HUMAN VISITATION AND THE FREQUENCY AND POTENTIAL EFFECTS OF COLLECTING ON ROCKY INTERTIDAL POPULATIONS IN SOUTHERN CALIFORNIA MARINE RESERVES

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ABSTRACT

Humans intensely use southern California rocky shores for recreational activities such as fishing, exploration, walking, enjoyment of the out-of-doors, and educational field trips. People also collect intertidal organisms for consumption, fish bait, home aquariums, and other purposes. In Orange County, visitors concentrate their activities on a few rocky headlands and reefs. Many of these shores have been designated as California Marine Life Refuges (CMLRs) or State Ecological Reserves (SERs), where the removal of most intertidal organisms, except for scientific purposes, has been unlawful for 30 years. In a yearlong study of eight Orange County shores, unlawful collecting of organisms was often observed. In addition, lifeguards have frequently observed unlawful collecting on these and other shores. The CMLR or SER designation did not deter collecting. Mussels, trochid snails, limpets, urchins, and octopuses were the most commonly collected organisms, primarily for food or fish bait. Several of the gastropod species targeted by human collectors had low population densities and population structures dominated by smaller and less fecund individuals, characteristics that often occur in populations exploited by humans. Most collected invertebrates were broadcast spawners that require high densities of fertile individuals to optimize reproduction. The cascading effects of collecting on community structure and the reproductive success of exploited populations are unknown. Except for state park rangers at one site, no state enforcement personnel were seen during 768 hours of low-tide observations throughout the year. Without effective enforcement, adequate signage, and educational programs to increase public awareness, CMLRs and SERs are not protecting rocky intertidal populations on heavily visited southern California shores. Improved management practices are needed if CMLRs and SERs are to protect rocky intertidal populations and to serve as benchmark sites where changes in populations due to regional climatic events or chronic human disturbances can be measured and evaluated in the absence of exploitation.

INTRODUCTION

The human population residing in the coastal zone is growing by more than 1% per year in the United States (Culliton et al. 1990). This growth has been particularly rapid in coastal southern California counties, where the population has increased by more than 50% over the past three decades (Anon. 1969, 1998). The disturbance produced by the activities of this expanding population is thought to have resulted in a widespread reduction in the biodiversity of southern California's rocky shores (e.g., Littler 1980; Littler et al. 1991; Murray and Bray 1994).

Previously, declines in rocky intertidal biodiversity have largely been ascribed to chronic, persistent disturbances including discharged sewage and industrial effluents (Dawson 1959, 1965; Widdowson 1971; Thom and Widdowson 1978; Littler 1980). But more episodic disturbances resulting from visitor foot traffic (Brosnan and Crumrine 1994; Keough and Quinn 1998); the collection of organisms for human consumption, fish bait, aquariums, and other purposes (Griffiths and Branch 1997); and the exploratory manipulation of rocks and specimens (Addessi 1995) can also significantly affect rocky intertidal populations and communities. Yet, little attention has been given to the effects of human visitation, despite the large numbers of people that use southern California rocky shores throughout the year for activities such as recreational fishing, food and specimen gathering, educational field trips, exploration, walking, and enjoyment of the out-of-doors.

Globally, marine protected areas (MPAs) are receiving increasing attention as management tools for protecting marine populations from human activities (Gubbay 1995; Ticco 1995; Agardy 1997). In the last fifteen years, the number of MPAs has grown from about 400 to more than 1,000 worldwide (Gubbay 1995). Along the heavily urbanized southern California mainland, California Marine Life Refuges (CMLRs), State Ecological Reserves (SERs), and Marine Resources Protection Act (MRPA) Ecological Reserves are the most common MPAs established to protect intertidal organisms from on-site visitor disturbance (McArdle 1997).

Although minor variations occur among sites, CMLRs and SERs prohibit the removal of almost all marine plants and invertebrates except with a scientific permit or special authorization by the California Department of Fish and Game (Smith and Johnson 1989; McArdle 1997). Exceptions generally include invertebrates of historical importance to recreational sport and commercial fishers, such as lobster (and in the past, abalone), which can be extracted lawfully from most CMLRs and SERs with an appropriate license or permit. The taking of most species of finfish with a sportfishing or commercial license is also allowed in most CMLRs and many SERs; only MRPA Ecological Reserves prohibit the extraction of all plants and invertebrates, and fishing for finfish without special authorization (McArdle 1997). Interestingly, none of these CMLRs, SERs, or MRPA Ecological Reserves include regulations that limit human access or restrict exploratory human activities.

Most of southern California's CMLRs and SERs were established between 1968 and 1973 (Smith and Johnson 1989; McArdle 1997), a period of heightened public interest in environmental issues. Unfortunately, like many other coastal conservation measures enacted at that time, the measures did not institute programs to evaluate the results of CMLR or SER establishment. Thus, a question of fundamental importance to the management and conservation of rocky intertidal populations and communities in southern California is: Have CMLRs and SERs been effective in protecting rocky intertidal invertebrate, plant, and finfish populations from the activities of an expanding human population during the last 30 years?

The purpose of this paper is to discuss how visitors can affect CMLRs, SERs, and unprotected rocky shores in urban southern California. On the basis of work performed on Orange County rocky shores, we describe and discuss (1) the magnitude of human visitation; (2) the collecting of intertidal invertebrates for food, fish bait, home aquariums, and other purposes; (3) the apparent decline of selected intertidal invertebrate populations; and (4) the effectiveness of CMLRs and SERs in protecting rocky intertidal populations and communities in urban southern California.

THE STUDY AREA AND HUMAN VISITATION

Orange County, located just south and east of the city of Los Angeles, has undergone extensive urbanization as its population has more than doubled during the past 30 years (Anon. 1969, 1998). The infrastructure created to support this urbanization includes major highways and roads that have made most of the county's shoreline easily accessible to visitors throughout the region. Because rocky headlands and low-lying bedrock reefs mostly occur along the Orange County coast between Little Corona Del Mar and Dana Point (fig. 1) and are separated by stretches of sandy beach, human visitors concentrate their activities on only a small portion (<20 km) of the county's shoreline. Most of this rocky intertidal habitat lies within the boundaries of seven CMLRs and the Heisler Park SER; these MPAs were established about 30 years ago. An additional section of the Orange County coastline was placed under CMLR protection with the implementation of SB-716 on January 1, 1994. This bill expanded the southern boundary of the Laguna Beach MLR to include the previously undesignated section of coastline between the Laguna Beach and South Laguna MLRs (fig. 1).

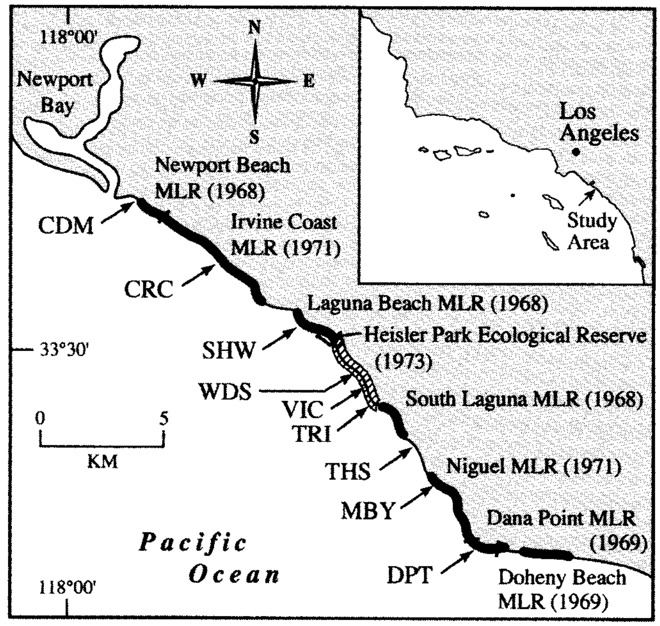

Figure 1. The south Orange County coastline, indicating California Marine Life Refuges (CMLRs) and State Ecological Reserves (SERs) and the dates of their establishment. Shaded areas indicate longstanding (ca. 30 years) CMLRs; the cross-hatched area depicts the January 1, 1994, extension of the Laguna Beach MLR. Arrows indicate the 8 sites assessed for human collecting: Crystal Cove (CRC), Shaw's Cove (SHW), Woods Cove (WDS), Victoria Beach (VIC), Treasure Island (TRI), Thousand Steps (THS), Monarch Bay (MBY), and Dana Point (DPT). The Little Corona Del Mar site (CDM) and the Heisler Park SER are also shown.

Rocky shores have long served as important recreational and educational resources for outdoor-oriented southern Californians (fig. 2). Although data on the number of visitors are not kept for most sites, partial records are available for selected locations where educational group activities take place. During 1996, for example, 7,690 people explored three to four rocky intertidal reefs at Crystal Cove State Park (M. Eaton, G. Scott, and W. Bonin, Calif. Park Service, pers. comm.) and 12,204 participated in organized field trips held within the Dana Point MLR (H. Helling and J. Goodson, Orange County Marine Inst., pers. comm.). In the same year, 12,000–15,000 persons made low-tide visits to a shoreline extending only about 125 meters at Little Corona Del Mar (fig. 1), a popular location for educational field trips in the Newport Beach MLR (T. Melum, City of Newport Beach, pers. comm.). At times, the number of shore visitors during a single afternoon low tide has reached levels as high as 1,443 persons in the Dana Point MLR (H. Helling, pers. comm.).

The activities of high concentrations of visitors, including their foot traffic, can significantly damage a wide

Figure 2. A large group of young people walks on organisms while participating in an educational field trip in the Dana Point MLR.

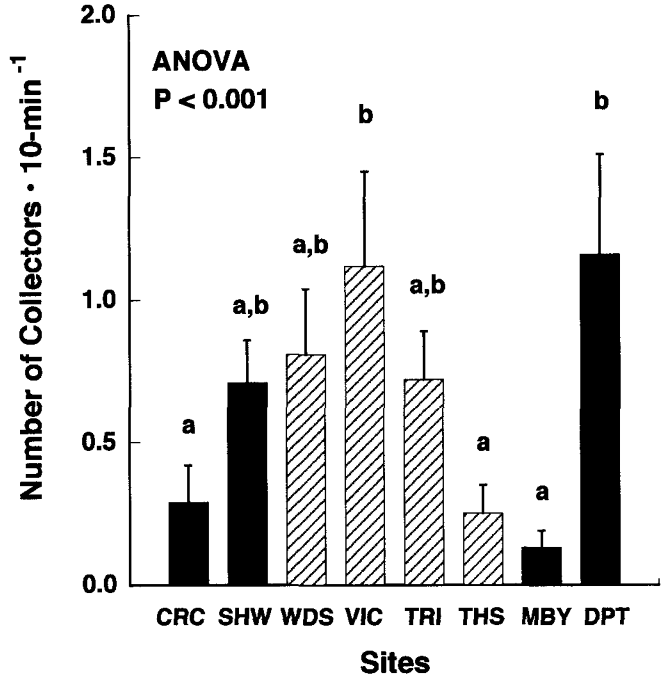

Figure 3. Human collecting activity at eight Orange County study sites (see fig. 1 for locations and abbreviations; after Murray 1998). Filled bars indicate longstanding, signed CMLRs; cross-hatched bars designate nonreserve sites (prior to 1994). Signs indicating CMLR status were not posted at nonreserve study sites given protection on January 1, 1994, until after all our data were collected. Plotted values represent the annual mean number of collectors (+1 SE) for each site calculated from the twelve monthly averages obtained between February 1995 and January 1996. Mean values designated by the same letter (a or b) belong to the same subset on the basis of the Student-Newman-Keuls (SNK) a posteriori multiple comparison test.

variety of rocky intertidal species (Keough and Quinn 1991, 1998; Brosnan and Crumrine 1994; Addessi 1995; Brown and Taylor 1999). Southern California intertidal populations susceptible to trampling include fleshy seaweeds, coralline algae, fragile tube-forming polychaetes, bivalves such as mussels, acorn barnacles, limpets, and grapsid crabs that seek refuge under loose rocks and seaweeds during low tide (Ghazanshahi et al. 1983; Murray 1998). Upper-shore fleshy seaweeds have been shown to be particularly susceptible to damage from human foot traffic throughout the world (Boalch et al. 1974; Beauchamp and Gowing 1982; Povey and Keough 1991; Brosnan and Crumrine 1994; Keough and Quinn 1998; Murray 1998; Schiel and Taylor 1999).

HUMAN COLLECTING ON ORANGE COUNTY ROCKY SHORES

Collecting Activity

A direct and potentially damaging effect of human visitation to the intertidal zone is the extraction of organisms. We quantified the frequency of human collecting of invertebrates and plants monthly for one year at eight rocky intertidal sites, four of which were within well-signed, longstanding CMLRs where collecting intertidal organisms without a scientific collector's permit was unlawful (Murray 1998). We visited the sites four times per month, twice during weekends and twice during weekdays between February 1995 and January 1996, to obtain monthly averages of collecting frequency. All site visits took place between sunrise and sunset; we did not sample on rainy days. Observations began one hour before and ended one hour after the predicted time of lower-low water. During each visit, the number of persons observed collecting was recorded for 10 minutes at the beginning of each 30-min period to produce five 10-min samples. We used these data to calculate the mean number of collectors observed per 10-min period for each site visit.

Our surveys indicate that collecting is frequent on Orange County rocky shores and does not appear to be deterred by CMLR designation in the absence of active education and enforcement. We estimated annual means of 0.1 to 1.1 collectors per 10-min observation period, indicating that at sites where collecting activity was most intense (i.e., Victoria Beach and Dana Point), an average of at least one person was engaged in collecting during every 10-min low-tide observation period throughout the year (fig. 3). No significant difference in the amount of collecting was detected between longstanding CMLRs and unprotected areas (one-tailed paired t test; $T = 1.007$; df = 11; $P = 0.17$; analysis based on comparisons of monthly averages of the number of collectors per 10-min period recorded for CMLR and nonreserve sites).

Collecting intensity, however, did vary significantly (ANOVA performed on square-root transformed data: df = 7; $MS = 0.342$; $F = 4.162$; $P < 0.001$) among the eight sites (fig. 3). Collecting was generally greatest on shores most easily accessible to visitors (e. g., Shaw's Cove, Woods Cove, Dana Point) and where recreational fishers were frequently seen removing organisms for fish bait (Shaw's Cove, Victoria Beach, Treasure Island).

Uniformed or other identifiable enforcement officials were never seen viewing the shore from overlooks, questioning people leaving the beach, or on the shoreline at our study sites during a total of 768 hrs of low-tide observations throughout the year. The only visible enforcement officials were state park rangers at our study site located inside Crystal Cove State Park, and lifeguards on duty during the summer and on holidays at sandy beaches adjacent to several of our study areas.

Records kept by Laguna Beach lifeguards also provide evidence that collecting is widespread and extensive along Orange County rocky shores, even in CMLRs and SERs (M. Klosterman, Marine Safety Chief, City of Laguna Beach, pers. comm.). For example, in 1997 and 1998, Laguna Beach lifeguards gave an annual average of 25,532 ecological advisements to persons collecting or engaged in ecologically damaging activities to intertidal populations and communities. Most advisements were given when tides were unfavorable for low-tide visitors, in the late morning and afternoon during the late spring and summer months when lifeguards were on duty. Lifeguards generally were not present in the fall and winter, when visitors most intensely use southern California rocky shores during favorable midday and afternoon lower low tides (Murray 1998). All advisements were given over a shoreline span (ca. 5 km) that extended from just north to just south of the historical limits of the Laguna Beach MLR and that included the Heisler Park SER (fig. 1). In summer (June–August) 1996, more than 40% of a total of 12,269 advisements were given at stations located either inside the Laguna Beach MLR or the Heisler Park SER. Heisler Park is a well-signed SER where all recreational and commercial extraction of marine plants, invertebrates, and finfish is prohibited without a scientific collector's permit or special authorization (McArdle 1997).

Species Collected

Slow-moving and sessile intertidal invertebrates are particularly vulnerable to collecting. Our surveys, and observations made during subsequent visits to our study sites, indicate that the organisms most commonly collected on southern California rocky shores are mussels, trochid snails, limpets, urchins, and octopuses.

Most collectors seemed to remove organisms for food or fish bait, although sometimes we found people taking animals for personal or commercial aquariums. Specimen collecting for scientific or educational purposes was seldom observed. Collectors often used iron bars, hammers, knives, or chisels to obtain mussels, and they frequently overturned rocks or damaged the rocky substrata while probing crevices and searching beneath larger boulders for octopuses. Flagrant collecting of large quantities of organisms occurred mostly when visitors took bags of mussels, presumably for food (fig. 4). Laguna Beach lifeguards also reported that the most extreme collecting incidents usually involved mussels (M. Klosterman, Marine Safety Chief, City of Laguna Beach, pers. comm.). On a few occasions, collectors took organisms for unusual purposes. For example, we saw a fisher leaving a signed CMLR with a bucket filled with kelp snails (*Norrisia norrisi* Sowerby) to be used the next day for fish bait in a nearby freshwater lake. We saw plants being collected only for scientific or educational purposes.

Figure 4. Collectors fill a bag with mussels in the Laguna Beach MLR.

We saw that recreational shore fishers fished at sites with steeply sloping rock platforms containing beds of mussels. Like recreational shore fishers in Australia (Kingsford et al. 1991), local fishers concentrated their bait-gathering adjacent to their preferred fishing spots, whether or not they were inside a CMLR or SER. Our observations indicate that mussels are by far the most commonly collected bait organism on southern California shores. Recreational fishers pull and cut mussels directly from the substratum; these practices also eventually dislodge other mussels by weakening their byssal attachment threads to each other and to rock surfaces. Recent surveys at our sites also revealed more gaps and less mussel cover within beds frequented by recreational fishers, probably as a result of bait removal.[1]

Effects of Collecting

The most direct effects of intense collecting are decreased abundances of exploited species and, because humans preferentially collect larger individuals, altered population size structures (Griffiths and Branch 1997). Decreased density and reduced size structures have been reported for exploited invertebrate populations in Chile (Moreno et al. 1984; Castilla and Durán 1985; Oliva and Castilla 1986); Costa Rica (Ortega 1987); South Africa (Branch 1975; McLachlan and Lombard 1981; Hockey and Bosman 1986; Lasiak and Dye 1989; Branch and Moreno 1994); Tanzania (Newton et al. 1993); and Australia (Catterall and Poiner 1987; Keough et al. 1993). In addition, reduced abundances of certain exploited invertebrates, including mussels (Siegfried et al. 1985; Hockey and Bosman 1986), oysters (Dye 1988), predatory gastropods (Moreno et al. 1986; Durán and Castilla 1989), and limpets (Hockey and Bosman 1986; Oliva and Castilla 1986; Lindberg et al. 1998) can lead to significant changes in community structure.

The status of several intertidal invertebrate populations on southern California shores may reflect recent human exploitation, even where CMLRs and SERs have made almost all extraction by humans unlawful for nearly 30 years. For example, recent qualitative observations made at longstanding CMLRs and SERs and at historically unprotected southern California sites revealed sparse populations of most species of mid- and large-sized snails (>30 mm in maximum shell dimension) and grapsid crabs, particularly on smaller rocky platforms (<75 m of shoreline) that receive high concentrations of human visitors. On some of these small rocky platforms, the densities of common mid-intertidal turban snails (*Tegula gallina* Forbes and *T. funebralis* A. Adams) were found to be extremely low (0 to <1 m^{-2}) despite the availability of suitable habitat (Sato and Murray, unpublished data). Also, Kido[2] found the mean shell sizes (26.2 to 35.2 mm maximum shell length) of populations of the relatively long-lived owl limpet (*Lottia gigantea* Sowerby) at our eight study sites to be comparable to sizes reported by Pombo and Escofet (1996) for sites in Mexico where human exploitation is common. Collecting of *L. gigantea* is known to drive populations toward low densities of small individuals and to have cascading effects on other intertidal populations (Lindberg et al. 1998).

Reduced density and altered size structures can also have profound repercussions on the reproductive success of intensely exploited populations (Branch 1975; Wells 1997). As discussed by Hockey and Branch (1994), this is particularly true for broadcast spawners, where the probability of fertilization is already low for individual gametes (Denny et al. 1992); decreased density can further reduce fertilization success (Levitan 1991; Tegner et al. 1996). Furthermore, the preferential exploitation of larger-sized individuals can significantly decrease reproductive output because the production of gonadal mass greatly increases with size in most marine invertebrates. For example, changes in size structure due to human exploitation led to more than an 80% reduction in the reproductive output of a South African limpet population (Branch 1975; Branch and Moreno 1994). For protandrous species like *Lottia gigantea*, whose individuals change from males to females with age, greater exploitation of larger and older animals may further diminish the reproductive output of local populations by reducing the availability of females. Allee effects on the reproductive success of southern California invertebrates that rely on external fertilization are unknown but may be significant where density and size structure have declined over broad regional scales.

CONCLUSIONS

Our observations raise serious questions about the effectiveness of CMLRs and SERs as they are currently being managed in urban southern California. Low-tide surveys made throughout the year at eight Orange County sites, together with records kept by Laguna Beach lifeguards, indicate that unlawful collecting of intertidal organisms is common on many southern California rocky shores. Moreover, sites that are easy for visitors to reach and that are preferred by fishers seem to have the highest frequency of collecting disturbance regardless of whether the sites have long histories of CMLR or SER designation and whether signs indicating their protected status are posted at entry points. Unfortunately, historical data on the abundances and sizes of recreationally exploited invertebrates are unavailable for most southern California shores, so it is difficult to measure population declines and to evaluate the current status of any population. However, our qualitative observations and recent studies suggest that several exploited intertidal invertebrates have densities and size structures characteristic of overexploited populations.

Compliance with regulations is listed as a key to MPA success (Causey 1995; Ticco 1995) but is often difficult to achieve (Proulx 1998). The almost complete absence of visible enforcement officials has clearly contributed to the high frequency of unlawful collecting in southern California CMLRs and SERs. Maintaining effective

[1]Smith, J. R. 1999. The effects of bait collection and trampling on *Mytilus californianus* Conrad communities on southern California rocky shores. M.A. thesis, Calif. State Univ., Fullerton (in preparation).

[2]Kido, J. S. 1999. The status of *Lottia gigantea* Sowerby (owl limpet) populations among and within sites on southern California rocky shores. M.A. thesis, Calif. State Univ., Fullerton (in preparation).

enforcement is important especially for urban shores where visitors come from inland locations many kilometers away to exploit intertidal populations, and where coastal residents cannot depend on peer pressure or local educational efforts to achieve compliance with MPA regulations.

Clearly, the management of state MPAs in urban southern California has not received appropriate attention, and CMLRs and SERs do not seem to be effective in protecting intertidal populations from damaging activities. Improved and new management practices are needed, including the provision of effective enforcement, the use of volunteers or docents, the development of educational programs, and the initiation of scientific studies to evaluate MPA effectiveness. Only under these conditions can CMLRs and SERs protect rocky intertidal populations and communities, preserve coastal ecosystem functioning, and serve as benchmark sites in rapidly changing urban environments against which changes due to regional climatic events or the chronic inputs of anthropogenic pollutants can be scientifically evaluated in the absence of human exploitation.

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