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Factors influencing human visitation of southern California rocky intertidal ecosystems

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ABSTRACT

In highly urbanized regions, rocky intertidal habitats attract a large number of visitors for recreation, education, and subsistence harvesting. The collecting, trampling, and handling activities of visitors can have detrimental impacts on intertidal flora and fauna, including reduced abundances and biodiversity and alteration of community structure and function. Despite the large human population in southern California, USA, the level of visitor use at accessible rocky intertidal locations can vary greatly. The goal of this study was to investigate a suite of factors that may influence the number of visitors a site receives. Thirty-two rocky intertidal sites interspersed along ~175 km of shoreline between Los Angeles and San Diego County in southern California were established and the relative visitor use intensity determined during four aerial surveys conducted during low tide periods. Site-specific characteristic, including cost and availability of parking, physical exertion in reaching a site, popularity of site for educational field trips, density of local human population, and the presence of local attractions, were examined and related to relative use intensity. Popularity of a site for educational field trips was the most significant driver, followed by physical exertion and presence of non-tidepooling attractions. Results from this study may be used as a potential management tool to reduce use and protect anthropogenically-disturbed rocky shores by, for example, regulating educational field trips and manipulating attributes that could alter the degree of physical exertion needed to reach a site.

1. Introduction

Coastal ecosystems are threatened by various human activities associated with heavy urbanization of coastal areas (Thompson et al., 2002; Halpern et al., 2008; Crain et al., 2009), including impacts from pollution (Islam and Tanaka, 2004; Rabalais et al., 2009), habitat destruction (Rotschild et al., 1994), climate change (Harley et al., 2006; Helmuth et al., 2006; Hoegh-Guldberg and Bruno, 2010), the introduction of non-native species (Ruiz et al., 2000; Carlton, 2001; Molnar et al., 2008), and overexploitation (Jackson et al., 2001; Scheffer et al., 2005; Ling et al., 2009). The rocky intertidal ecosystem, located at the interface of the land and sea, is particularly threatened by human activities due to its near proximity to terrestrial runoff, often containing pollutants, and easy access to humans for exploitation and other detrimental visitation activities during exposure at low tide. Rocky intertidal ecosystems are known to attract a large number of individuals for a diverse array of activities, including subsistence harvesting, recreation, and education. These activities can significantly deplete floral and faunal populations, reduce biodiversity, and alter trophic and community structures through the detrimental impacts from the intensive collection of targeted species (e.g. Castilla and Bustamente, 1989; Duran and Castilla, 1989; Kingsford et al., 1991; Smith and Murray, 2005), exploratory manipulation of rocks, also known as 'rock-turning' (Addessi, 1994), handling of organisms (Ambrose and Smith, 2005), and trampling (e.g. Beauchamp and Gowing, 1982; Keough and Quinn, 1998; Brown and Taylor, 1999; Schiel and Taylor, 1999; Smith and Murray, 2005; Huff, 2011).

The most obvious impact from human visitation is the collection of targeted flora and fauna for food, fish bait, research, souvenir, and home aquaria use. Extraction has been documented to deplete the population size of numerous target species, including mussels, limpets, octopus, abalone, and seaweeds collected for subsistence (Santelices et al., 1980; Moreno et al., 1984; Hockey and Bosman, 1986; Pour et al., 2012) and mussels and tunicates collected for fish bait (Fairweather, 1991; Kyle et al., 1997; Smith and Murray, 2005). Given that humans tend to be large size-selective

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predators (Branch. 1975; Moreno et al., 1984; Siegfried et al., 1985; Hockey and Bosman, 1986), collection can also result in shifts in the size and age structure of the population towards younger, smaller individuals (Siegfried et al., 1985; Ortega, 1987; Hockey et al., 1988; Roy et al., 2003; Smith et al., 2008); this also can indirectly alter the reproductive output of the population (Espinosa et al., 2009) as gonadal indices increase exponentially with size. Indirect effects on community structure as a result of the collection of target species also has been documented (Godoy and Moreno, 1989; Sharpe and Keough, 1998). For example, community changes were documented at locations where the large, predatory snail *Concholepas* is collected, with a mid-intertidal zone dominated by a monoculture of mussels, compared to a mid-intertidal zone consisting of barnacles and macroalgae where collecting is prohibited (Duran and Castilla, 1989).

Maybe less obvious is the impact of trampling, handling, and rock turning. These activities can have similar impacts as collecting when mortality occurs. Trampling and rock turning can crush or dislodge flora and fauna (Beauchamp and Gowing, 1982; Addessi, 1984; Denis, 2003; Smith and Murray, 2005) while handling can lead to indirect mortality through attachment damage or zone displacement (Addessi, 1984; Ambrose and Smith, 2005). In some cases, mortality does not directly occur but trampling, rock-turning, and handling can cause decreased fitness. For example, trampling on mussel beds can weaken the attachment strength of a clump of mussels causing them to be dislodged from wave forces (Smith and Murray, 2005) while walking on rockweeds causes the reproductive tips to be pinched off, resulting in lowered reproductive potential of a population (Denis, 2003). Similar to collecting, indirect impacts can be observed; for example, trampling of a coralline turf habitat resulted in declines in turf associated organisms due to reduced turf height and loss of sand caused by trampling, rather than the damage to the organisms by trampling itself (Brown and Taylor, 1999).

In southern California, USA, the coastal Los Angeles, Orange, and San Diego Counties are heavily urbanized, with ca. 16 million people in 2010 (http://factfinder2.census.gov/); a majority of this population lives within driving distance ($<$50 km) from the coastline. Coastal ecosystems in this region, therefore, are particularly subject to anthropogenic impacts (see Schiff et al., 2000). For rocky intertidal habitats, visitation can vary greatly, with levels reaching remarkable numbers at some sites. For example, Murray et al. (1999) documented over 1400 persons on a 500-m length shoreline within a single afternoon low tide while yearly estimates, standardized to a 100 m shoreline, ranged from ~50,000–75,000 people at some high use locations (Ambrose and Smith, 2005; Ware, 2009) in the region. During the last several decades, during a period of large population growth, large alterations in rocky intertidal community structure have been documented (Widdowson, 1971; Thom and Widdowson, 1978; Gerrard, 2005; Smith et al., 2006; Smith et al., unpublished data), likely attributable to some degree to human visitation. In addition, comparisons of sites with high and low visitation intensities in the region have documented depletions in abundance and size of particular organisms, such as mussels, limpets, sea hares, and sea stars, and shifts in community composition (Kido and Murray, 2003; Ambrose and Smith, 2005; Smith et al., 2008).

The detrimental impacts of human visitation in rocky intertidal habitats are widely documented; thus in urbanized regions such as southern California, coastal managers are concerned with visitation levels and their associated disturbances. A common management tool for protecting particular rocky intertidal habitats worldwide is the establishment of Marine Managed Areas (MMAs), such as Marine Protected Areas (MPAs), Conservation Areas, and State or County Beaches and Parks (Murray et al., 1999; Ambrose and Smith, 2005; Smith et al., 2008). In southern California, MMAs offer various levels of protection, mostly in laws prohibiting collecting of flora and fauna (California Department of Fish and Game: www.dfg.ca.gov). However, studies have indicated that MMAs in southern California may not be particularly effective in protecting rocky intertidal populations (Murray et al., 1999; Kido and Murray, 2003; Ambrose and Smith, 2005; Smith et al., 2008). Many MMAs are lacking the necessary enforcement to uphold existing regulations, often combined with low compliance, poor signage, and lack of public awareness that certain activities are unlawful (Murray et al., 1999; Smith et al., 2008). Furthermore, legal prohibition of collecting organisms does not limit the number of human visitors in rocky intertidal habitats, thus trampling, rock turning, and handling are still major sources of disturbance (Smith et al., 2008). Therefore, protection of rocky intertidal ecosystems from detrimental human activities will require a new management approach aimed at addressing the other detrimental activities of visitors (Smith et al., 2008). In addition, for those sites not afforded MMA designation, alternative means of protection may be desired.

While exclusion of humans from some shorelines will eliminate all visitor impact, thus likely an effective tool, this strategy is not entirely feasible as the California Coastal Act explicitly encourages open use of the coast. Despite the necessity for open access to the shoreline in California, some *de facto* human exclusion sites exist due to the technical or physical difficulty required in reaching the rocky intertidal habitat. For example, sites on private lands or exclusive communities may be fenced off with an entrance point some distance away. In addition, offshore islands or at sites surrounded by steep cliffs, access may only be provided through use of a boat. Although not resulting in complete exclusion, locations with open access but with limited or expensive parking combined with a long, strenuous hike to the site may drastically reduce the numbers of visitors. In these cases, there are certain characteristics about these sites that lead to low levels of human use; equally, there are other site characteristics that could potentially lead to increased intensity of use. Therefore, it is imperative to investigate whether there are characteristics of sites that may drive or influence the level of visitation in order to better understand potential management strategies to reduce visitation and their associated impacts. The purpose of this study was to determine the relationships between the relative level of use at numerous rocky intertidal sites in southern California, USA, and the characteristics of the site, including measures of: cost and availability of parking, physical exertion required in reaching the site, popularity of site for educational field trips, density of the local human population, and presence of nearby attractions. Results from this study may give coastal managers and policy-decision makers potential tools to decrease use at severely disturbed locations.

2. Methods

2.1. Study sites

Thirty-two rocky intertidal sites (Fig. 1; Table 1) interspersed along ~175 km of shoreline between Los Angeles and San Diego Counties in southern California, USA, were established to examine factors influencing human visitation. The coastline in the region is characterized by long sandy beaches interspersed between small rocky headlands; thus rocky intertidal habitat in this region is somewhat limited. Nine sites were sampled in southern Los Angeles County (Palos Verdes Peninsula), sixteen sites were sampled in Orange County, and seven sites were sampled in northern San Diego County. Given the use of aerial photographs from a plane to obtain relative use levels, sites in northern Los Angeles County were not sampled due to difficulties in conducting

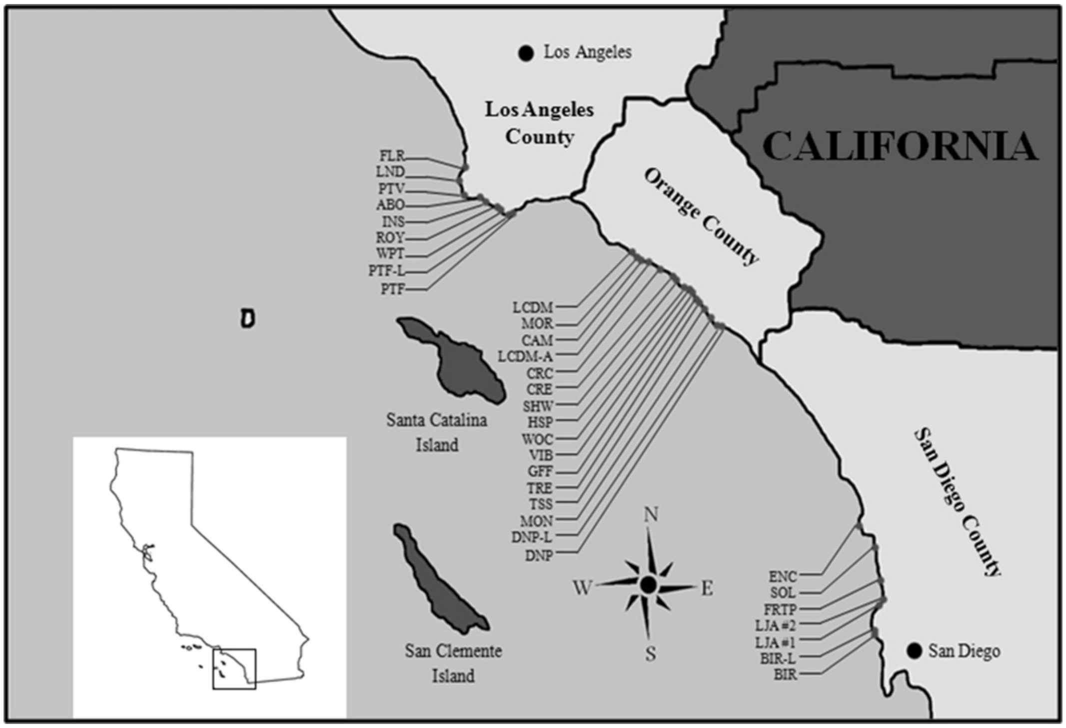

Fig. 1. Map of the 32 rocky intertidal sites within Los Angeles, Orange, and San Diego County, California. Site codes and their corresponding names are located in Table 1.

aerial surveys because of the Los Angeles International Airport and sites in southern San Diego were not sampled due to limited ability to fly near military establishments. Sites were chosen in attempts to obtain a range of differing levels of use from low to high in different regions based on estimates from previous knowledge. Additional sites were chosen haphazardly to fill in geographic gaps between sites of known levels of usage. In some cases, sites that were particularly large or that offered the ability to isolate certain driving factors were divided in two separate sections, separated by a distance of non-sampled area in between. For example, Dana Point and Point Fermin were both divided into two locations, one near the entrance point and one ~1/2 km away that required a longer hike for access.

2.2. *Relative human use measures*

To quantify the relative frequency of human visitation within each site, high resolution digital photographs were taken during a total of four aerial surveys of the sampled coastline using a fixed-wing airplane provided by LightHawk. Aerial surveys were conducted as it is known that intensity of use varies on a daily basis (Ambrose and Smith, 2005; Ware, 2009), thus surveys across a large geographic area were required to be conducted on the same low tide period for appropriate relative comparisons. Three surveys were conducted on clear, warm days during daylight hours between 10 AM and 3 PM during low tides lower than 0.1 m amplitude between March and April, 2010, with an additional survey under similar conditions in February, 2011. Two of the four surveys were conducted on weekdays (Friday April 23, 2010 and Tuesday February 15, 2011) with the remaining two on weekends (Sunday March 29, 2010 and Sunday, April 15, 2010). Several additional flights were scheduled but canceled due to weather and logistical problems. Although additional surveys would have been ideal, we feel the limited data collected is a robust representation of the relative intensity of visitation among sites. Intensity of visitation was determined by counting the number of visitors within a photograph at each location for each survey. Only visitors within the rocky intertidal portion of the beach were counted while visitors on the sandy beaches adjacent to the intertidal zone were ignored. Site boundaries were typically determined by the extent of the rocky outcropping and the natural breaks of sandy beach separating rocky habitats. In cases where a sandy beach break was not obvious, we attempted to use other barriers such as large, difficult to cross crevices or other distinguishable breaks. Although the length of shore for each site varied from 20 m to 200 m, with most sites in the 55–105 m range, the length (or area) was not deemed important as the relationship between use and site characteristics were determined for each isolated site. No linear relationship existed between use and shoreline length ($R^2 = 0.0004$).

To determine whether instantaneous photographic counts of use from aerial surveys were appropriate measures of relative use intensity at sites over a longer period (e.g. a 2 h low tide), on-site observations were conducted on 46 occasions (spread across all sites with some locations sampled on multiple occasions) in Spring and Fall 2010 and Winter and Spring 2011. Beginning 1 h before and ending 1 h after the time of low tide, we counted the number of persons on site at 20-min intervals as an indicator of instantaneous counts, yielding a total of seven instantaneous count samples per site; a mean instantaneous count was then determined from these seven counts. In addition to instantaneous counts, the total number of unique individuals to visit each site during the whole 2 h duration of low tide also was counted. These data were used to determine the relationship between the mean instantaneous counts per sampling period and total count over the 2 h period. If no relationship occurred, instantaneous photographic counts would prove an ineffective method to obtain relative level of use among sites.

2.3. *Site characteristics*

To determine whether relative intensity of use was related to a suite of site characteristics that could attract or deter human visitation, we determined for each site: the cost and availability of

Table 1
Name, code, county (LA = Los Angeles, O = Orange, SD = San Diego), location (latitude and longitude), use intensity, number of parking spots, mean cost of parking ($), physical effort in reaching a site (Z-score), subjective rank of popularity for educational field trips, sum of ranks of attractions, and nearby human population density for 32 sites sampled. Sites are listed in order from North (Los Angeles County) to South (San Diego County). Site codes are used in the map located in Fig. 1.

Site name	Site code	County	Latitude	Longitude	Use intensity	Parking spots	Cost of parking ($)	Physical effort *Z*-score	Education popularity scale	Human population	Attractions scale
Flat Rock	FLR	LA	33° 47.838′N	118° 24.488′W	5.3	147	0.0	3.6	0	16,035	0
Lunada Bay	LND	LA	33° 46.278′N	118° 25.364′W	0.0	393	0.0	2.3	0	16,134	6
Point Vincente	PTV	LA	33° 44.461′N	118° 24.685′W	0.0	48	0.0	2.8	0	8663	13
Abalone Cove	ABO	LA	33° 44.268′N	118° 22.534′W	13.3	45	5.0	2.3	5	16,744	4
Inspiration Point	INS	LA	33° 44.199′N	118° 22.192′W	3.0	45	5.0	3.6	0	16,744	4
Royal Palms	ROY	LA	33° 43.105′N	118° 19.472′W	0.0	110	8.0	−3.0	0	24,628	13
White Point	WPT	LA	33° 42.944′N	118° 19.190′W	28.0	207	5.9	−3.1	7	26,242	10
Point Fermin Low Use	PTF-L	LA	33° 42.344′N	118° 17.281′W	1.0	353	0.6	−1.1	0	19,824	28
Point Fermin	PTF	LA	33° 42.419′N	118° 17.147′W	24.5	353	0.6	−1.7	10	19,824	28
Little Corona Del Mar	LCDM	O	33° 35.341′N	117° 52.091′W	19.3	322	0.0	−1.2	9	16,447	20
Morning Canyon	MOR	O	33° 35.218′N	117° 51.952′W	0.3	322	0.0	−0.5	0	16,447	11
Cameo Shores	CAM	O	33° 35.177′N	117° 51.915′W	1.3	322	0.0	0.4	0	16,447	4
Little Corona Del Mar Arches	LCDM-A	O	33° 35.079′N	117° 51.848′W	3.0	322	0.0	1.8	0	16,447	11
Crystal Cove	CRC	O	33° 34.251′N	117° 50.270′W	14.0	231	15.0	1.2	7	17,396	28
Crescent Bay	CRE	O	33° 32.709′N	117° 48.033′W	8.3	359	0.2	−1.2	2	22,814	17
Shaw's Cove	SHW	O	33° 32.684′N	117° 47.971′W	9.0	107	0.1	−1.7	3	24,474	17
Heisler Park	HSP	O	33° 32.573′N	117° 47.530′W	19.8	516	0.6	−0.8	4	27,607	24
Wood's Cove	WOC	O	33° 31.485′N	117° 46.129′W	2.8	171	0.0	−0.2	0	14,874	11
Victoria Beach	VIB	O	33° 31.186′N	117° 45.842′W	3.8	84	0.1	0.6	0	14,458	17
Goff Island	GFF	O	33° 30.831′N	117° 45.619′W	13.0	284	0.3	0.3	0	13,102	22
Treasure Island	TRE	O	33° 30.801′N	117° 45.485′W	17.0	285	0.3	−1.0	1	13,102	22
Thousand Steps	TSS	O	33° 29.923′N	117° 44.578′W	0.0	148	0.0	3.5	0	13,646	11
Monarch Bay	MON	O	33° 29.062′N	117° 43.907′W	2.3	532	1.0	2.9	0	26,889	16
Dana Point Low Use	DNP-L	O	33° 27.624′N	117° 42.676′W	1.8	183	0.0	0.1	5	22,440	12
Dana Point	DNP	O	33° 27.624′N	117° 42.676′W	6.0	183	0.0	−0.8	9	22,440	25
Encinitas	ENC	SD	33° 2.076′N	117° 17.645′W	23.5	41	0.0	0.6	0	25,575	20
Solana Beach	SOL	SD	32° 59.932′N	117° 16.709′W	18.5	762	5.0	−3.3	0	16,996	17
Flat Rock Torrey Pines	FRTP	SD	32° 54.837′N	117° 15.526′W	12.0	337	10.0	0.4	0	23,450	21
La Jolla #2	LJA #2	SD	32° 51.068′N	117° 16.415′W	20.3	1259	4.5	−2.7	7	12,626	28
La Jolla #1	LJA #1	SD	32° 50.862′N	117° 16.733′W	16.8	1259	4.6	−1.7	7	11,386	28
Bird Rock Low Use	BIR-L	SD	32° 48.973′N	117° 16.434′W	2.3	373	0.0	−0.9	0	20,694	3
Bird Rock	BIR	SD	32° 48.973′N	117° 16.434′W	2.3	373	0.0	−1.1	3	20,694	3

parking, the physical effort required in reaching a site, the popularity of a site for educational field trips, the nearby human population, and non-tidepooling site attractions. In some cases, sites that use the same entrance point may share some similar site characteristics. Therefore, both locations at Dana Point, for example, shared the same entrance point thus parking numbers/cost and human population were similar.

Parking availability was determined by constructing a 0.32 km radius around the closest parking spot to the entrance pathway leading down to the rocky intertidal site using Google maps; all available parking spots within that radius were manually counted during visits to each individual site. Available parking that did not contain designated markers or parking spots (i.e. residential neighborhoods) were counted by using the length of a typical car, roughly 5 m long, to estimate parking spaces along the sidewalks. The price of each parking spot was also determined during site visits; often parking was free or at a flat rate but, if metered (timed) parking spots, the cost for an hour of parking was determined. In several cases, a mixture of different types of parking costs were present; the mean cost per parking spot was calculated.

Physical effort required in reaching a site was measured using a combination of techniques, including change in heart rate, total distance needed to walk, and slope of the pathway (indicating whether the pathway was flat or required walking up and down hills). Heart rate change was determined by one individual (Garcia) during visits to each individual site by measuring heart rate by hand before and after walking from the closest available parking spot to the rocky intertidal site, and vice-versa. The maximum change in heart rate, either to the site or returning to the pathway entrance, was used as the first indicator of physical exertion. The second indicator of physical exertion was the total distance required to walk from the closest parking spot to the rocky intertidal site, determined using a GPS. Finally, the slope of the entrance pathway leading to the rocky intertidal site was determined by calculating change in elevation from the highest point to the lowest point over distance walked using a GPS. A *z*-score of physical exertion was constructed by taking the sum of the standardized values of the maximum heart rate change, total distance, and the slope of the pathway in order to determine the physical effort required per site. The *z*-score ranking of physical exertion that each site required was compared with qualitative ranks of exertion by both authors prior to *z*-score establishment; *z*-scores and qualitative estimates of physical exertion were closely matched.

The rank popularity of a site for educational field trips was assessed using a number of methods, including published reports, records of organized field trips, contacting various pre-college (also known as K-12, or elementary and secondary) schools, two-year community colleges, and four-year universities within the three counties, using both aerial and ground surveys, and use of previous knowledge (summarized in Table 3). Minimal reports (Ambrose and Smith, 2005; Ware, 2009) have examined human use at established sites in the region but provided some data on educational use at ten of our sites. Where applicable, managers of rocky intertidal locations were contacted via email or in person to provide any recorded estimates of: a) the number of different schools, and b) the total students to visit their respective locations over a year period; for a school group to visit some locations, such as the Crystal Cove State Park or Little Corona del Mar reserve, each

Table 2
Results of the multiple regression, including the coefficient, standard error coefficient, *T*-stat, and *p*-value (significance denoted in bold).

Predictor	Coef	SE Coef	*T*-stat	*p*-value
Constant	0.3051	6.4351	0.05	0.963
Education field trips	1.0113	0.4367	2.32	**0.029**
Attractions	0.2057	0.1806	1.14	0.265
Physical effort	−0.7586	0.7855	−0.97	0.343
Parking cost	0.2737	0.3584	0.76	0.452
Population	0.0001	0.0003	0.40	0.695
Total parking	0.0014	0.0052	0.28	0.781

ANOVA: Regression df = 6, MS = 185, *F*-stat = 3.89, *p*-value = 0.007.

individual school must contact the park or reserve manager prior to their visit, although cases of schools not contacting managers prior to visits are acknowledged. Managers of many of these sites have kept informal records of schools and/or the number of students visiting but the data varies in integrity. We also contacted the major educational programs in the region, such as the Ocean Institute in Dana Point, the Cabrillo Aquarium in San Pedro, and the Orange County Department of Education Inside the Outdoors program, to determine the number of schools and/or estimates of students that visited local sites through their organized programs. Data from both managers and educational programs likely accounted for a large number of schools in the region, although a number was not obtainable due to the variability in the type of data reported by those contacted. We also attempted to directly contact a large population of schools and teachers throughout the area both at the pre-college level and college level. For pre-college schools, we first posted a request on the UCLA Oceanlistserv (mass email) whose membership contains a large number of pre-college educators in the region that are interested in marine biology to determine whether they or any other teachers at their school take students to local rocky intertidal locations, what location they visit, and how many students per year participate. A total of 12 responses were appropriate to our study, with a few additional responses that visited sites outside of our region or not on our site list. In addition, we contacted via email and telephone, 264 individual schools in the region as well as some of their respective districts with similar requests. Response to our communications was low with over 237 not responding and only 6 responses with field trips to our study locations. For college level field trips, 14 universities and community colleges in the region were contacted to determine whether field trips to rocky intertidal habitats are taken, what specific site they frequent, and how many students typically attend within a year; a total of 10 responses were applicable to our study sites. Through individual school/educator responses, 6 educational programs, and 5 rocky intertidal managers, we accounted for roughly 130,000 students within our rocky intertidal sites annually; recorded student counts are vastly underrepresented as not all responses included the number of students and only a portion of

Table 3
Education rank for each sampled location was obtained by incorporating information from rocky intertidal managers, educational programs, and pre-college/college teachers and programs. Data obtained from these sources varied in nature, mostly the number of different schools and/or the estimated number of students to visit the site in a year period. Additional information was considered, including the number of observations of school groups on site during aerial surveys and site visits, published reports of estimated levels of educational use (Ambrose and Smith, 2005; Ware, 2009), and experience of the authors during repeated site visits for other research purposes (only sites with authors' confidence are enumerated).

Site name	Education rank	No. different schools/programs	% of school responses	No. students	No. observations	Other reports	Author experience
Flat Rock	0	0	0.0		0		
Lunada Bay	0	0	0.0		0		
Point Vincente	0	0	0.0		0		
Abalone Cove	5	4	8.2	>65	2	Moderate	Moderate
Inspiration Point	0	0	0.0		0	None	None
Royal Palms	0	0	0.0		0		
White Point	7	2	4.1	>80	0	High	High
Point Fermin Low Use	0	0	0.0		0	None	None
Point Fermin	10	6	12.2	>120000	1	High	High
Little Corona Del Mar	9	8	16.3	>1000	0	High	High
Morning Canyon	0	0	0.0		0	None	None
Cameo Shores	0	0	0.0		0	None	None
Little Corona Del Mar Arches	0	0	0.0		0		None
Crystal Cove[a]	7	10	20.4	>7000	0	Moderate to High	Moderate
Crescent Bay	2	1	2.0	>50	0		Low
Shaw's Cove	3	4	8.2	>200	0		Moderate
Heisler Park	4	0	0.0		0	Moderate	Moderate
Wood's Cove	0	0	0.0		0		
Victoria Beach	0	0	0.0		0		None
Goff Island	0	0	0.0		0		None
Treasure Island	1	0	0.0		0		Low
Thousand Steps	0	0	0.0		0		
Monarch Bay	0	0	0.0		0		None
Dana Point Low Use[b]	5	7	14.3	>5000	1		Moderate
Dana Point[b]	9	7	14.3	>5000	2		High
Encinitas	1	0	0.0		1		
Solana Beach	0	0	0.0		0		
Flat Rock Torrey Pines	0	0	0.0		0		
La Jolla #2[c]	7	5	10.2	>800	0		Moderate to High
La Jolla #1[c]	7	5	10.2	>800	0		Moderate to High
Bird Rock Low Use	0	0	0.0		0		None
Bird Rock	3	2	4.1	>30	1		Moderate to Low

[a] One rocky outcropping of several rocky intertidal areas at Crystal Cove was chosen for this study. However, educational use information from managers did not distinguish which outcropping was used by students. Therefore, more emphasis was placed on other observations for the specific rocky shore studied.

[b] Educational use information given for Dana Point and did not distinguish between Dana Point proper, located near the entrance point, from Dana Point Low Use, accessible only by hiking ~1/2 km on boulder rock field. Based on experience of the authors, Dana Point Low Use was given a lower ranking.

[c] La Jolla divided into two sites, it is unclear from the responses which site was visited by each educator response. Based on experience of the authors, sites were both given equal ratings.

schools responded. Aerial and ground surveys were also used to determine the relative popularity of a site for school field trips. In total, 7 school field trips were observed within our sites. To a lesser degree, the estimated level of popularity of sites for educational field trips based on the author's (Smith) 15+ years of experience at these locations was also taken into account when gaps in data existed. For example, at Crystal Cove, numerous schools and students were recorded to have visited this site based on educator responses but Crystal Cove contains multiple rocky intertidal patch habitats and it is unclear whether these recorded school groups visited the particular reef sampled in this study. Here, experience of repeated sampling at this specific reef was taken into account. Given that we were examining the relative ranking of popularity, our subsampling and combination of techniques provided a robust measure of overall popularity of sites in relation to one another. Because of the complexity in the type of data obtained on educational use by schools in the region, we scaled the level of popularity for educational field trips from 0 to 10. The most important characters determining scale was: a) the relative frequency of field trips occurring among the different sampling sites, and b) the number of students and schools that annually visited the sites. For example, sites that received no reports or indications of educational use received a score of 0, while sites that contained a combination of a high frequency of school visitation and a high number of total students received a score of 10.

Local human population was determined using GIS measurements of population densities using 2010 census data estimates within a 2 km radius around the entrance pathways leading down to the rocky intertidal sites. The southern California coastline is heavily populated in most areas, except locations that are not accessible, such as the Camp Pendleton Marine Corps Base, thus sites isolated from urbanization were mostly absent.

The influence of local attractions, such as aquariums, museums, historical monuments, restaurants, surfing or fishing spots, were scaled based on the number and type of different attractions potentially bringing visitors to the rocky intertidal sites. During visits to each site, we determined the presence of eight different categories of attractions placed in ranking order of likelihood (1–8) in attracting the most visitors. In order of most to least likely to attract visitors, we determined whether the site: (8) had educational facilities, aquariums, or historic sites, such as the Ocean Institute and the Cabrillo Aquarium; (7) was next to popular sandy beaches; (6) was adjacent to popular water recreation activities such as diving or surfing spots; (5) was close to large resort hotels or other vacation rentals; (4) was a popular fishing spot; (3) contained picnicking areas, tables and/or fire pits; (2) was near restaurants or locally exclusive dining places adjacent to the site (excluding major fast food restaurant chains); and (1) was close to stores, shops, or malls. When present, each attraction at a site was given a value based on the ranking of the attraction and the total value determined by calculating the sum of all attractions. For example, a site with an educational facility (8), a resort hotel (5), and restaurants (2) was given an attraction value of 15; the highest possible score was a 36.

2.4. Statistical analyses

To determine whether certain site characteristics are influencing the relative intensity of human use that sites receive, we conducted a series of regressions comparing the mean relative use intensity obtained from aerial photographs to the individual site characteristics. A multiple-regression was conducted to determine the most important characteristic influencing intensity of use.

3. Results

3.1. Level of use

The mean instantaneous intensity of human use varied greatly among sites (Table 1) and ranged from zero visitors (multiple sites) to a high of ~28 visitors (White's Point). Although we chose sites to obtain an expected range of levels of use, most sites fell in the 6–12 visitors range. The highest number of visitors found in a single aerial survey was at Heisler Park, with 66 visitors observed. Instantaneous counts were found to correlate well with the total number of visitors over a 2 h low tide period ($R^2 = 0.837$; df 1, 46; $F = 235.8$; p-value < 0.001; Fig. 2), suggesting our methodology of using aerial photography was a good indicator of relative levels of use among sites.

3.2. Site characteristics

Measures or scaled rankings of site characteristics, including the cost and availability of parking, the physical effort in reaching a site, the popularity of a site for educational field trips, the density of human population near the site, and other attractions at the site, varied greatly among sites (Table 1). Parking availability ranged from 1259 total spots at the La Jolla #1 and #2 study areas while Encinitas contained only 41 parking spots. On average, the highest cost per parking spot was found at Crystal Cove State Park where a flat fee of $15 US is required; several sites offered free parking. Physical effort in reaching a site was based on a z-score where zero requires the standardized mean effort, negative numbers indicating easier access, and positive numbers indicating more physical effort is needed. Flat Rock was found to be the most difficult to reach physically with an effort z-score of 3.6 with several other sites in close range of difficulty. Most of these sites contained combinations of long walks up steep cliffs, hikes over difficult to traverse boulder fields, or in the case of Thousand Steps, a steep staircase with 230 steps (often used as an exercise medium). On the other end of the spectrum, sites such as Solana Beach, White's Point, and Royal Palms were physically easiest to reach, where you can drive and park your car <50 m from the intertidal zone. Of the 32 rocky intertidal sites studied, 10 sites were reported to have been visited by school groups/educational programs with an additional three having other data suggesting educational use (Table 3). The site that contained the highest number of educational field trips by schools and programs was Crystal Cove (10 different schools and programs) while the highest number of students were reported at Point

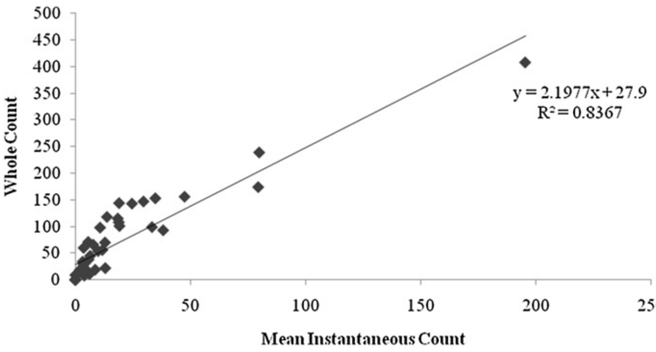

Fig. 2. The relationship between ground survey instantaneous counts and whole counts over a 2-hr low tide period. Instantaneous counts are the mean number of visitors measured during 20 min interval surveys for the 2 h period of low tide ($n = 7$); representative for our mean aerial snap-shot surveys. Whole count is the total number of unique visitors a site received throughout the 2 h period of low tide. Each site was surveyed at least once ($n = 46$). Regression analyses revealed a significant correlation.

Fermin (>120,000 over 1 yr). Using our scaling system, Point Fermin, Dana Point, Little Corona del Mar, and La Jolla were the most popular sites for educational field trips. These sites are spread out geographically and likely used by schools within each region. Using the 2010 census data estimates, the Heisler Park study area in the heart of Laguna Beach contained the highest local human population of 27,607 people in a 2 km radius from the entrance point while Point Vincente, located on the isolated bluffs of Palos Verdes Peninsula contained the least with 8663 people. Since most of southern California's shoreline is heavily urbanized, a majority of population counts fell in the 15,000–23,000 range. Using the local attraction scale of 1–8 based on the eight different categories of attractions, the highest ranking of local attractions were Point Fermin, Point Fermin Low Use, Crystal Cove, La Jolla #1, and La Jolla #2, with a score of 28. These sites contained education facilities (except La Jolla) and are located near popular beaches that attract tourists, residents, and recreational water users, such as divers and surfers. The lowest score was found in Flat Rock, which contained no local attractions, thus receiving a score of 0.

3.3. Relationships of site characteristics and relative intensity of use

A series of regression analyses were conducted using each site characteristic measure/ranking against the relative intensity of use. Parking availability ($R^2 = 0.073$; df 1, 30; $F = 3.427$; p-value $= 0.074$; Fig. 3A) and mean cost per parking spot ($R^2 = 0.077$; df 1, 30; $F = 2.486$; p-value $= 0.125$; Fig. 3B) exhibited weak positive relationships but neither were significant. Physical effort required to reach a site was significantly related ($R^2 = 0.195$; df 1, 30; $F = 8.498$; p-value $= 0.007$; Fig. 3C), indicating that use was higher at sites that more physically easier to reach. In addition, the more popular a site is for use for educational field trips, the higher the relative level of use ($R^2 = 0.341$; df 1, 30; $F = 17.070$; p-value < 0.001; Fig. 3D). The density of local human population had no relationship with use ($R^2 < 0.01$; df 1, 30; $F = 0.823$; p-value $= 0.372$; Fig. 3E), although the most isolated from a high human population had the lowest visitation, while the presence of site attractions increased the level of use ($R^2 = 0.240$; df 1, 30; $F = 10.797$; p-value $= 0.003$; Fig. 3F). A multiple regression was used to determine the most important factors influencing use when all other factors were taken into account. Results indicate (Table 2) that the popularity of a location for educational field trips is the most important factor driving relative visitation levels while the remaining factors were not significant.

4. Discussion

At low tide, rocky intertidal ecosystems attract a large number of visitors as these habitats provide a peak into the natural marine world that is normally inaccessible without specialized equipment and offer a source of food, fish bait, entertainment, and education. Therefore, coastal managers are challenged with balancing open public access to the shore with the protection of rocky intertidal populations that are known to be detrimentally impacted by the activities of these visitors. Numerous experimental studies have documented the detrimental impacts of human activities on intertidal biota (e.g. Schiel and Taylor, 1999; Smith and Murray, 2005; Huff, 2011) with comparisons of flora and fauna at high and low use sites further supporting negative impacts on susceptible populations and alterations of community structure (e.g. Castilla and Bustamante, 1989; Addessi, 1994; Ambrose and Smith, 2005). In southern California, long term changes in macroinvertebrates and seaweeds have long been attributed to human impacts (Dawson, 1959; Littler, 1980), often noted by large declines of conspicuous organisms, such as octopus, abalone, sea stars, sea hares, and mussels, and shifts in seaweed composition from large fleshy seaweeds to more disturbance-tolerant, turf forming seaweeds (Miller and Lawrenz-Miller, 1993; Addessi, 1994; Smith et al., 2006; Smith et al., unpublished data). Current management tools for protecting rocky intertidal habitats rely on Marine Managed Area (MMA) designation of some locations where laws inhibit the collecting of flora and fauna (Murray et al., 1999; Ambrose and Smith, 2005; Smith et al., 2008; California Department of Fish and Game: www.dfg.ca.gov). However, in many cases, these management tools are ineffective as enforcement and compliance are low (Murray et al., 1999; Ambrose and Smith, 2005) and these laws do not protect intertidal population from the negative impacts of trampling, handling, and rock turning (Smith et al., 2008). In addition, several locations are not protected by MMA designations. It is, therefore, imperative that alternative strategies to protect rocks shores be considered.

This study was an attempt to determine whether there are specific site characteristics that influence the intensity of human visitation over a large geographic region with results that potentially could be used by coastal managers to decrease levels of use as an indirect means to decrease the impacts from visitation. Of the site characteristics investigated, the popularity of a site for use by schools and educational programs provided the clearest relationship with relative levels of use, followed by physical effort required in reaching a site and the presence of local attractions. Parking availability, parking cost, and nearby human population density were not related.

Surveys of pre-college schools/districts, colleges, and educational groups reveal that educational field trips are limited to 13 of the 32 sites used in this study with an additional three sites in the study region that were reported to be used but were not on our study site list. Therefore, across ~175 km of shoreline, albeit mostly consisting of sandy beaches with interspersed rocky headlands of an unknown but large number of isolated sites, well over the underreported 130,000 students are funneled into 16 rocky intertidal locations, with a majority of the schools and students visiting six particular sites (Point Fermin, Dana Point, Little Corona del Mar, Crystal Cove, La Jolla, and White Point). While it is clear that the students visiting these sites are influencing the level of use, counts of human visitors during aerial and on-site surveys did not frequently included school groups. This suggests that the educational field trips themselves were not necessarily influencing the relative level of use. We believe that an indirect effect of these educational field trips also plays a role in the relative level of use whereby visitors are more likely to revisit sites that they visited while in school or where their children visited during school trips. In essence, we hypothesize that popular sites for schools groups propagate continued visitation during non-school related visits in the future.

While the authors recognize the importance of education and hands-on learning and, therefore, would not recommend banning field trips, it is clear that school field trips lead to higher levels of use and subsequent detrimental impacts to rocky intertidal flora and fauna. Our study suggests that managers may have the means to help regulate levels of use through regulation of educational field trips, if deemed appropriate. Regulation may be approached in several ways, including continued funneling of a majority of the school groups to a few, specific locations, spreading out school groups across several locations, or creating a carrying capacity which limits the number of school groups and students that can visit a site during a certain time period. These strategies rely on strong communication between schools and managers and, in some regions of southern California, this system is already in place. For example, in Orange County, school groups are required to request permission of managers to visit rocky intertidal

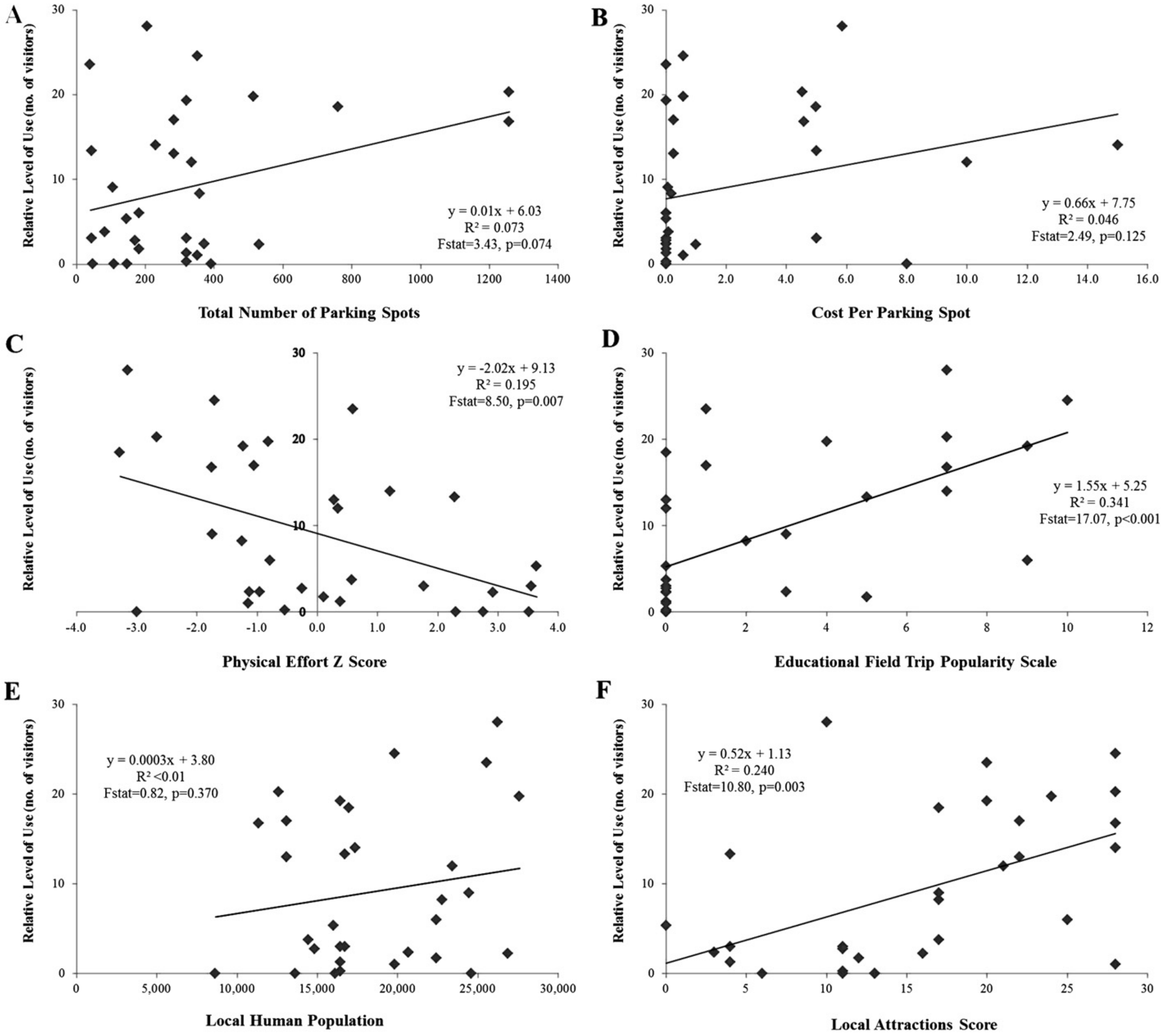

Fig. 3. Regression analyses for 32 rocky intertidal sites of the relative intensity of use and: A) total available parking; B) mean cost per parking spot; C) physical effort *z* score required in reaching (positive values requires more physical effort to reach than the mean – 0); D) popularity for educational field trips (with 10 being the most popular, based on a combination of the number of schools, programs, and students that conducted field trips to the site); E) size of the local human population; and F) local attractions score (eight different categories of local attractions were assessed and ranked from 1 to 8 based on its influence of human visitation with higher scores having more attractions). Reported is the results of the individual regression analyses, including r^2, *F*-stat, and *p*-value (df of all analyses = 1.30).

locations, facilitated by the Orange County Marine Protected Area Council (http://www.ocmarineprotection.org), a consortium of managers, state parks officials, NGOs, consulting firms, universities, and state and county officials. In some rare cases, managers have urged school groups to visit on alternate dates as too many school groups have requested to visit that site on a particular day (Newport Beach manager M. Clemente, pers. comm.). Although this strategy appears to be working at the local county level, a more integrated approach should be considered state-wide. This relies on appointments of marine managers and an enhanced communication system with pre-college and college educational systems.

The first strategy of continued funneling of educational field trips to a few locations leads to a focus of visitation and their detrimental impacts to a few specific sites, allowing other sites to escape a majority of visitation. This strategy also facilitates a system in which docents or educational staff can be strategically placed at these limited number of sites to decrease the impacts of use (such programs are in place in Orange County). Educational staff at these locations communicate verbally with visitors and hand out brochures on environmentally-friendly tidepooling rules. They also monitor the activities of visitors to ensure no egregious activities are taking place and have direct communication with enforcement officers in cases where offensive activities occur. Given the funding limitations of most municipalities, focused education and docent programs on a few specific locations is financially necessary. Education is a key component of rocky intertidal conservation and a funneling of students to a limited number of locations could lead to enriched educational programs that may lead to the long-term preservation of these habitats.

A second strategy could be undertaken whereby sites used for educational field trips are rotated on a periodic basis; for example, schools can be encouraged to visit a few sites in one year and in the following year encouraged to visit other sites, allowing previously heavily visited sites to recover. Although a little less feasible, coastal managers could attempt to distribute school field trips across a larger number of sites, spreading out the impacts so that no one site is particularly damaged by visitors. Given that school groups are likely focused around sites that have easy access for children and at sites where educational programs are in place, spreading out field trips may prove difficult. An additional strategy would be to limit the number of students that can visit a site over a period of time, based on a carrying capacity. In terrestrial systems, monitoring the level and intensity of different types of visitors is common, and recreational usage of parks and other natural systems by visitors has received much attention. Often, parks and other managed terrestrial ecosystems are protected through limitations of types and extent of use. For example, the Visitor Experience and Resource Protection (VERP) framework attempts to balance resource use while reducing impacts by determining the carrying capacity (the point in which the level of human visitation affects the natural and cultural resources) for the ecosystem and limiting the number of visitors below that capacity (Valliere and Manning, 2003). Management of educational field trips among the rocky intertidal ecosystems could follow the terrestrial park carrying capacity framework; however, the carrying capacity for rocky intertidal zones in the region, and worldwide, are unknown with some research suggesting the carrying capacity is quite low (Ambrose and Smith, 2005) whereby a good number of schools and students would be unable to visit any rocky shores.

Physical effort was related with levels of use with a site that is more difficult to access having lower visitation intensity. Physical effort also may be closely related to educational field trips as the sites most heavily used by school groups tend to be physically easy to access; however, this is a complex relationship as there are a number of easily accessible sites that are not used by educational field trips. Given that physical effort can influence visitation intensity, coastal managers may use this knowledge to decrease use at particular sites. It may be feasible that entrance pathways leading down to the rocky intertidal habitats can be reconstructed to make it more difficult for visitors to reach the sites, such as through removal of paved pathways or moving parking a longer distance away from the access point.

The number and type of other attractions adjacent to the rocky intertidal zone is also related to intensity of human visitation. Here, humans may be visiting the location primarily for the non-tidepooling attractions but may wander into the rocky intertidal zone as an unplanned additional exploration, therefore drawing visitors that typically would not visit the intertidal zone. For the cases of hotels or resorts adjacent to tidepool habitats, guests that would not typically visit the intertidal zone may do so because it is available for them at relative ease. Alternatively, visitors may specifically choose locations where there is a combination of both tidepooling adventures and other activities, such as a popular beach or an aquarium. Although not likely feasible to remove attractions, recognition that sites with certain types of attractions leads to higher levels of use could be used as a management tool. For example, hotels, restaurants, and shops could contribute funds or provide services to help protect local rocky intertidal habitats since they are likely drawing a large number of visitors and, potentially, vice versa. Services could be as simple as providing literature to visitors on the environmentally safe ways to explore rocky intertidal habitats. In other cases, as new attractions are established, a system can be set up in which “mitigation” could occur whereby establishments are contributing to protection of rocky shores. This has occurred in the past when the Montage Resort was built adjacent to the Treasure Island rocky intertidal site in Laguna Beach; recognizing that the resort would draw a large number of guests who would venture into the adjacent tidepools, the Montage Resort has provided funding for an educational docent program in which an educator is present on-site during most low tides, as well as some monitoring of the impacts of increased visitation (Laguna Ocean Foundation, J. Rosaler pers. comm.).

Although some patterns emerge when examining site characteristics that influence relative human visitation intensity across a large geographic region, it is also evident that there are a number of sites that do not follow the pattern thus management action should carefully examine the specifics of the site in question. For example, Royal Palms in Palos Verdes is an easy site to access, sharing the same high capacity parking lot as the heavily used White’s Point location, yet has very low levels of use. Furthermore, Crystal Cove State Park is somewhat difficult to access physically yet is a popular site for educational field trips and has moderately high levels of use. Finally, there is a complexity of some of the factors examined that may correlate with each other. For example, educational field trips mostly occur at locations that are easy to access and may explain why physical exertion was not a significant driver in the multiple regression analysis.

5. Conclusions

Rocky intertidal habitats are heavily impacted by the activities of human visitors. Although open access to tidepool habitats is required by the California Coastal Act, we suggest that there are indirect ways to decrease the intensity of use if a particular site is being heavily damaged. Our results suggest that there are certain characteristics of sites, with some of the characteristics intertwined, that could be manipulated by managers to decrease use. The popularity of a site for educational field trips, the physical ease in reaching a site, and the presence of certain types and numbers of additional attractions at a site can lead to a higher intensity of human use. Managers concerned with visitation may consider actions such as controlling the number of educational field trips taking place at their site, increasing the physical difficulty in reaching a site through construction or displacement of nearby parking, and requiring that local establishments (such as resorts or stores) contribute to the protection of rocky intertidal habitats.

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