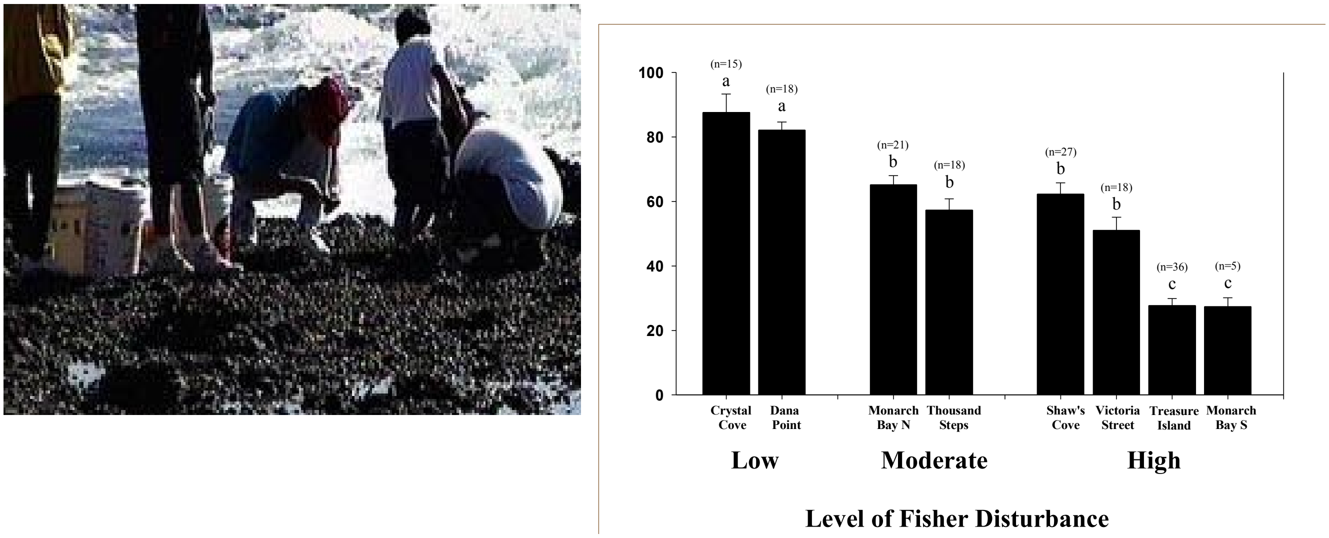
Levels of human use can be extremely high as seen here at Little Corona del Mar

Human Impacts on Rocky Intertidal Shores

In California, rocky shores attract a large number of individuals who frequent the intertidal zone for recreation, education, and for collecting flora and fauna for food, fish bait, or decoration (Smith, 1993; Addessi, 1994; Murray, 1997; Murray et al., 1999; Ambrose and Smith, 2004). Perturbations resulting from human visitation, such as handling, turning over rocks, trampling, and collecting, can deplete floral and faunal populations, reduce biodiversity, and alter trophic and community structures (e.g. Zedler, 1978; McLachlan and Lombard, 1981; Ghazanshahi et al., 1983; Castilla and Bustamente, 1989; Duran and Castilla, 1989; Brosnan and Crumrine, 1994; Smith and Murray, 2005).

Human impacts on rocky intertidal zones have been studied extensively in many parts of the world including Chile (e.g. Moreno et al., 1986; Olivia and Castilla, 1986), Australia (e.g. Kingsford et al., 1991; Keough et al. 1993), New Zealand (e.g. Brown and Taylor, 1999), Africa (e.g. Lasiak and Dye, 1989; Lasiak, 1991), and Costa Rica (Ortega, 1987). A large number of studies have further investigated human impacts in California (e.g. Beuchamp and Gowing, 1982; Smith, 1993; Murray et al., 1999; Engle and Davis, 2003; Tenera, 2003; Ambrose and Smith, 2004; Smith and Murray, 2005; Smith et al., 2008). A majority of these studies have investigated the impacts of human activities, such as trampling or food harvesting, which have been shown to be detrimental to a large number of species including seaweeds (e.g. Bally and Griffiths, 1989; Brosnan et al., 1996; Keough and Quinn, 1998; Schiel and Taylor, 1999), seagrasses (Zedler, 1978; Ambrose and Smith, 2004), barnacles (Zedler, 1978; Ghazanshahi et al., 1983), limpets (Pombo and Escofet, 1996; Kido and Murray, 2003; Roy et al., 2003), sea stars (Ghazanshahi et al., 1983; Ambrose and Smith, 2004), octopuses (Ghazanshahi et al., 1983), snails (Roy et al., 2003), crabs (Murray et al., 1999), and bivalves (Brosnan and Crumrine, 1994; Smith, 2002; Smith and Murray, 2005).



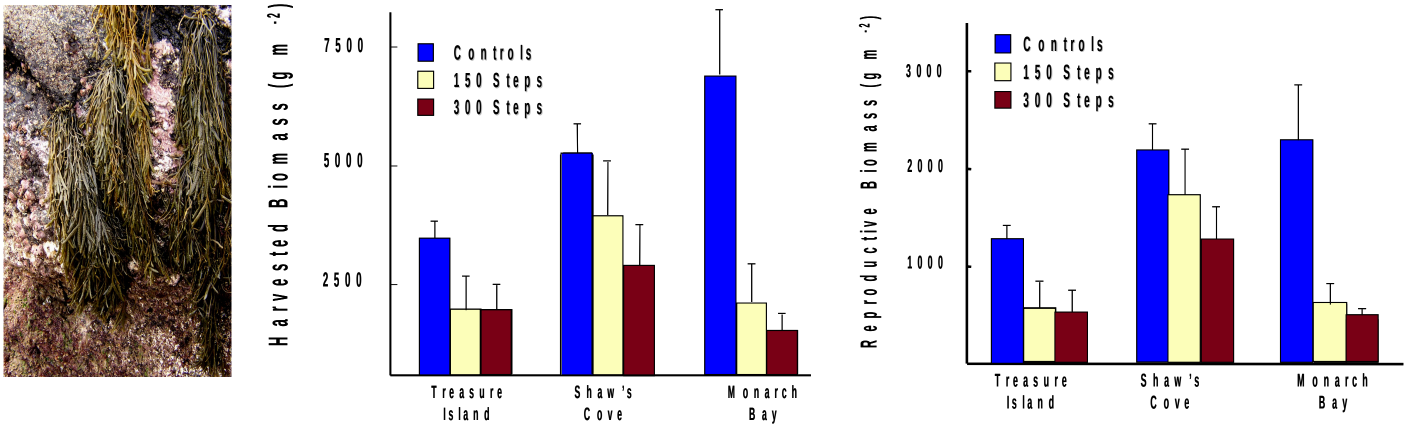
Collection of mussels by fishermen has been shown to greatly reduce mussel cover (Smith 2002)

Until recently, little research has been done to quantify the number of visitors and characterize their activities. However, Ambrose and Smith (2005) found that rocky intertidal sites within Santa Monica Bay were subjected to an alarming number of visitors at high use sites (25,000-50,000 visitors per year per 100 m shoreline). In addition, sites that were considered to have low levels of use were, nonetheless, subjected to a large number of visitors (2,000-10,000 per 100 m shoreline). Many visitors were characterized as being walkers, yet there was a high number of others engaging in destructive activities such as collecting or handling.

Direct Impacts

Trampling. Trampling in the rocky intertidal zone is a common but often unnoticed disturbance. The degree of trampling can be incredibly high at many sites. Some studies have reported a high number of visitors within a small area all of which spend a great deal of time walking on organisms. In fact, “high use” sites have been reported as having from approximately 50 people (Addessi, 1994) to a maximum of 1443 persons (Murray et al, 1999) on a site during a low tide.

There have been several studies aimed at assessing the impacts of trampling on flora and fauna of the rocky intertidal. A majority of these studies have shown deleterious effects. Trampling has been shown to crush or dislodge many species of invertebrates (e.g. Povey and Keough, 1991). Dislodgment often leads to death from exposure, especially with limpets (Zedler, 1978). If trampling does not immediately dislodge organisms, it can weaken attachment strengths making them more susceptible to loss from wave activity. This is especially true in mussel beds. In dense mussel beds, several layers of mussels attach themselves to the rock and to each other making a strong but complex system of intertwining attachment (byssal) threads. Trampling has been shown to weaken the byssal threads resulting in increased susceptibility and loss to wave activity (Smith and Murray 2005). Trampling can cause decreases in seaweeds by dislodging holdfasts from the surface. Even if the holdfast is not dislodged, algae can sustain morphological damage that may have an effect on other physiological or reproductive processes. For instance, trampling on the rockweed *Silvetia compressa* results in damaged frond tips that hold the receptacles for reproduction (Denis 2003). Therefore, the loss of receptacles reduces the plants reproductive ability. Another example of altered physiological process was observed when trampled rockweeds, *Hormosira,* sustained a loss of its vesicles or air bladders (Keough and Quinn, 1998). This ultimately affects how it can compete for sunlight and how the plant withstands heat stress (Schiel and Taylor, 1999).

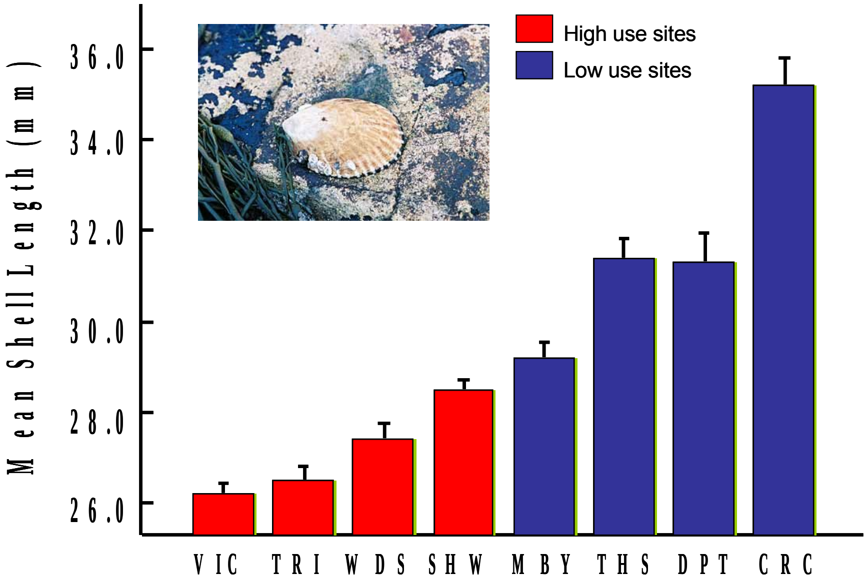


Trampling on rockweeds has been shown to cause declines in (a) biomass and (b) reproductive materials when trampling treatments (150 or 300 steps per month) are applied (Denis 2003)

Extraction. Human exploitation of the rocky intertidal in many parts of the world has been occurring for many 1000s of years (Vedder and Norris, 1963; Speed, 1969; Abbot and Haderlie, 1980; Dillehaye, 1984). Historically, intertidal populations were exploited as a food resource but in modern times, flora and fauna are also collected for fish bait, for research, as souvenirs, and for home aquaria use.

The most common species collected for food are large gastropods such as mussels, limpets, snails, octopi, sea hares, chitons, abalone, echinoderms such as sea stars and sea urchins, crustaceans such as crabs and lobster, tunicates, and kelp (Ghazanshahi et al., 1983; Castilla and Bustamente, 1989; Fairweather, 1991; Addessi, 1994; Murray et al, 1999; Ambrose and Smith 2005). As fish bait, the most commonly collected species are mussels, chitons, octopi, and tunicates as well as a few species of limpets (Addessi, 1994; Murray et al., 1999; Ambrose and Smith 2005).

Extraction of individuals causes direct decreases in abundances and often alters the size structure of the population because humans are know to be 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; Levitan, 1991; Levitan et al., 1992; Tegner et al., 1996).



Collecting can result in decreases in the size of target populations, as humans tend to select larger individuals. Mean size of the owl limpet is markedly smaller at sites in Orange County subjected to high levels of collecting (modified from Kido and Murray, 2003)

Overturning of Rocks. Another disturbance of humans on rocky intertidal ecosystems is the overturning of rocks. Humans pick up boulders and turn them over either in search of food or bait, or just for curiosity to see what is located underneath. This can cause damage by crushing those organisms hidden under the rock, crushing organisms attached to the top of the rock after overturning it, exposing hidden fauna to predation, wave action, and desiccation, and preventing algae from getting sunlight for production by turning the top of the rock face down. Very few studies have examined the impacts of boulder movement. One study looked at the abundance of “monks head rocks” (rocks with only a fringe of organisms on it; none on the top or bottom because of overturning) at sites with high levels of human use and compared them to abundances at low use sites (Addessi, 1994). Significant differences in the number of monks head rocks were found which correlated to the amount of human use.

Indirect Impacts

Trampling and collecting have been repeatedly shown to cause decreases in abundances, damage to morphology, changes in size structures, and/or a decrease in biomass of rocky intertidal species. In addition to these damages, human disturbances also result in indirect effects on other populations. Removal of species can alter habitat provision or disrupt the ecological balance of competitors, predators, and/or food supply.

One indirect effect occurs when habitat-providing organisms are disturbed. The loss of a habitat forming species results in the loss of all species that rely or are associated with that habitat. For example, the California sea mussel, *Mytilus californianus*, dominates many wave-exposed shores of the eastern North Pacific (Ricketts et al., 1968). These mussels form communities that are often made up of a structurally complex matrix of living mussels, shells, sediment, and debris that provide food and shelter for up to 300 associated organisms within a bed (Suchanek, 1979) and 640 species in the region (Kanter, 1979). Brown and Taylor (1999) also showed that decreases in a habitat forming species, in this case coralline algal turf, resulted in additional loss of associated species. Trampled turf resulted in additional declines in gastropods, polychaetes, ostracods, bivalves, and nematodes. These losses are due to decreases in the turf that provide food, trap sand for sand inhabiting species, and provide shelter from desiccation, predation, and wave action.

Another indirect impact of reduced abundances of disturbed species is a change in the community structure. The most dramatic example of this was reported by Duran and Castilla (1989). In this study, the community structure was altered by the exploitation of a large predator, the snail *Concholepas concholepas*. In areas where the predator is harvested, the mid-intertidal is dominated by a monoculture of the mussel *Perumytilus purpuratus*. However, in areas were humans were excluded, the mid-intertidal was dominated by barnacles and macroalgae and was shown to have a higher diversity of primary space users. This change occurs because the snail controls the population of the mussels. With the snails removed, the mussel can dominate and outcompete all other species thus becoming a monoculture. When the snails are present and feeding on the mussels, bare space opens which allow for other species to settle. In a sense, *Conchopelas* is a keystone predator and mediates the community structure of the mid-intertidal in Chile.

Another possible cascading impact of human activity may be the reduction of food sources for other organisms. For example, Kingsford et al. (1991) reported that *Pyura* is an important food source for several large gastropods. Decreases in the food source may eventually lead to decreases in the predator. This is certainly true for many species of predators and even herbivores whose main prey has been reduced due to human activity. Very few studies attempt to examine this.

Management Issues

The multitude of studies around the world that have reported the negative impacts of human use on rocky intertidal shores shows the need for conservation of these ecosystems. The implementation of marine reserves and laws aimed to halt the collection of organisms has been shown to be somewhat successful in some areas but ultimately depends on the enforcement of the laws and compliance by the public. Without enforcement, the protective laws seem to be ineffective (e.g. Murray, 1997, 1999). Even if collecting is stopped through enforcement, the other impacts of human use (trampling, overturning of rocks) still persists. Thus, effective protection of rocky intertidal communities will require an approach that may need to go beyond the singular focus on collecting to reduce the full suite of impacts (Smith et al., 2008).

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