. Pattern within site group is a summary of the nominal (not statistically significant) differences between low and high use sites within a site group. Overall t-test presents the results of the t-test pooling low-use and high-use sites, rather than using site groups. Leo Carrillo t-test presents the results of the statistical comparison between low- and high-use sites at the best-matched site pair. For the t-tests, parentheses indicate 0.05<P<0.10. Regression analyses show the slope of the regression line; slopes are shown as "0" when $R^2 \leq 0.02$; statistically significant regressions are indicated by *; the statistically significant result for seagrass was for Malibu sites only. NA=not applicable due to small sample size. Boxes are shaded for analyses indicating a negative effect of human use.

Species or grouping	Expected: +,–, or none	Overall pattern	Pattern within site groups	Overall t–test	Leo Carrillo t–test	Regression
Lottia gigantea	–	–	–4/4	–	NA	–*
Rare, conspicuous inverts	–	–	–4/4	0	–	–*
Pisaster	–	–	–2/4	0	–	–
Sea urchins	–	–	–4/4	(–)	(–)	–
Tegula spp.	–	0	–2/4	0	0	–
Pachygrapsus crassipes	–	0	–1/4	0	0	0
Pagurus spp.	–	0	–2/4	(–)	0	–
Aplysia	–	–	–4/4	(–)	–	–
Bivalves	–	0	–1/4	0	(–)	+
Total limpets	–	0	–2/4	0	–	–
Anemones	–	–	–2/4	(–)	–	–
Tube–building worms	–	0	–3/4	0	–	–
Articulated algae	–	0	–3/4	0	0	–
Blade algae	–	0	–2/4	0	(–)	–
Fleshy algae	–	0	–2/4	0	0	–
Rockweeds	–	0	NA	NA	NA	0
Bare rock	+	0	+2/4	0	+	0
Encrusting algae	None	0	–2/4	0	(+)	–
Tough and leathery algae	None	0	–2/4	0	+	0
Seagrass	None	–	–2/2	0	–	–*
Barnacles	None	0	–1/4	0	–	0
Littorina spp.	None	0	–0/4	0	0	+
Total chitons	None	0	–2/4	0	0	0
Filamentous algae	None or +	0	–1/4	0	0	+
Diversity – cover	Undetermined	0	–7/12	H index (–)	evenness +	–
Diversity – density	Undetermined	0	–9/12	0	evenness +	–
Total plant cover	Undetermined	0	–2/4	0	0	–
Total invertebrate density	Undetermined	0	–2/4	0	0	0
Total snail density	Undetermined	0	–1/4	0	0	+

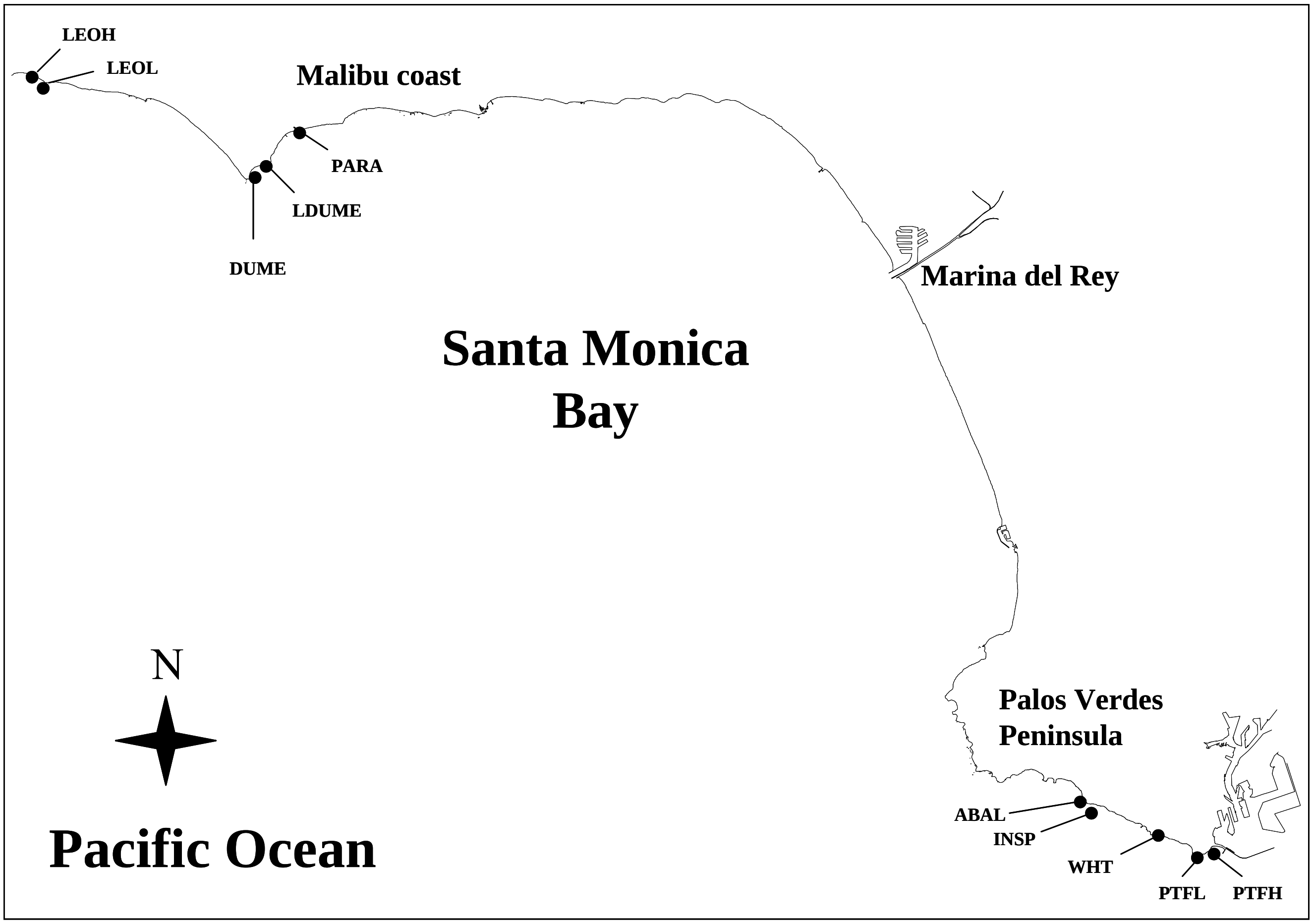

Figure 12. Map of ten sites located within the Santa Monica Bay, Los Angeles County, California.

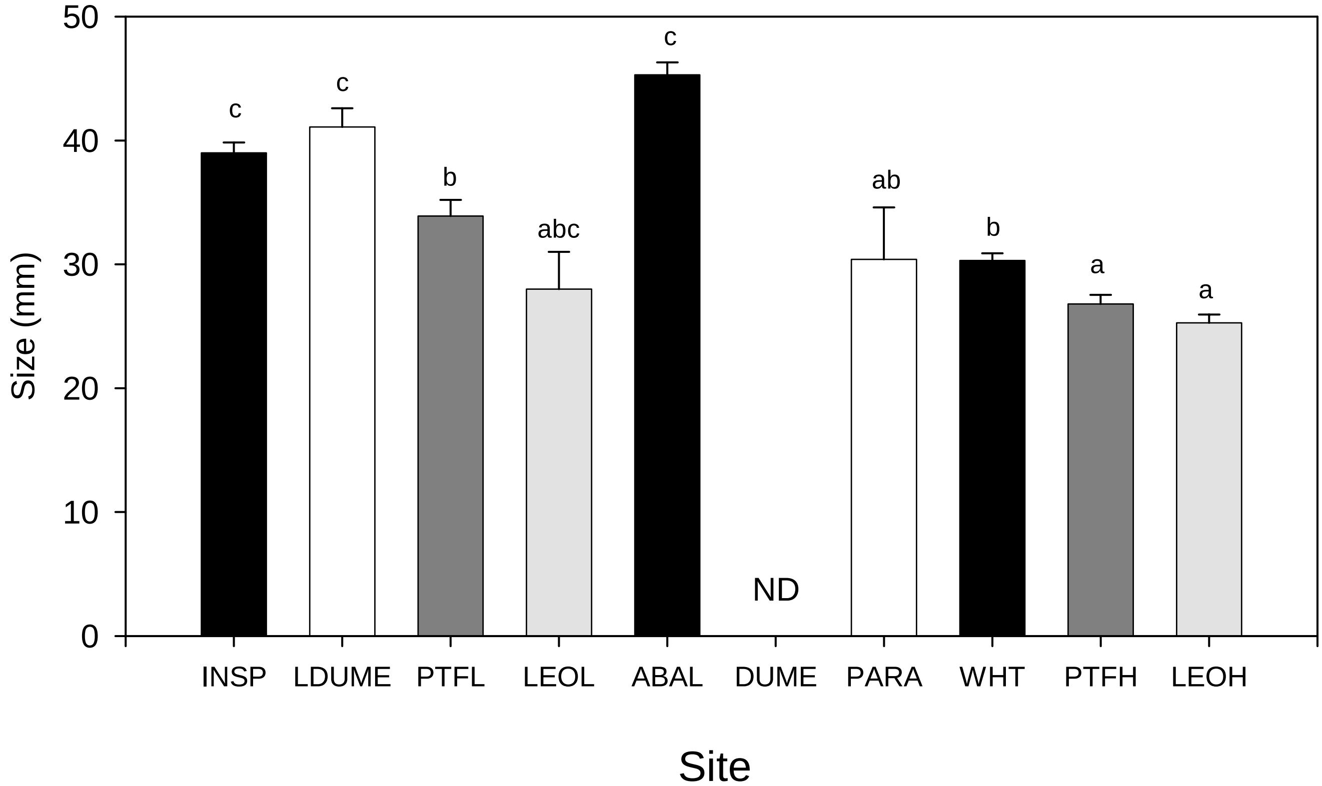

Figure 13. Mean size (± SE) of owl limpet *Lottia gigantea* populations at each site.

No owl limpets were found at Point Dume while few where found and measured at Paradise Cove and Leo Carrillo Low Use (n=10 and 2, respectively). A One Factor ANOVA revealed significant differences among sites (p<0.001); a,b,c lettering identifies sites not significantly different from each other by Tukey’s multiple comparisons test.

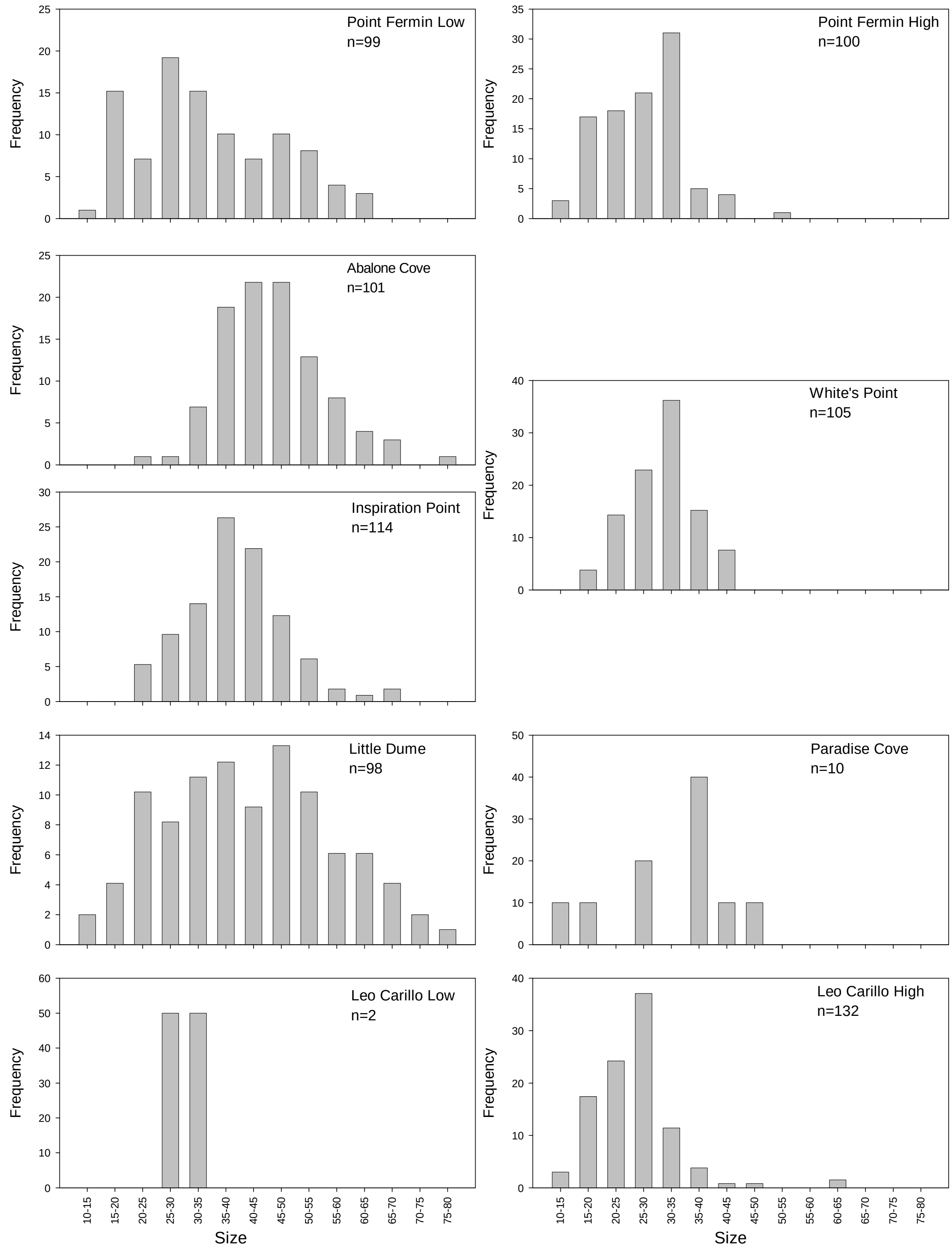

Figure 14. Size frequency histograms of owl limpet *Lottia gigantea* populations at nine of the ten sampled sites.

No limpets were found at Point Dume while only a few where found and measured at Paradise Cove and Leo Carrillo Low Use (n=10 and 2, respectively). Histograms are arranged with the low use site on the left and the matching high use site on the right. Abalone Cove and Inspiration Point are both matched with White's Point.

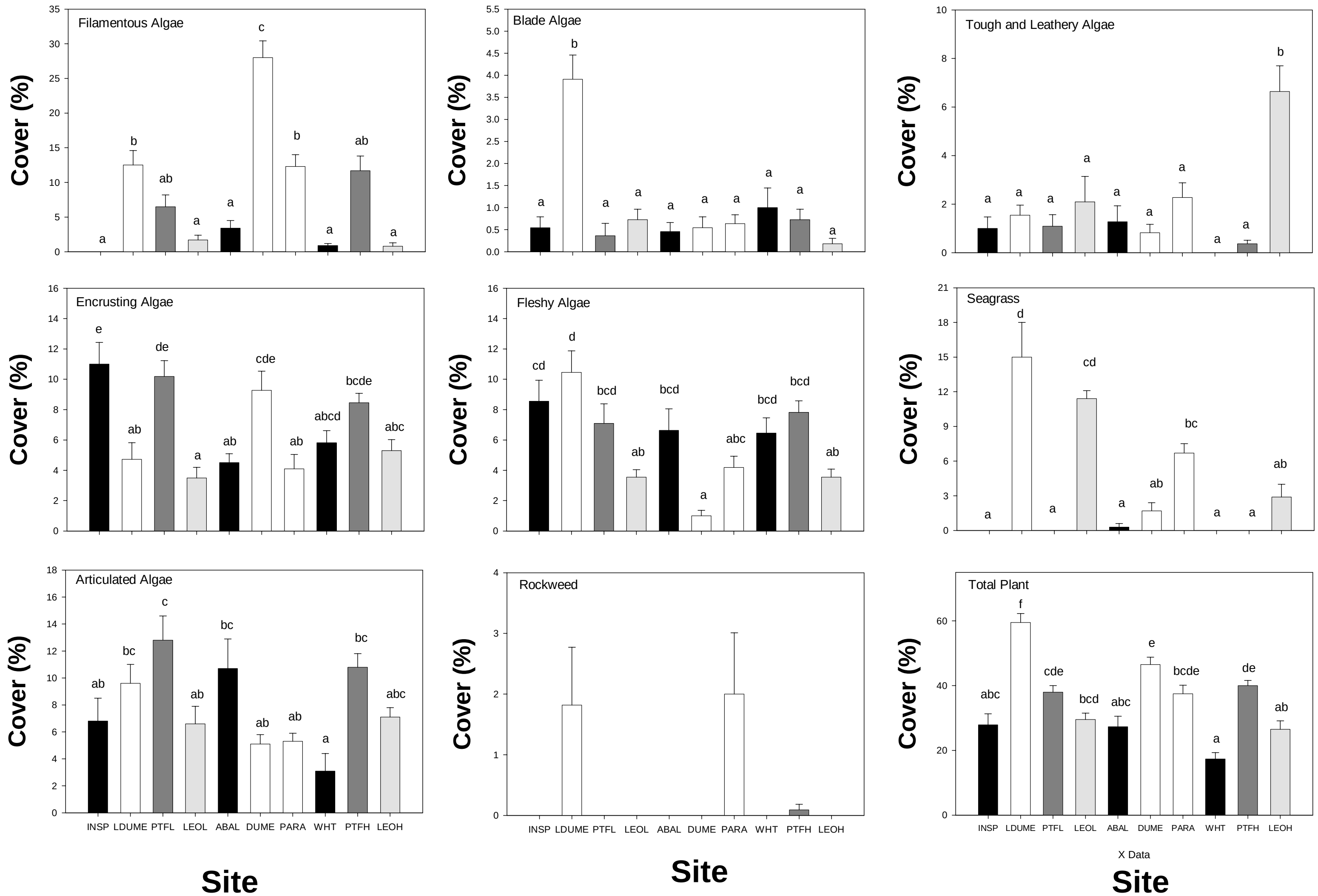

Figure 15. Mean cover (%) of bare rock and algae groups (± SE).

A One Factor ANOVA revealed significant differences among sites ($p<0.001$ for all groups) while a Tukey's multiple comparisons test combined sites into significantly similar groups (a,b,c lettering). Statistical analyses were conducted on arcsine transformed data. Sites are displayed in order of use from the lowest use site (Inspiration Point) to the highest use site (Leo Carrillo High Use) with sites within a matched pair or group with matching shaded bars.

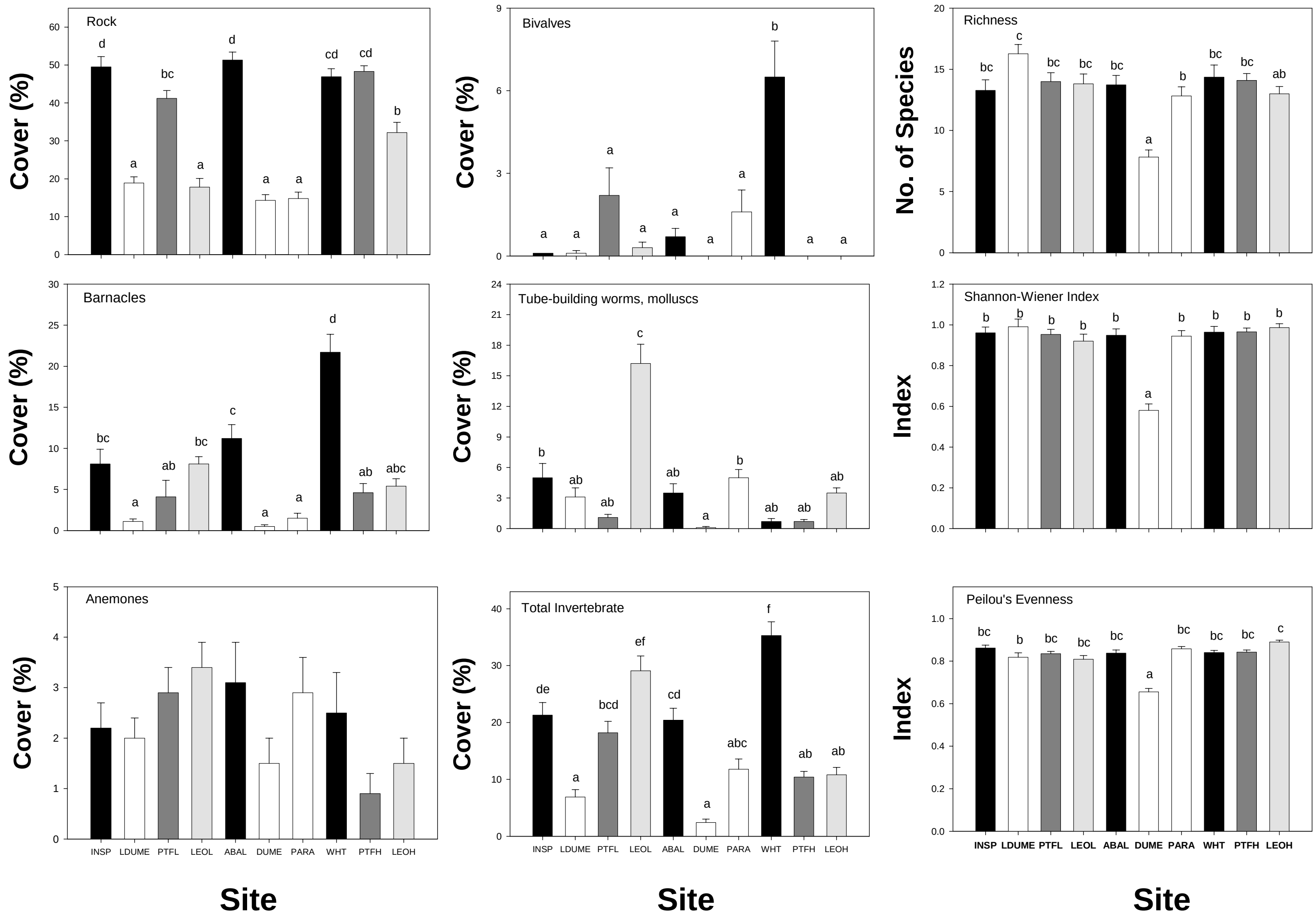

Figure 16. Mean cover (%) of bare rock, sessile inverts, all inverts (sessile and motile) and biodiversity (± SE) calculated using percent cover data.

A One Factor ANOVA revealed significant differences among sites ($p<0.001$ for all groups except anemones $p=0.045$) while a Tukey's multiple comparisons test combined sites into significantly similar groups (a,b,c lettering). Although anemones were found to differ among sites, Tukey's multiple comparisons test did not yield any significantly different groups. Statistical analyses were conducted on arcsine transformed data except biodiversity data, which was not transformed.

Sites are displayed in order of use from the lowest use site (Inspiration Point) to the highest use site (Leo Carrillo High Use) with sites within a matched pair or group with matching colored bars.

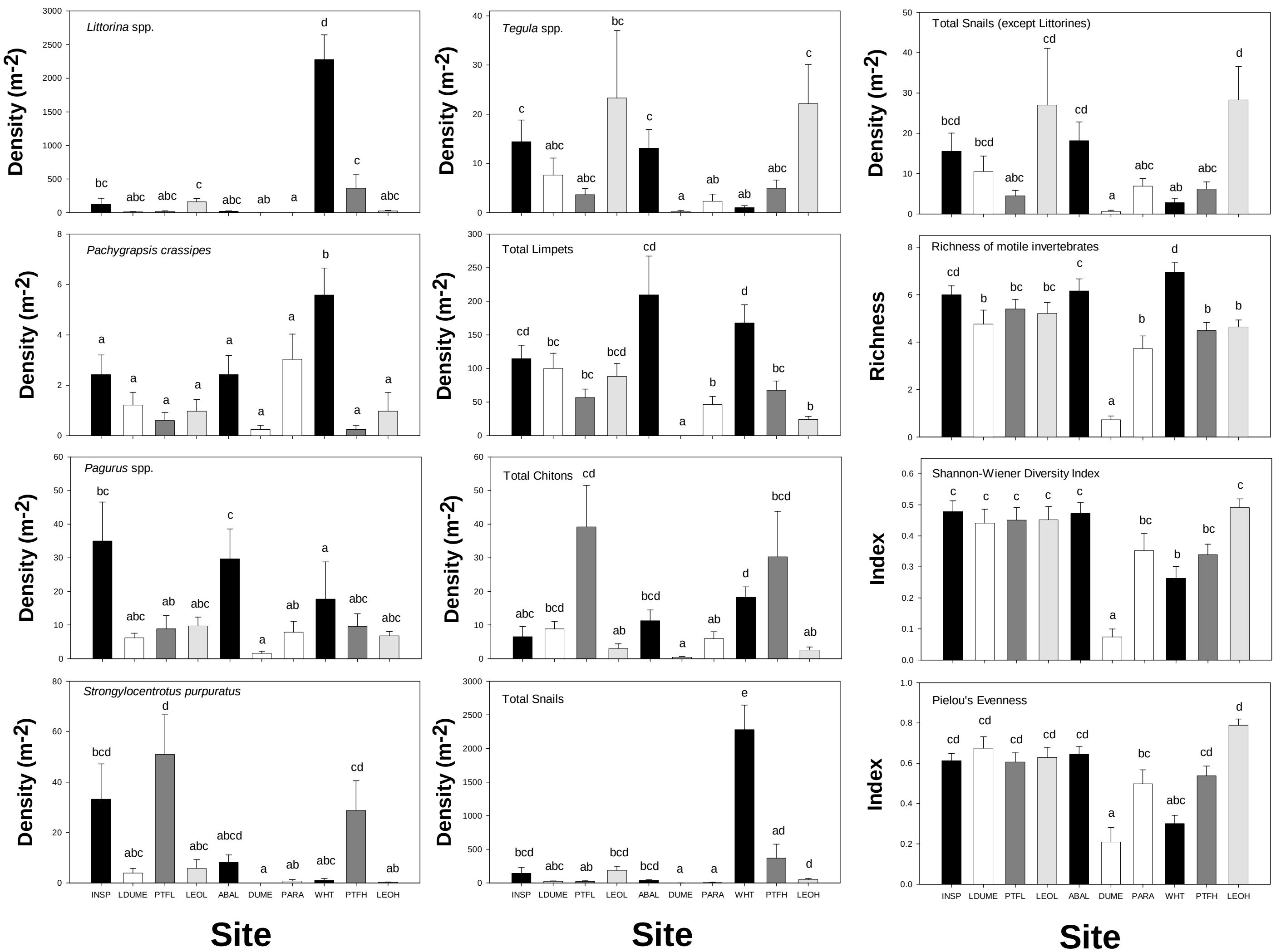

Figure 17. Mean density of motile invertebrates in plots and biodiversity (± SE) using plot density data.

A One Factor ANOVA revealed significant differences among sites (p<0.001 for all groups) while a Tukey's multiple comparisons test combined sites into significantly similar groups (a,b,c lettering). Statistical analyses were conducted on log (x + 1) transformed data except biodiversity data which was not transformed. Sites are displayed in order of use from the lowest use site (Inspiration Point) to the highest use site (Leo Carrillo High Use) with sites within a matched pair or group with matching colored bars.

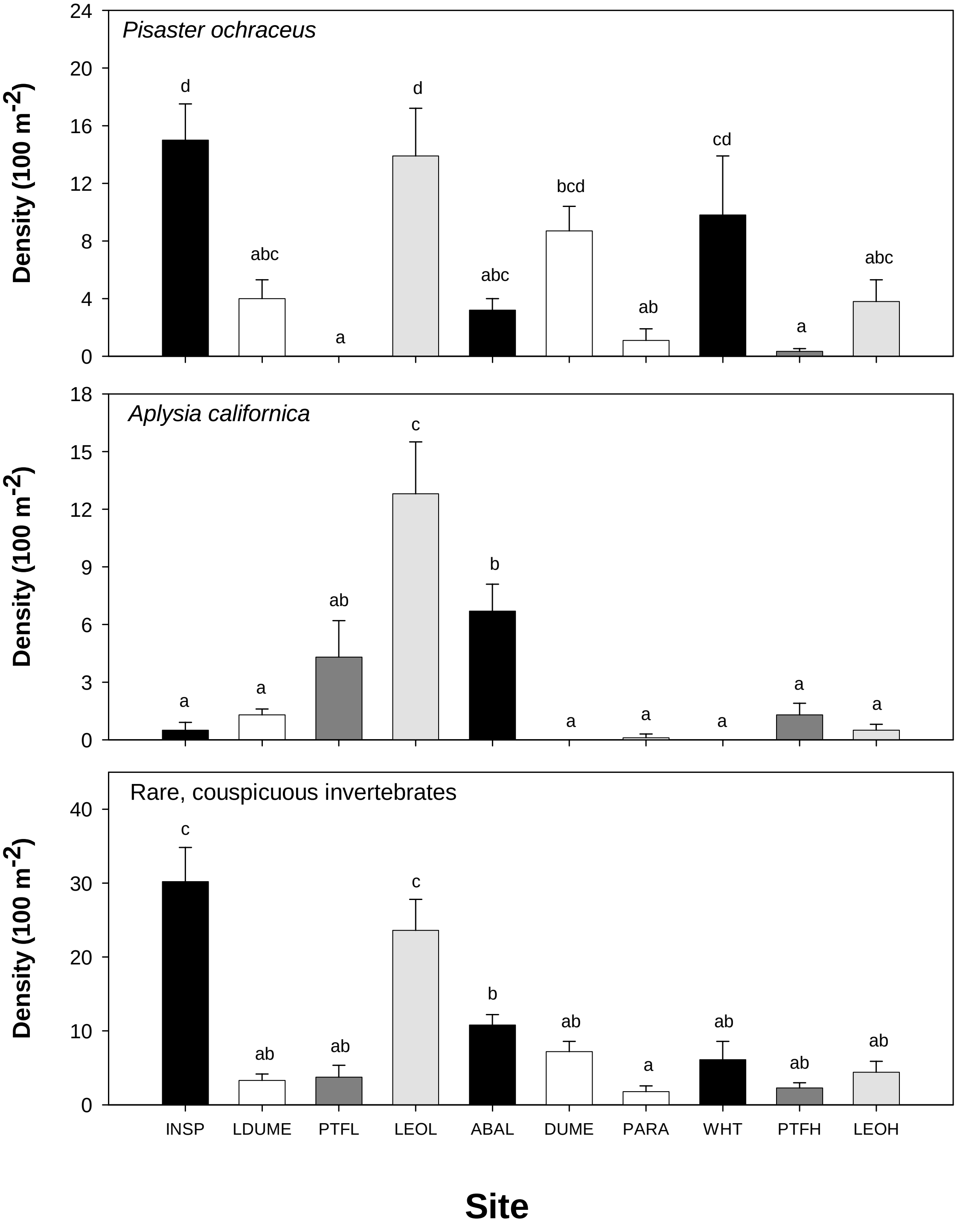

Figure 18. Mean density of rare, large, conspicuous species (± SE) measured using transect swaths.

A One Factor ANOVA revealed significant differences among sites ($p<0.001$ for all groups) while a Tukey's multiple comparisons test combined sites into significantly similar groups (a,b,c lettering). Statistical analyses were conducted on log (x + 1) transformed data. Sites are displayed in order of use from the lowest use site (Inspiration Point) to the highest use site (Leo Carrillo High Use) with sites within a matched pair or group with matching colored bars.

Chapter 4. Rocky intertidal restoration alternatives and recommendations for restoring Santa Monica Bay's rocky intertidal habitats

The evidence for a dramatic decline in rocky intertidal organisms in Santa Monica Bay over the past 50 years is largely anecdotal. However, a few studies (Thom and Widdowson, 1978; Miller and Lawrenz-Miller, 1993; Murray et al., 2001) have shown changes that appear to be associated with human use, while others have demonstrated impacts from human activities in Santa Monica Bay rocky intertidal habitats (Addessi, 1994; Ghazanshahi et al., 1983). This study demonstrates that Santa Monica Bay rocky intertidal sites receive an enormous number of visitors, and that these visitors' activities have affected a suite of organisms, including some of the most conspicuous organisms in the rocky intertidal zone. In addition to these, larger impacts that may have occurred earlier and were widespread throughout the Bay (such as the decline of black abalone; Miller and Lawrenz-Miller, 1993) would have been missed by our study design.

Although the full extent of changes in rocky intertidal biota are not known, it is clear that human activities have degraded the rocky intertidal habitats in Santa Monica Bay, and we should consider ways to restore these communities. Moreover, our results (and those of other studies) have shown that changes in rocky intertidal biota are associated with the prevalence of visitors to intertidal sites. Furthermore, impacts do not seem to be solely dependent on visitors collecting intertidal organisms; although some species seem to have been affected by collecting, the larger community was affected by people walking on and turning over rocks and handling organisms, activities that are not prohibited even in the most restrictive marine protected areas currently established in the Bay.

Restoration Background

With these findings in mind, some general evaluation of restoration alternatives is possible. We follow this with some specific recommendations.

In general, restoration of a habitat needs to be designed in the context of the specific impact(s) that caused the degradation of the habitat. For the Santa Monica Bay rocky intertidal habitat, there are three main potential causes for the degradation in the rocky intertidal biota over the past few decades: (1) water pollution; (2) collection of organisms; and (3) visitor impacts (trampling, turning over rocks, etc.).

Little can be done at a particular rocky intertidal site to restore impacts from water pollution. The exception would be a local pollution source, particularly something like a storm drain. (We did not notice obvious local pollutant sources like this at the sites we studied.) The main concern about pollution is whether the coastal waters are so polluted that water quality would constrain any attempt at rocky intertidal habitat restoration. That is, even removing some sources of impacts (collecting and trampling) would not help the rocky intertidal biota if the water was too polluted. This seems unlikely. Water quality in

Santa Monica Bay has improved tremendously since the sewage treatment plants moved to secondary treatment of wastewater. Clearly, not all water quality problems in the Bay have been solved. For example, stormwater has been shown to be toxic (although impacts on soft-bottom communities have not been demonstrated; Schiff and Bay 2003). However, the main storm drains in Santa Monica Bay empty onto sandy beaches; discharges near rocky intertidal habitats are considerably less. Thus, we conclude that improvements to specific rocky intertidal habitats are generally possible within the existing water quality conditions of the Bay[2].

As we and others have demonstrated, the collection of organisms from Santa Monica Bay rocky intertidal habitats has been widespread. The species most likely to be affected are the large invertebrates that are collected for food or curiosity, including sea urchins, octopuses, seastars, etc. (see Table 5). Trampling has also been implicated in the degradation of rocky intertidal communities in Santa Monica Bay. Although we did not separate trampling and handling in our assessment of biological impacts, in general they will co-occur (Chapter 2).

Once the cause of degradation has been identified, the first step in a habitat restoration is to remove the cause(s) of the degradation. There are then two possible courses of action: (1) allow recovery to take place on its own, without specific active restoration activities (passive restoration), or (2) actively manage the site by creating physical changes (such as altering topography or hydrology) or introducing organisms through planting or seeding (active restoration). In general, active restoration is more expensive and it is more difficult to achieve a fully functioning ecosystem.

Luckily, rocky intertidal communities respond quickly to the cessation of human use impacts. Restoration has usually happened incidentally in response to the exclusion of either harvesting or all human use in an area. In fact, most of the restoration case studies available were not explicitly designed as restoration projects, but rather restoration developed incidentally to other efforts, typically to eliminate harvesting from an area. There is rarely the need to manipulate the physical aspects of the habitat (as is often needed for wetland restoration, for example), which greatly simplifies the restoration process and reduces costs.

Although manipulation of the physical environment is generally not required for rocky intertidal restoration, active restoration to bring back target species might be necessary. One rocky intertidal species, surfgrass (*Phyllospadix* spp.), has been explicitly targeted for restoration. studies. In Santa Barbara County, one consequence of pipeline construction associated with oil and gas development was the destruction of surfgrass habitat. Because of the ecological value of surfgrass and the organisms associated with it, specific efforts were undertaken to restore surfgrass habitats, and this has expanded into a significant research program headed by Holbrook and Reed. Different techniques for surfgrass transplantation and establishment have been developed, and genetic

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[2] It does not follow that rocky intertidal habitats would not benefit from improved water quality. We know of no strong evidence one way or another on this question.

considerations have been explored. Although surfgrass restoration has not been applied widely and should still be considered experimental, there is a reasonable body of science behind it, and it is a viable restoration alternative.

Restoration Alternatives

In this section, we discuss four main classes of restoration alternatives: (1) reducing the trampling of intertidal organisms followed by passive recovery, (2) reducing the handling of intertidal organisms followed by passive recovery, (3) reducing the collection of intertidal organisms followed by passive recovery of the community, and (4) active restoration of target species (accompanied by the protection of these species from further impacts).

Complete restoration of Santa Monica Bay intertidal habitats will likely require a suite of restoration efforts. Although collecting has a disproportionate impact on some target species, restrictions on collecting alone would not fully restore rocky intertidal communities. Simply walking in a rocky intertidal habitat seems to adversely impact the biota. A full restoration outcome will require a restriction of walking on intertidal rocks and handling of intertidal organisms as well as collection.

Reducing walking on intertidal rocks:

The mere presence of people in the rocky intertidal seems sufficient to impact this sensitive habitat. This presents a challenge, since the exclusion of people is in conflict with desires to have people appreciate and enjoy marine resources – which in the long term is likely to translate into greater support for conservation efforts.

The rocky intertidal is not unique in this regard. Terrestrial habitats with similar constraints include meadows and wetlands. How is this challenge met in these terrestrial habitats? Human use is generally confined to a very limited area, typically a trail, with the trail surface constructed from gravel or a boardwalk to minimize direct impacts. In the case of extremely sensitive or rare resources, visitors may be directed to another area altogether.

How can walking on intertidal rocks be restricted? There are at least three possible approaches.

1. Boardwalks could be constructed. In other sensitive habitats, especially wetlands, this approach has been extremely effective. Unfortunately, it is not technically feasible in a rocky intertidal habitat along the open coast; the force of waves is simply too destructive.

2. Set pathways could be established through an intertidal area, with travel outside of the pathway not allowed. Although uncommon in rocky intertidal habitats, visitors have come to expect the admonition “please stay on the trails” in terrestrial parks. A marine analogue is the snorkeling trails established on coral reefs. Because corals are sensitive to direct

contact from snorkelers, some marine parks have established routes for snorkelers to concentrate impacts in a limited area. There would be some logistic issues to be resolved in rocky intertidal habitats, since the combination of corrosive seawater, forceful waves, and sand scour would make it challenging to maintain markers. In addition, sites consisting of frequently turned boulders might not be suitable for this approach, if markers could not be maintained well enough to identify clearly the pathway.

3. Public access to a rocky intertidal site could be restricted. Eliminating access would eliminate all impacts from trampling, handling and collecting, providing the maximum restoration benefit. Besides the ecological benefits, a closed area would yield scientific benefits, providing a reference site against which other sites could be compared when assessing ecological impacts.

Is it reasonable, or even desirable to restrict access from all rocky intertidal habitats in Santa Monica Bay? Although this would have the greatest ecological benefit, there would undoubtedly be objections. California has a long history of protecting coastal access. Although there are many examples of similar restrictions to sensitive habitats on land, this approach is not common in the ocean. The public's expectations for the ocean are different. Finally, one needs to be concerned about the effects of such restrictions on the development of the public's appreciation of nature. Although clearly some rocky intertidal visitors are coming to harvest food, most are there to appreciate the natural beauty and resources of intertidal habitats. There are long-term benefits to encouraging such appreciation, so any efforts to restrict access need to be done in a way that does not undermine the public's appreciation of the intertidal zone.

One way to restrict access would be to create a permanent, legislatively established restriction, much like the brown pelican nesting area on West Anacapa Island (where all access is prohibited when pelicans are nesting or raising their young in order to avoid disturbing them). However, restriction of access would not have to be permanent. Managers of a particular area could set aside an area to exclude visitors, and as that area recovered, the exclusion area could be shifted to allow the recovery of another area.

We recommend that restoration should initially focus on one or two sites selected for ecological and logistic reasons. From the ecological perspective, the site should be degraded but with excellent potential for recovery. Any of the high use sites could be considered to be degraded. Although it seems likely that the low use sites are also somewhat degraded, their recovery potential is not as great; that is, their degradation is not as great, so they would benefit less from protection. Any of the sites would have potential for recovery. However, the Malibu sites are naturally more disturbed due to the influence of sand in the Malibu region. The two high use sites we studied on the Palos Verdes Peninsula were Point Fermin at White's Point.

The logistics of restoration involve mainly the accessibility for enforcement or docent participation, which means the site should be close to parking; both Point Fermin and White's Point meet this criterion. However, there is a more fundamental policy question: should an exclusion area be established at an area used by relatively few people, or by many people. In the former case, fewer people would be inconvenienced, and so perhaps there would be less public opposition to setting aside an area for preservation. On the other hand, excluding people from an area with relatively little use would have relatively little effect. The maximum restoration benefits would be realized by excluding public access from an area that currently receives high use.

It would not be reasonable to close off the entire intertidal region at Point Fermin or White's Point. These two sites are among the most popular rocky intertidal sites in the entire state. Both are used regularly by school groups, and Point Fermin has an active docent program. However, it's not unreasonable to consider setting aside a portion of these sites; at Point Fermin, in particular, an exclusion area could provide a useful education opportunity. It is not obvious how large such an exclusion area should be; it needs to be large enough to allow substantial development of a complete community.

The other area with good logistical conditions is the Paradise Cove/Point Dume area. Both sites are adjacent to communities with a strong connection to the beach and rocky intertidal zone. Although no docent program current exists, the presence of an interested local school and an involved local community raise the possibility of having the necessary presence at this region, too.

Although this approach of excluding visitors from a section of the rocky intertidal habitat is not used widely, there are at least two examples of its use in California. At the Cabrillo National Monument in San Diego, there are several areas with rocky intertidal habitat. The National Park Service has closed one of these completely, so there is no public use of the site. This was relatively easy because of the physical arrangements of the different intertidal sites and the ease of controlling access to the one site.

A second example is the Fitzgerald Marine Reserve in central California. The approach taken there is quite different from the complete closure of a discrete rocky intertidal site used at Cabrillo. Instead, docents place poles to mark off a restricted area at every low tide, and remove the poles as the tide comes in. The docents are available on site to answer questions about the exclusion area (and to ensure it is obeyed). This approach is quite flexible, allowing for modifications in terms of timing (the area would not have to be marked off on every low tide throughout the year) and location (the locations of the poles can be moved relatively easily). This approach also avoids some of the logistical problems on maintaining structures in the corrosive, powerful sea-land interface.

Although we have suggested an initial focus on one or two locations, ultimately, protection could be more extensive, and might include a network of sites in Malibu and Palos Verdes, including sites that currently have relatively low use.

Reducing handling of intertidal organisms:

It might be possible to prevent people for handling organisms even though they have access to a site and could look at organisms on the rocks. (For this discussion, handling including turning rocks over in order to view organisms under them.) Some organized groups brought to the rocky intertidal, such as those led by Heal the Bay, are given such instructions.

Education might be effective. All intertidal users should certainly be informed about proper tide-pooling etiquette, such as the need to turn rocks back over after looking underneath them, and returning organisms to their original location. Attempts to inform intertidal users about handling effects should perhaps focus on the organisms most affected by handling – such as sea hares.

Education could be conducted on site by docents, where those exist. Established organizations such as public aquaria could also have educational programs and material. Suitable signage at heavily used areas might be useful. School trips to the rocky intertidal should include a component teaching proper intertidal etiquette. It might also be useful to distribute a videotape or DVD providing information about the rocky intertidal and proper etiquette, as has been done in Orange County.

Regulation of handling alone is unlikely to be effective; it would be difficult to let people onto a site but not allow them to touch or look closely at the organisms there.

Although educating the public to avoid unnecessary handling impacts is unequivocally appropriate, eliminating all handling of intertidal organisms may not be the best course of action. For developing the public's appreciation of intertidal organisms, it is probably best to allow them to handle organisms. Many interesting organisms can be found by turning over rocks, and in our experience intertidal visitors become more engaged in the intertidal resources when they can touch them.

Reducing collection of intertidal organisms

At many intertidal sites, the collection of intertidal organisms is already prohibited. Improved enforcement of these existing regulations would certainly reduce the impacts of collecting. Existing enforcement is sparse. During all of our visitor use surveys, there was seldom an enforcement presence, an only once did a ranger actually walk through the intertidal zone and speak with visitors. (In that case, no citations were given, even though collecting had been observed before the ranger arrived.) Murray (1997) found a similar lack of enforcement in Orange County.

A limitation to increased enforcement of regulations controlling collections is the cost of paying enforcement officers. In some cases, lifeguards can play a role in ensuring that visitors follow rules about collecting, but they have other priorities. At sites with appropriate infrastructure or community interest, docents can be an excellent supplement to formal enforcement officers. Docents are used effectively at Dana Point in Orange County, in association with a Marine Science center at the site, and at Carpinteria State Park in Santa Barbara County, in association with a State Park. In Santa Monica Bay, the

Cabrillo Museum runs a successful docent program at Point Fermin. In fact, the frequency of collecting was quite low at the Point Fermin high use site where the docents are. The situation at Leo Carrillo might be similar to Carpinteria State Park, so a docent program might be possible there. Finally, there is a great deal of community interest in the ocean in Malibu. Sites like Paradise Cove and Little Dume are obvious possibilities, as well as Malibu State Beach. However, these latter sites would require the development of the infrastructure necessary to support a docent program.

Although collecting is prohibited at many of the sites we studied, the regulation of collecting is not uniform along the coast. It might be possible to reduce collecting by expanding the regulations against it. However, this alternative will be pointless unless there is effective enforcement of the regulations.

Finally, education could have a significant impact on the extent of collecting occurring at intertidal sites. Particularly among visitors who are going to the intertidal zone to appreciate the organisms there, collecting may be partly a result of ignorance about its consequences. (Education would seem less likely to affect collectors who are harvesting organisms for food or bait.) Formal education programs about the ocean (such as occurs in public aquaria or schools) should include a component about the consequences of collecting. Organized intertidal trips (whether for the public or as a school field trip) should also include clear instructions about intertidal protocol. An advantage of a docent program is that it provides an ideal setting for educating the public about the impacts of collecting.

Restoring target species

The black abalone is an obvious candidate for active restoration. Black abalone were once common along the mainland coast, but disappeared from the Santa Monica Bay region in the 1980s and 90s. The disappearance was primarily caused by harvesting, but subsequently the black abalone population in southern California was decimated by a wasting disease. Although not impossible, at this point it seems unlikely that black abalone could re-establish themselves due to life history limitations (although occasionally an individual black abalone is still found on the Palos Verdes Peninsula; Lawrenz-Miller, *personal communication*). Adults need to be in close proximity to spawn successfully, and larvae apparently have fairly limited dispersal ability. Thus, black abalone could not be expected to recovery passively, and some active management is likely to be needed to restore this important species. However, abalone restoration is not simple; we know of no attempts at restoring intertidal populations, but there have been many attempts at restoring subtidal populations, and although progress has been made over the past few decades, success is still elusive. In addition to the typical problems associated with restoring a species, the black abalone have the additional problem of the wasting disease, and uncertainty about its persistence as a result. It may nonetheless be feasible to restore black abalone.

Consider re-establishing surfgrass if declines continue. Surfgrass restoration techniques have recently be developed by Reed and Holbrook at UCSB. Although there are challenges, as with every restoration effort, the techniques are well enough developed that there is a reasonable likelihood of success. However, the techniques are intensive and relatively expensive, so it is only worth implementing a surfgrass restoration effort if the declines we infer continue or expand.

Recommendations

Our recommendations for approaches to be used for restoring Santa Monica Bay rocky intertidal habitats include:

Establish or expand an education program

Impacts from collecting and handling could be reduced by better educating visitors to rocky intertidal habitats. Educational materials (including a video or DVD) might be prepared for widespread distribution to educators. Existing programs might be expanded to include more people, and possibly standardized. Docents (see below) could play a critical role in educating intertidal visitors.

Establish or expand docent programs

Docents provide an on-site presence that can help minimize impacts to rocky intertidal organisms while increasing the public's appreciation of marine habitats. Because a docent program requires an infrastructure and some level of institutional support, only a few key sites are likely to be able to have docents. However, adding docents to the two or three most-used sites in Santa Monica Bay (and perhaps expanding the existing docent program at Point Fermin) would ensure that a substantial fraction of intertidal users in the Bay went to sites with docents.

Docents could educate intertidal visitors (see above) about proper intertidal etiquette, thereby reducing impacts from collecting and inappropriate handling. (The relatively low rate of collecting at Point Fermin is presumably a result of the docents there.) Docents can also assist with some "soft" enforcement of intertidal regulations by informing visitors of the regulations. In some areas, docents work closely with law enforcement agencies to inform the agencies of legal violations; law enforcement personnel can then go to the intertidal site to issue citations.

Docents could be a key component of any effort to exclude people from a portion of a rocky intertidal site (see below).

Expand enforcement activities, including educating enforcement personnel

Enforcing the existing regulations protecting intertidal organisms could reduce the impacts of collecting on those organisms. The most cost-effective enforcement would target large-scale collectors. We have observed large buckets of turban snails and sea urchins being removed from sites; one collection event like these does more damage than thousands of typical intertidal visitors. Unfortunately, these events are rare and unpredictable, so difficult for routine enforcement to stop. A more constant presence at intertidal sites by docents or interested community members, if coordinated with enforcement personnel, might be more likely to stop these large-scale collection events.

In some areas, docents work closely with law enforcement personnel who can give citations. This may require better education of the enforcement personnel, so that could be explored here in Santa Monica Bay.

Establish a pilot exclusion area

The single action that can best protect rocky intertidal organisms is to exclude visitors from an area. This is the only restoration alternative that can reduce impacts from trampling, and thus it is the alternative that is likely to restore most fully the biological community. We recommend that one area be established as a pilot restoration effort. This effort would need to be maintained for a minimum of five years, and more likely ten years, for its effectiveness to be evaluated. Considerable effort would be needed for planning the exclusion, including identifying the best location (from both biological and social/institutional perspectives) and implementing the pilot. Docents would most likely have to be in place to maintain the exclusion during low tides.

Monitor trends in surfgrass abundance in Malibu

Surfgrass is a key intertidal species. Not only is it a productive primary producer, but it provides critical habitat for other species. In some ways, it is the intertidal equivalent of giant kelp. Little is known about its abundance over the past decades; however, our data indicate that it has lower cover where human use is high, suggesting it may have declined in places along the Malibu coast. It would be worth monitoring surfgrass cover to track this valuable resource. In addition, surfgrass cover is readily determined from aerial photographs, so it might be possible to do a retrospective inventory of surfgrass abundance. Significant declines should trigger consideration of a restoration effort.

Table 9. Summary of restoration alternatives.

Technique	Effectiveness	Logistical considerations	Enforcement	Cost	Comments
Reducing walking on intertidal rocks					
Established pathways	Effective if enforced Although it would allow some impacts, they would be concentrated in a small area	Hard to maintain pathways	Enforcement required; relatively close inspection needed to determine compliance	Moderate cost to establish and maintain; enforcement costs	Would avoid outright elimination of access, so might be more acceptable than area closures
Restrict public access to an area	Maximally effective, would allow to the development of the best-functioning community possible	Best established at site with easy access for docents and enforcement officials	Enforcement required; easy to determine compliance	Enforcement costs only (including docent program)	Possible objections to restrictions on access; best done at a State Park or other area with easy control
Reducing handling of intertidal organisms					
Education	Might be effective for organized groups; effectiveness for individual visitors depends on long-term effort	Easily implemented for organized groups. Requires docent program for individual visitors	No legal enforcement required; docents could provide on-site education	Cost of training docents or other educators; maintaining docent program	Education to minimize unnecessary handling impacts would be important, but not clear that elimination of all handling is best course of action

Technique	Effectiveness	Logistical considerations	Enforcement	Cost	Comments
Reducing collection of intertidal organisms					
Increased enforcement of existing regulations	Could be moderately effective	Only sites close to access are likely to have an enforcement presence	NA	Moderate additional cost if law enforcement officers used; lower cost if docents used	
Education	Could be moderately effective	Would need a diversified approach to reach all intertidal users	No legal enforcement required; docents could provide on-site education	Cost of training docents or other educators; maintaining docent program	Likely to be less effective for visitors harvesting organisms for food or bait
Restoring target species					
Black abalone	Uncertain success; abalone enhancement has been difficult for subtidal species	Depends on techniques adopted; recruitment structures require maintenance	Strict enforcement would be needed to prevent poaching	Moderate to high cost	Although costly and with uncertain success, black abalone represent a “poster” species for the loss of intertidal species
Surfgrass	Effective		None required	Moderate cost	Only required if studies show a substantial decline in surfgrass in the

					region

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Appendix 1. Study site information

PV Site # 1: Point Fermin High Use Site

Directions to site:

- Take 110 Freeway south towards San Pedro
- ~ 8 miles from the 405/110 freeway interchange, 110 freeway ends at San Pedro/Gaffey St.
- Make a LEFT on Gaffey St.
- Stay on Gaffey for 1.6 miles to 22nd
- Make a LEFT on 22nd St.
- Stay on 22nd St. for 0.25 miles to Pacific
- Make a RIGHT on Pacific
- Stay on Pacific for 0.9 miles to 36th/Stephen M White Dr.
- Make a LEFT on 36th/Stephen M White Dr
- This road quickly curves to the right
- You can park on 36th/Stephen M White Dr or make a LEFT turn into the Cabrillo Aquarium Parking lot (pay $$ lot)
- Walk down to beach and go to north end where a boardwalk will take you down to the intertidal

Boardwalk

Walk along the boardwalk until it ends and you will see the rocky intertidal site with the remains of an old, man-made wall along the cliff.

Man-made wall

End of walkway with man-made wall in site

About 100 feet past the end of the man-made wall, there is a nice, flat rock coming out from the cliff. This is a good spot to be used as a viewpoint

Viewpoint

Rockweed
patch

View of Site with left boundary (when looking at the ocean) from the man-made wall out to the ocean and the right boundary just near a large patch of rockweed approx 45 meters from the left boundary.

PV Site # 2: Point Fermin Low Use Site

Directions to site:

- 110 Freeway south towards San Pedro
- ~ 8 miles from the 405/110 freeway interchange, 110 freeway ends at San Pedro/Gaffey St.
- Make a LEFT on Gaffey St.
- Stay on Gaffey for 1.6 miles to 22nd
- Make a LEFT on 22nd St.
- Stay on 22nd St. for 0.25 miles to Pacific
- Make a RIGHT on Pacific
- Stay on Pacific for 0.9 miles to 36th/Stephen M White Dr.
- Make a LEFT on 36th/Stephen M White Dr
- This road quickly curves to the right
- You can park on 36th/Stephen M White Dr or make a LEFT turn into the Cabrillo Aquarium Parking lot (pay $$ lot)
- Walk down to beach and go to north end where a boardwalk will take you down to the intertidal (see pictures in previous site descriptions)
- Walk past high use site and around the corner Once you turn the corner, you should see a large storm drain/water pipe coming down from the cliff top.
- Walk about 400 feet past the storm drain
- You should see a large concrete slab in the splash zone (see picture) – just past the slab, there is a large, rocky shelf jutting into the ocean

Storm drain from clifftop

Conspicuous concrete slab

Site with boundaries

Site boundaries are from rocky shelf jetting out into ocean just past the conspicuous concrete slab on left of picture to about 100 feet north of there as shown

PV SITE # 3: White's Point

Directions to site:

- 110 Freeway south towards San Pedro
- ~ 8 miles from the 405/110 freeway interchange, 110 freeway ends at San Pedro/Gaffey St.
- Make a LEFT on Gaffey St.
- Stay on Gaffey for 1.75 miles to 25th St.
- Make a RIGHT on 25th St.
- Stay on 25th St for 1.2 miles to Western
- Make a LEFT on Western
- Stay on Western down the hill for 0.7 miles
- At the bottom of the hill, the road splits – stay to the left (the right is Paseo del Mar)
- Make a RIGHT into the White Point/Royal Palms County Beach
- Immediately make another RIGHT and go down the hill towards the beach
- At the bottom of the hill, the road forks – go to the LEFT and take the road until the concrete parking lot ends (do not go into the dirt parking area)
- At the end of the parking lot, you should see a concrete bench – the rocks in front of the bench can be a good viewpoint

Clifftop view of site including boundaries of study site

Parking lot view of bench/viewpoint

Site with boundaries

Site boundaries – Right boundary (when looking at the ocean) is along rocky reef boundary (along the waterline)
Left boundary is about 100 ft from the right boundary and jets out to two fingers covered with mussels that stick out into the low intertidal zone

PV SITE #4: Inspiration Point

Directions to site:

- 110 Freeway south towards San Pedro
- ~ 8 miles from the 405/110 freeway interchange, 110 freeway ends at San Pedro/Gaffey St.
- Make a LEFT on Gaffey St.
- Stay on Gaffey for 1.75 miles to 25th St.
- Make a RIGHT on 25th St.
- Stay on 25th (turns into PV Drive South) for 5.1 miles
- Just past the Narcissa St. sign, make a LEFT into the Abalone Cove Shoreline Park
- If you pass Narcissa St or Wayfarer’s Chapel (both on the left), you have gone to far
- Enter the gated Abalone Cove Shoreline Park entrance and park off the road on the right just past the gate
- Walk back to PV Drive South road and walk south (downcoast) about ¼ mile
- You will see a sign for Peppertree Dr.
- Just past the sign on the right, there is a path that takes you down the hill to the site
- It is about a 5-10 minute walk down the hill

Abalone Cove Shoreline Park gated entrance

Abalone Cove Shoreline Park gated entrance

Pathway just past
Peppertree Dr sign

Peppertree Dr as you are walking south (downcoast)

View of site as you walk down pathway

View of site as you walk down pathway with boundaries

Site with boundaries

PV SITE#5: Abalone Cove

Directions to site:

- 110 Freeway south towards San Pedro
- ~ 8 miles from the 405/110 freeway interchange, 110 freeway ends at San Pedro/Gaffey St.
- Make a LEFT on Gaffey St.
- Stay on Gaffey for 1.75 miles to 25th St.
- Make a RIGHT on 25th St.
- Stay on 25th (turns into PV Drive South) for 5.1 miles
- Just past the Narcissa St. sign, make a LEFT into the Abalone Cove Shoreline Park
- If you pass Narcissa St or Wayfarer's Chapel (both on the left), you have gone too far
- Enter the gated Abalone Cove Shoreline Park entrance and drive down the road all the way to the beach (see pictures in above site description)
    - About ½ down the hill, the road will fork – take the road that keeps going straight down the hill (do not turn left)
    - About ¾ down the hill, the road will fork again – take the road that keeps going straight (do NOT turn right)
- There is a parking lot at the bottom of the hill with trash cans and a portable bathroom (see picture)

Site with boundaries

MALIBU SITE #1: Paradise Cove

- Head north on PCH from the Santa Monica area.
- About 13.9 miles past Sunsent Blvd. on PCH, make a LEFT into Paradise Cove Road.
- If you hit Kanan Dume Rd. or Point Dume, you have gone too far.
- Follow road 0.25 miles until you see a parking booth.
- Stop at the parking booth and ask attendant about parking which should be arranged a head of time for you visit.
- Walk down to beach and upcoast about 400 feet.
- As you walk upcoast along the beach, you should see that the cliff turns sharply at a corner.
- Just before that corner, there is a sign saying “Collecting or disturbing tidepools is illegal” on the face of the cliff
- This corner is a good viewpoint for the site and is in the center of the site boundaries

Viewpoint at corner

VIEW FROM PARKING LOT

"Collecting or disturbing tidepools is illegal" sign

VIEWPOINT AT CORNER

Paradise Cove Pier

SITE WITH BOUNDARIES

MALIBU SITE # 2: POINT DUME

- Head north on PCH from the Santa Monica area.
- About 15.75 miles past Sunsent Blvd. on PCH, male a LEFT on Westward Beach Rd (Point Dume State Beach).
- If you hit Zuma beach, you have gone too far.
- Stay on Westward for 0.6 miles and this road will come to a fork
- Make a LEFT on Birdview Ave but keep in mind of this fork because is no parking is available on Birdview, then you will need to come back here and go straight to the alternate parking area.
- Stay on Birdview Ave for 1.1 miles.
- There are a few parking spots on the right hand side (do not park on side of street, only within designated parking areas).
- If full, go back to Westward and make a left into road that takes you to the alternate lot (sometime this is a pay $ parking area).
- Park at the end of the parking lot nearest to Point Dume.
- If you parked on Birdview:
  - Walk down path a “Point Dume Natural Preserve” sign near parking area.
  - Follow signs to beach and take stairs down to the site (~5 minute walk).
  - The site is directly at the bottom of the stairs as shown by the pictures
- If you parked in alternate lot off Westward:
  - Take stairs along fenceline (see picture) up to clifftop
  - This path should end on Birdview Ave.
  - Make a right on Birdview and walk to the parking lot you first attempted to park in.
  - Walk down path a “Point Dume Natural Preserve” sign near parking area.
  - Follow signs to beach and take stairs down to the site (~5 minute walk).
  - The site is directly at the bottom of the stairs as shown by the pictures

FORK AT WESTWARD AND BIRDVIEW

STAIRS ALONG FENCELINE TO WALK BACK UP UP TO BIRDVIEW AVE FROM ALTERNATE LOT

Point Dume Natural Preserve sign

START OF PATH DOWN TO SITE AT SIGN

CLIFFTOP VIEW OF SITE

Right boundary of site

STAIRCASE DOWN TO SITE

View of site from bottom of stairs with boundaries. Note that site is covered in sand when this picture was taken – will look very different when sand is gone and cobble is exposed.

MALIBU SITE #3: LEO CARILLO HIGH USE SITE (NORTH)

- Head north on PCH from the Santa Monica area.
- About 23.0 miles past Sunsent Blvd. on PCH, you should see a sign for Leo Carillo State Beach.
- Make a right into the Leo Carillo State Park parking lot (pay $ lot) OR park on the beach side of the road near there within legal parking limits (free parking)
- From the parking lot, there is a path that takes you under the PCH overpass.
- You should see the site directly in front of you with a lifeguard tower on the clifftop above to the right (see picture)
- Walk down to beach.
- The left boundary (when facing the ocean) is the tall, large rock in your view (see picture) and right boundary just downshore of lifeguard tower on clifftop.

Lifeguard tower on clifftop

VIEW OF SITE AREA AFTER YOU CROSS UNDER PCH

Tall, large rock marking the
left boundary

VIEW OF SITE WITH BOUNDARIES

MALIBU #4 LEO CARILLO LOW USE (SOUTH)

- See directions to site in above site description (For Leo Carillo High Use site north)
- From Leo Carillo high use site, walk downcoast about 1000-1200 feet.
- Just about 200 feet past Lifeguard tower zero (cation: towers are sometimes removed seasonally), you will see an odd shaped rock in the intertidal zone (see picture)
- This odd shaped rock is your right boundary (when facing the ocean)

View of low use site from high use site at Leo Carillo with lifeguard tower in view

Lifeguard tower about 200 feet before site begins

Two views of odd shaped rock marking the right boundary of the site

Site view with boundaries

BIRDS

BLACK OYSTERCATCHER

GULLS

GULLS

SHOREBIRDS

OTHER BIRDS (SPECIFY IF POSSIBLE)

EGRET

HERON

CROW

PELICAN