Integrating Law, Science, and Regulation in Public Lands Management: An Application of Policy Science to Manage Impacts from Human Trampling on the Rocky Shore of Olympic National Park, Washington, USA

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DEDICATION

For my father, Marcell (Bud) Benoit, with love, for introducing me to Washington's wilderness when I was a child

1. The Policy Problem

The rate of human population growth in the state of Washington is among the highest in the USA. According to the US Census Bureau, Washington can expect an increase in total population of 45% over the next 30 years (Campbell 1997). Land managers in other regions of the country have found that growth in urban populations leads to an increase in demand for outdoor recreation in outlying areas, and that this recreation can damage natural systems (Liddle 1975). Population growth and subsequent increases in coastal recreational activities have significantly altered intertidal habitats in California (Widdowson 1971, Liddle 1975, Thom and Widdowson 1978, Liddle 1991, Addessi 1994, Murray et al. 1999) and Oregon (Brosnan and Crumrine 1992, 1994).

Scientists and land managers have been studying anthropogenic impacts to intertidal areas for several decades. Studies have focused on the changes to intertidal communities when people overturn boulders or collect organisms (Duran and Castilla 1989, Kingsford et al. 1991, Keough et al. 1993, Addessi 1994, Keough and Quinn 1998, Lasiak 1998), as well as impacts from sewage discharge (Littler and Murray 1975) and human trampling of shorelines (Beauchamp and Gowing 1982, Povey and Keough 1991, Brosnan and Crumrine 1994, Keough and Quinn 1998, Brown and Taylor 1999, Schiel and Taylor 1999). Particular attention is being directed at understanding the effects of trampling because residential developments along coastlines are growing and because increasing numbers of people are visiting coastal areas for recreation (Brosnan and Crumrine 1994). A demand for coastal recreation, and resulting impacts, can be expected to accompany population growth in the state of Washington.

The Pacific Coastal Area (PCA) of Olympic National Park (ONP, or Park) is located on the west coast of the state of Washington, approximately 150 miles west of the city of Seattle. This interface of aquatic and terrestrial habitat supports a diverse range and abundance of species and may be one of the most biologically complex coastlines in the western United States (Dethier 1988). The PCA is bordered on the west by the Olympic Coast National Marine Sanctuary (OCNMS), which contributes to the protection of resources on the coast. The two agencies have overlapping boundaries, and both engage in research and educational activities in the area. The intertidal zone is managed cooperatively by OCNMS and ONP, but the Park has rulemaking authority granted by the State of Washington when the Park became the legal manager of the intertidal lands in 1986. This paper is directed to ONP managers, and only the Park's guiding legislation, laws, and regulations are described in the text.

As the human population of Washington grows, managers of ONP can expect recreational use of its coastal area to increase. To minimize or mitigate impacts, national parks are required to develop policies to manage their resources. ONP is currently revising a general management plan that was developed in 1976, prior to incorporation of the intertidal zone within its boundary. Officials are now faced with the task of developing policies for the intertidal zone without empirical information about how current levels of human activity impact intertidal resources. This thesis project was initiated in the autumn of 2001 to address this information gap, and to apply the results of the scientific investigation and analysis of trampling effects in the ONP intertidal area to the decision making process.

I begin this paper by describing the PCA and its recreational uses, then introduce the theory and methods of policy science used to perform this analysis. I follow with the Park's management problem presented in economic terms, a review the laws and regulations that guide Park management, and the results of my investigation of trampling impacts on intertidal resources. Finally, I present policy goals, criteria for their evaluation, and an evaluation of potential management variables to minimize trampling impacts in the intertidal zone.

1.2. The Study Area and its Uses

1.2.2. Physical Boundaries and Characteristics of the Coastal Area of ONP

The PCA covers approximately 65 linear miles, or 43,000 area-acres, of rocky and sandy intertidal habitat and coastal spruce forest on the Olympic Peninsula of western Washington State (Fig 1.1). It stretches from the Quinault Indian Reservation in the south to the Makah Indian Reservation in the north. The PCA is bounded on the west by extreme low water (~4.5 feet below mean lowest low water [MLLW]), and the eastern boundary meanders through the coastal forest to nearly two miles west of the shore. The geology of the northernmost 50 miles of coastline is dominated by rocky bluffs and headlands, and cobble or gravel beaches. Low-gradient, sandy beaches with sandstone benches dominate the southernmost 15 miles of Park coastline. Visitors to the Olympic coast enjoy a diverse range of recreational activities such as fishing, clamming, beachcombing, nature study, photography, backpacking, wildlife observation and primitive camping.

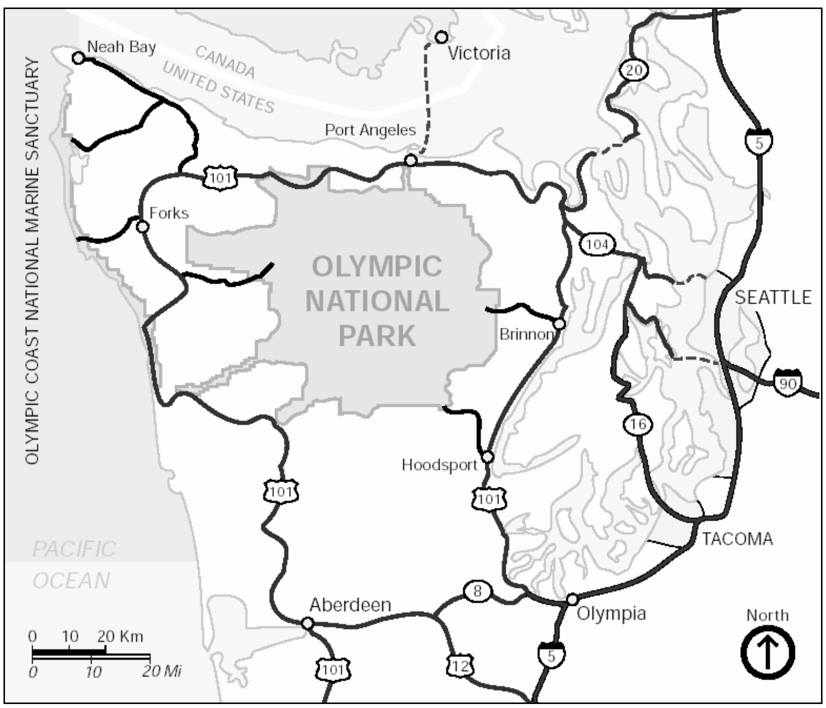

Figure 1.1. The Pacific Coastal Area of Olympic National Park.

1.2.3. Visitor Access to the Park Coastline

A highway next to the coastline and proximity to heavily populated western Washington facilitates public use of the PCA. US highway 101 runs parallel to the southern 15 miles of the coast and visitors are provided ample parking areas within the Park and short, well maintained trails to access this long sandy stretch of beach. Because

US 101 is located on the bluff above the beach and the coastal area is not fenced, people can access the beach without using approved parking areas. This is commonly done during razor clam season in the autumn and spring.

There is a concessionaire at Kalaloch, approximately five miles from the southern Park boundary, that offers lodging accommodations and dining facilities. Interpretive programs, which include ranger-guided interpretive walks in the intertidal zone, are offered daily during the high-use season which lasts from Memorial Day to Labor Day. These walks are offered to visitors at Starfish Point near Kalaloch, and at Hole-in-the-Wall, which is approximately 10 miles north of Kalaloch. There is an ONP-managed campground on a shoreside bluff less than one mile north of Kalaloch that is generally filled to capacity throughout the high-use season. Beach camping is not permitted on the southern coast.

The northernmost 50 miles of coastline, or 36,000 area-acres, are less accessible and appeal to a different sort of recreationist. Visitors park at the north (Ozette Ranger Station), south (Hoh River trailhead) or mid-point (Rialto Beach) of this remote, rocky shoreline and traverse the area by foot. Although there are interpretive programs and campground facilities available in the vicinity of Rialto Beach, recreation on most of the northern coast is comprised of wilderness activities such as backpacking, primitive camping, nature and wildlife observation and photography. Some surfing occurs in the Sand Point area, but this entails a three-mile hike to access the beach. Steep, inaccessible rocky or muddy bluffs and rocky headlands characterize the northern coast. This portion of the PCA is attractive to people wishing to explore one of the few temperate coastal rainforests in the world, seventy percent of which is congressionally designated wilderness.

1.2.4. Extent of Visitor Use of the Coast

I used overnight permit applications from years 1988 to 1997 to determine the extent and location of visitor use on the wilderness coast and the residential origins of backcountry visitors. Visitor Use Nights (VUNs) describe the number of nights one individual camped in the wilderness. VUNs along the coast ranged from 34,644 in 1988 to 41,617 in 1997, with a high of 46,894 in 1996 (ONP 1999). Between 1988 and 1997, coastal overnight use comprised 40-45% of total wilderness camping in the Park; yet, the coastal strip accounts for only 20% of the Park's total wilderness landmass. The majority of wilderness campers came from western Washington (76%). Fifty seven percent of those were from the Puget Sound basin and 11% from the Olympic Peninsula. Eastern Washington residents accounted for 2% of coastal visitors, 19% were from other states and 3% resided in foreign countries.

The majority of visitors to the coastal wilderness in 2001 were residents of the Pacific Northwest region (85%) (Tab. 1.1) Because the PCA has a moderate year-round climate and is relatively close (~150 miles) to the heavily populated Puget Sound basin, urbanites can make the trip in a weekend. Residents of Seattle, Washington, accounted for 30% of the wilderness camping permits submitted in 2001 (ONP 2001a).

Table 1.1. Coastal wilderness camping, by party. 2001 data.

Location	# Parties	% Total
Western Region (WA, OR, ID, MT, BC Canada)	3,624	85
Other US	620	14
Total US	4,244	99
Other Country	33	1
Total	4,277	100

Adapted from ONP VUN data (ONP 2001a)

Participation in guided interpretive walks offered by Park rangers at Starfish Point and Hole-in-the-Wall is variable from year to year. Numbers of seasonal contacts for years 1995-2001 ranged from 1,579-2,665 at Starfish Point, and 1,237-1,827 at Hole-in-the-Wall (ONP 2001b). Walks average two hours in length, and participation varies from two to 45 individuals per tour (ONP 2001b). Both interpretive sites have parking areas nearby that can accommodate several dozen vehicles, which makes these two locations popular day-use destinations. Interpretive rangers have long believed that day-use at Starfish Point and Hole-in-the-Wall greatly exceeds that of participants in intertidal walks (M. Gurling, pers. comm.). On-site observations of use are consistent with this interpretation (personal observation). Another popular access point is Lake Ozette on the northern coast, which is where visitors park to hike to Cape Alava and Sand Point. Although access to these locations requires a three-mile hike, both are popular destinations for day hikers, and the parking area at Lake Ozette is often full during the busy summer tourist season. Both Cape Alava and Sand Point have historically received the highest level of camping of any location on the coast (ONP 1999).

The Park does not routinely collect information about unguided day-use by visitors. However, ONP interpretive rangers made visitor counts at Starfish Point during intertidal tours between July 7 and September 24, 2002, to determine the ratio of tour participants to other visitors and to document the activities of people on the Point (ONP 2002). Rangers found that this ratio was roughly 1.8/1 for 82 hours of observation on 46 days. This count should be viewed as conservative because in some instances rangers conducting the educational program reported that the human density on the beach was too high to gather an accurate count of non-participants. For instance, on a clear, sunny day in July, a ranger conducting a tour with 42 participants reported more than 52 non-participants on the beach: “Tons of people on rocks—scrambling to see an otter in the surf. Too many to count in places.” Additionally, it is important to remember that 82 hours of observation represents a very small portion of the 10-week period in which the survey was conducted.

1.3. Legal Mandates for Park Management

The federal government has managed the terrestrial portion of the PCA since 1953 and the intertidal zone since management was transferred to the Park by the state of Washington in 1986. Under state law, activities such as harvest of some intertidal organisms that were permitted on this portion of the coast prior to acquisition by the Park are still allowed within the Park’s jurisdictional boundaries. The Park may administer more stringent harvest and other restrictions so long as there is credible scientific evidence to show that populations of animals and plants will be damaged or threatened by continued exploitation. The Park may not develop or administer management policies for the coast that are less restrictive than laws that apply to coastal areas under the jurisdiction of the state of Washington.

1.3.2. The Organic, General Authorities, Wilderness, and Redwood Acts

ONP, like other parks in the NPS, was established to "conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (Organic Act of 1916 [16 USC 1]). Provisions in this law were clarified and supplemented by Congress through the enactment of the General Authorities Act of 1970.

Ninety-five percent of ONP was proposed for wilderness designation in 1974, and signed into law by President Reagan on November 16, 1988. This wilderness designation applies to approximately 70% of the PCA north of the Hoh River. The long sandy beaches that comprise the southern 15 miles of coastline are outside the wilderness boundary. Wilderness within the park must be managed according to the Wilderness Act of 1964 (16 USC 1133). Section 4(b) of this law states that "…each agency administering any area designated as wilderness shall be responsible for preserving the wilderness character of the area and shall so administer such area for such other purposes for which it may have been established as also to preserve its wilderness character." Restrictions for wilderness lands include group size limits, exclusion of household pets, and construction of facilities, which are permitted in non-wilderness areas.

The importance of wilderness protection and preservation in the national parks is further emphasized by the Redwoods National Park Expansion Act of 1978 (P.L. 95-250, 92 Stat. 163, as amended, 1978). This law states that park management must be consistent with "the first section of the Act of August 1916" [Organic Act], and that management actions "shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress." The District Court for the District of Columbia in National Rifle Association v. Potter (1978) stated that "In the Organic Act

Congress speaks of but a single purpose, namely conservation…finally, in its 1978 rider to the Redwood National Park Expansion Act, Congress reiterated its intention that the National Park System be administered in the furtherance of the 'purpose' of the Organic Act, that being of course, the conservation of…wildlife resources."

1.3.3. Management Policies 2001

Management Policies 2001 (NPS 2000) is a basic service-wide policy document that provides guidance to park superintendents and managers. It is updated periodically to respond to changes in laws, technologies, knowledge about natural systems, and Interior Department directives. This document replaces and supersedes the 1988 edition. Perhaps most important for the purpose of the present discussion is that Management Policies 2001 defines and describes several common terms used in laws that guide park managers (NPS 2000). For instance, it emphasizes that there is to be no distinction between the meanings of the words, "impairment" and "derogation," which are used interchangeably in the Organic Act and the Redwood amendment to warn the Park Service of what it must avoid. "Impairment" is defined as "an impact so severe that, in the professional judgment of a responsible NPS manager, it would harm the integrity of park resources or values and violate the 1916 NPS Organic Act" (NPS 2000). "Impact" is defined as "the likely effects of an action or proposed action upon specific natural, cultural, or socioeconomic resources. Impacts may be direct, indirect, cumulative, beneficial, or adverse. Severe impacts that harm the integrity of park resources or values are known as "impairments." Park resources and values are defined as:

1) The park's scenery, natural and historic objects, and wildlife, and the processes and conditions that sustain them, including, to the extent present in the park: the ecological, biological, and physical processes that created the park and continue to act upon it; scenic features; natural visibility, both in daytime and at night; natural landscapes; natural soundscapes and smells; water and air resources; soils; geological resources…and native plants and animals.
2) Opportunities to experience enjoyment of the above resources, to the extent that can be done without impairing any of them.
3) The park's role in contributing to the national dignity, the high public value and integrity, and the superlative environmental quality of the national park

system, and the benefit and inspiration provided to the American people by the national park system.
4) Any additional attributes encompassed by the specific values and purposes for which it was established.

Management Policies 2001 also lays out the framework for policy development at individual parks. Managers in each park in the NPS are required to develop a general management plan (GMP) that describes policies and guidelines to address the protection and management of the unique attributes and values specific to their park. These policies will incorporate knowledge about current and expected conditions within the park and must be written in accordance with all applicable laws.

1.3.4. General Management Plan

The GMP will provide direction to the Park's superintendent, as well as division and district managers. Each park GMP is required to include the following (NPS 2000):

1) The types of management actions required for the preservation of park resources.
2) The types and general intensities of development (including visitor circulation and transportation patterns, systems, and modes) associated with public enjoyment and use of the area, including general locations, timing of implementation, and anticipated costs.
3) Visitor carrying capacities, and implementation commitments for all areas of the park.
4) Potential modifications to the external boundaries of the park—if any—and the reasons for the proposed changes.

The GMP being used to guide management decisions at ONP today was developed in 1976, ten years prior to the Park's acquisition of the intertidal zone; thus, there currently are no guidelines specific to the management of the Park's intertidal habitat. Because the terrestrial portion of the coastal strip was incorporated into the Park in 1953, guidelines for management of the forest are well established. One could argue that there is a "spill-over" effect of positive benefits from activities such as ranger patrols, where visitor contacts provide instruction in minimum impact camping techniques and regulations that apply to the Park in general and the coastal forest specifically. Yet, procedures do not take into consideration the present condition of the biological resources of the coastal strip, or the impacts of present levels of human recreational use.

ONP is currently engaged in the GMP revision process. This process has been underway for one year, and a draft document containing potential management alternatives has been released to the public for inspection. It is my intent that the information contained in this paper will be considered by ONP in its development of policies for visitor management of the Park's coastal beaches.

1.3.5. Dual Mandate for Resource Protection and Public Access

NPS enabling legislation clearly places the primary obligation of Park management on protection and preservation of resources. Concurrently, the NPS is mandated to provide public access to the coast for the purpose of recreation. Meeting this dual mandate is a difficult assignment that may require tradeoffs between access and protection. Adequate and complete information about the extent of human use and potential impacts is essential to assessing these tradeoffs.

The Park must develop management plans according to the laws that govern its management in consideration of the resources and values within its jurisdiction (NPS 2000). If high levels of use by the public are jeopardizing intertidal resources the Park must address this use, and it may be necessary to take restrictive action to minimize or mitigate impacts. Such actions may be politically unpopular but necessary to manage Park resources responsibly in accordance with NPS guiding legislation.

2. Policy Science as a Decision-making Tool

Natural resource managers have long grappled with the question of how to develop and implement public policies intelligently, efficiently and effectively. Federal land managers, especially, are scrutinized for their resource management decisions. Policy science, which applies the scientific method to the policy making process, has been used for the last 30 years to substitute the rationality of science with the irrationality of politics and bureaucracy. The process includes the identification of goals to be achieved, formulation and evaluation of alternative management strategies, and the adoption, implementation and evaluation of the optimal strategy (Czech and Krausman 2001).

Weimer and Vining (1999) define policy analysis as “client oriented advice relevant to public decisions and informed by social values.” Policy analysis is more than advice about how a system should be managed or a problem solved. Good policy analysis considers the full range of social and political outcomes that are likely to be the result of adopting strategy A or strategy B over a suite of possible strategies. It has at its foundation a framework for performing a structured analysis of a problem and a systematic method for analyzing constructive alternatives designed to solve the problem at hand (Weimer and Vining 1999). The application of policy analysis begins with the identification of the problem. Intuitively, it seems that alternatives for problem resolution cannot be crafted until the problem to be addressed is thoroughly understood. However, a complex problem is best solved by developing and evaluating alternatives early on, to uncover less obvious aspects of the problem and develop effective alternatives (May 1980).

My application of policy analysis to address visitor management policies for the PCA was guided by Weimer and Vining (1999) and May (1980). I initiated this process under the assumption that the “problem” was twofold (and relatively simple): (1) The Park had no policies in place that were specific to the intertidal zone; this fact placed the Park in violation of National Park Service directives to develop and implement decisions based on current and expected levels of use and impacts, and (2) The Park had no information about how trampling impacts were affecting intertidal resources. Additionally, because the Park is a federal civil service agency, its decisions were likely to be scrutinized and perhaps questioned by the public. Any policies developed for the coast were to be based on credible science and thorough public policy analysis.

I found that it was not enough to merely state the Park's problem without having some means of valuing the products and services provided. I used economic theory to understand the value gained by the visiting public through the consumption of the natural amenities of the Park's intertidal zone. In economic theory, efficiency is defined by the Pareto condition: In order for a market to be Pareto efficient, each individual in a society will maximize his/her utility (pleasure) by consuming a combination of goods and services in such an optimum manner that no other allocation of goods and services could be made that would make one person better off without making another worse off. This definition classically refers to the pricing of goods and services in a fully functional marketplace to produce an equitable distribution for all, without intervention by regulatory authorities. The Park is not a marketplace in the classical sense; but it does provide goods and services to the visiting public, and these services are allocated (or chosen) by this public according to a suite of "signals" that are both monetary and non-monetary in nature.

Signals for consumption of the natural amenities of the Park can be positive or negative. Positive signals, such as environmental quality, outstanding educational programs, beautiful weather, ample and accessible parking areas, and plenty of open space can create a demand for the "consumption" of a recreational experience on the coast (e.g., a walk on the beach, tidepool excursion, participation in a ranger-guided walk, a backpacking trip on the coast, a family beach-side picnic). Alternatively, negative signals, such as poor environmental quality, poor weather, lack of parking or high parking fees, or human congestion can reduce the demand for consumption of a recreational experience on the coast. People will choose an alternative form of recreation or location for their recreational experience if they perceive that the quality of the experience on the ONP coast will be low, or the cost high; if an alternative exists which will allow the consumer (park visitor) to maximize his/her utility (pleasure) while minimizing cost (money, time), the alternative will be selected. This process of relative cost/benefit analysis—weighting one experience over the other, one location over the other—is something we all do, and it's initiated subtly by "signals" produced by nature and by the actions of other Park visitors enjoying the coast.

Pareto efficiency aside, there are issues related to the Park's management problem on the coast that cannot be addressed without some form of intervention. These are, namely, the problems of information asymmetry and uncertainties, and the problem of intertemporal allocation of the recreational experience and environmental quality. Both issues are rooted in a lack of information and confounded by the actions of individuals seeking, rationally, to maximize their individual recreational pleasure on the coast.

2.2. Visitor Use as Market Failure with Negative Externalities

The intertidal area of ONP can be viewed as a regulated open-access public good (Weimer and Vining 1999) managed by the federal government for the American people. No one can be excluded from enjoying the Park unless managers can show that resources are being damaged, or there is a concern for public safety. The intertidal habitat in the Park is unique and rare, and not replaceable in the private market. The Park meets one of its mandates by encouraging visitor use through outdoor education and by providing information about coastal camping and tidepooling. Negative externalities occur when crowding and congestion in the backcountry diminish wilderness values. Negative externalities also occur because visitors, through their experience with the wilderness, trample and damage or kill the plants and animals they have come to enjoy. Both issues are applicable to protecting public resources in the Park.

2.2.3. The Problem of Information Asymmetry and Uncertainties

Impacts to coastal recreational areas by the public are caused, at least indirectly, by the presence of information asymmetry and uncertainties. People who hike on the Olympic coast or explore its many tidepools don't intend to harm intertidal life; they just don't understand the damage created by their actions. Tourists who visit the coast infrequently, or only once, cannot know whether resource conditions have changed through time. Many first-time visitors to the PCA believe the area is pristine (personal observation). Yet, they lack a historical perspective of coastal resource quality. These individuals have insufficient information with which to assess and properly value the quality of their coastal experience. Many think, and have no reason to doubt, that the environmental quality is high; the asymmetry comes into play when they fail to realize how behavior that they don't regard as destructive can degrade coastal resources. It is unlikely that these visitors notice that the plants (here broadly construed to include seaweeds and non-vascular pants such as lichens) and animals they are enjoying are subtly damaged by trampling, or that the abundance and diversity of rocky intertidal wildlife in some areas of the Park coast may have diminished over time due to trampling.

There is equal uncertainty on the part of Park management about the true quality of the marine environment, as the effects of overuse may be subtle or masked by natural variation. Intertidal areas are highly dynamic and patchy, and it is difficult to ascribe any one activity as a causative agent in any particular environmental condition because there are natural and human-caused factors on a global scale that can and do affect intertidal communities (e.g., global climate change, and El Nino Southern Oscillation (ENSO) events that create variable weather patterns). There are limited baseline data for high-use areas on the Olympic coast with which to assess temporal changes in intertidal community structure, and little understanding on what management actions may be able to limit visitor-related damage. Because there are no current or historical data to describe impacts from trampling associated with recreational use of the coast, the Park is uncertain about how to develop and implement management policies. This data and understanding gap leads to management uncertainty.

2.2.4. The Problem of Intertemporal Allocation

Intertidal communities are composed of complex and interdependent assemblages of plants and animals. Many of these organisms are long-lived and do not quickly recolonize an area once removed. For example, the green sea anemone, *Anthopleura xanthigrammica*, is a common inhabitant of the Olympic coastline that grows slowly and is reported to have a life span exceeding 100 years (Kozloff 1990). This soft-bodied animal is easily damaged by human trampling. Mussels (*Mytilus californianus* and *M. trossulus*), which can live 30 years (Kozloff 1990), are easily crushed and removed from rocks by trampling. Experimental trampling research performed by Povey and Keough (1991) revealed that small patches of detached mussels weakened the entire bed, resulting in the removal of many additional mussels by the natural force of wave action; it was many years before this mussel bed reached pre-disturbance density and coverage.

The current level of human trampling associated with recreational activities may generate community instability and degradation that persists through time. Unless management actions are taken to understand and address the effects of trampling on intertidal communities, future generations of Park visitors may not have the same opportunity to enjoy intertidal life that current visitors have. As stewards of the Olympic coastline, responsibility for insuring intergenerational equity in resource allocation rests with ONP.

3. Research on Impacts from Trampling on the ONP Shore

To develop management policies for its coastal beaches managers must determine whether biological resources in highly visited areas have been impacted by human access. In this section I present a scientific study of the effects of human trampling on the intertidal resources of ONP, which I performed during the summer of 2002. I begin by introducing the impacts of human trampling on intertidal biota as described in the scientific literature. I then introduce my study objectives and the methods I used for selecting and sampling sites and analyzing field data. I conclude this section by presenting and discussing the results of my research.

3.2. Direct and Indirect Effects of Trampling

Human trampling can alter intertidal communities both directly and indirectly. Direct impacts include the immediate removal of algae and invertebrates through the crushing and shearing action of footsteps. Indirect impacts include the loss of organisms by wave action when their basal attachments are weakened by foot traffic and changes in assemblages of organisms by habitat removal. Barnacles, mussels, limpets, and foliose algae are susceptible organisms affected by human trampling.

3.3. Experimental Evidence from Other Intertidal Systems

Researchers have found that human tramping in the intertidal zone affects species abundance, diversity and the composition of plant and animal communities (Povey and Keough 1991, Brosnan and Crumrine 1994, Keough and Quinn 1998, Brown and Taylor 1999, Schiel and Taylor 1999, Jenkins et al. 2002). Experimental trampling on San Juan Island, Washington, removed algal cover and fostered growth of crustose algae, which was followed by colonization by grazing limpets (Jenkins et al. 2002). Brosnan and Crumrine (1994) imposed experimental trampling on an algal-barnacle community and a mussel community at two sites along the Oregon coast. Plots were trampled once per month for twelve months. *Fucus* cover decreased from 80% to 35% in one month. Barnacle cover fell from 66% to 7% in four months. Mussel cover fell from 98% to 40% after three months of trampling. Mussels had declined to 50% of pre-trampling cover one year after treatment, and continued to decline for two years after trampling ceased. Crustose algae were unaffected. The turf alga *Endocladia muricata* was unaffected or increased in cover in trampled areas.

In New Zealand, scientists found that the fucoid alga, *Hormosira banksii*, and articulated coralline communities were highly susceptible to damage by trampling (Povey and Keough 1991, Schiel and Taylor 1999). Experimental trampling of *Hormosira* beds by Schiel and Taylor (1999) reduced algal cover by 25% to 90% at 10 and 200 trampling passes, respectively, during a single tide. Povey and Keough (1994) report that *Hormosira* declined 20% to 60% with variable trampling treatments. In one habitat the trampling effect was obscurred by seasonal changes; in the other, short-term algal canopy removal was followed several months later by dramatic change in community structure, with open-space animals dominating the community. Brown and Taylor (1999) discovered that trampling of articulated coralline turf communities in New Zealand reduced macrofaunal organisms by 50% after 5 days of treatment at 150 footsteps per day. Polychaete worms were particularly affected, and populations had not recovered three months after treatment.

3.4. Non-Experimental Evidence from Other Intertidal Systems

Beauchamp and Gowing (1982) evaluated three rocky sites at Natural Bridges State Park near Santa Cruz, California, that receive varying levels of human trampling. They reported high species abundance and diversity in less trampled plots, but no difference in densities of mussels and barnacles or algal diversity. However, the brown alga, *Pelvetiopsis limitata*, and a small bivalve, *Lasaea spp*., were absent at the more trampled site.

Monitoring of open and closed areas at Cabrillo National Monument in California suggest that turf algae communities are affected by trampling (B. Becker, pers. comm.). Intertidal monitoring has been performed at Cabrillo since 1990. Park managers have measured lower percent cover of turf in the open than in the closed area, and qualitative observations show a reduced thickness of the coralline turf in the open area. Thicker mats in the closed area support greater densities of the small snail *Secum californicum*, as well as other small littorine-like snails (B. Becker, pers. comm.).

3.5. Objectives

I examined the effects of human trampling on the shoreline of ONP in order to test the hypothesis that trampling on rocky intertidal benches has caused a detectable change in the abundance and size-frequency distribution of common intertidal species. I predicted that intertidal communities in areas of high visitor use would be dominated by turf algae, barnacle scars (basal plates of *Balanus glandula*), bare space, and small, uniformly-sized plants and invertebrates, and that barnacles (*B. glandula*, *Semibalanus cariosus*, and *Chthamalus dalli*) or mussels (*Mytilus californianus* and *M. trossulus*) and fleshy algae such as *Fucus gardneri*, *Mazzaella spp*. and *Pelvetiopsis limitata* would dominate communities in areas that experience low levels of visitor use.

3.6. Methods

3.6.1. Selection of Study Locations

I sampled the following seven locations, or sites: Starfish Point, Hole-in-the-Wall (2 paired sites), Yellow Banks, Cape Alava, Toleak Point, and Norwegian Memorial. These sites contain rocky platforms and benches near areas of high, moderate, and low levels of visitor use. The first two are used by Park rangers as interpretive sites and are popular day-use areas. The remaining four are within Park wilderness and are popular areas for overnight camping and long day trips. I used two criteria to select these locations: 1) locations must be highly frequented by campers, interpretive staff, and/or day-use visitors, and 2) locations must contain intertidal bedrock habitat. I used overnight permit applications from the Park, and qualitative information from Park rangers to determine areas of high, moderate, and low levels of camping on the wilderness coast.

3.6.2. Selection of Treatment and Reference Sites Within Locations

I performed a paired-site study to determine whether trampling has impacted rocky intertidal communities near popular day-use areas and wilderness campsites.

Studies focused on three zones within the intertidal, representing three different tidal heights: the barnacle-algal zone (barnacles *Balanus glandula*, *Semibalanus cariosus* and *Chthamalus dalli* and dominant fucoids *Fucus gardneri* and *Pelvetiopsis limitata*), protected low-elevation *Fucus gardneri* benches, and wave-exposed mussel-dominated communities (*Mytilus californianus* and *M. trossulus*). The locations are presented in figure 3.1. Habitat types and use levels are listed in table 3.1.

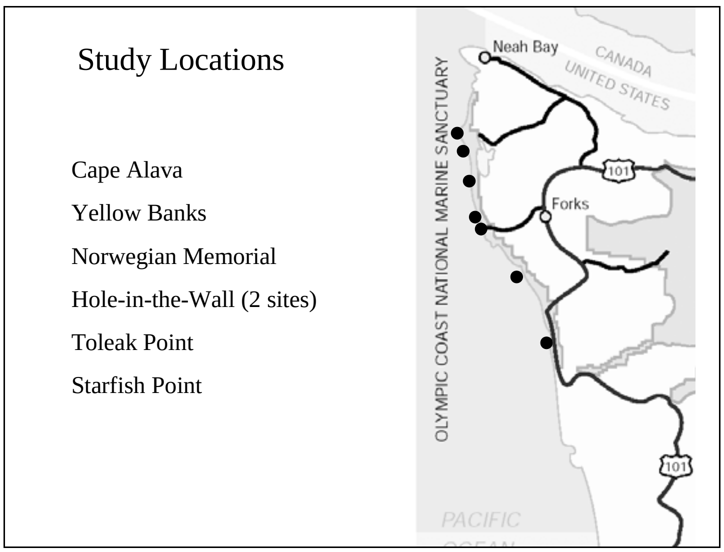

Figure 3.1. Locations of study sites that were identified and sampled on the Olympic coast during the 2002 pilot study. Sites are listed north to south.

Table 3.1. Use level and habitat type of paired sites.

Use Level	Location	Habitat Type
High	Starfish Point	Barnacle
High	Hole-in-the-Wall	Barnacle
High	Hole-in-the-Wall	Mussel
High	Cape Alava	Fucus
Moderate	Yellow Banks	Barnacle
Low	Toleak Point	Barnacle
Low	Norwegian Memorial	Fucus

At each location, water barriers separated reference and treatment areas, such that the least-accessible (LA, or reference) area is surrounded by water (and therefore inaccessible to the public) during all but the lowest tides. Areas that are most accessible (MA, or treatment) can be accessed during most tides until that point when the study transects become totally immersed in water. Pairs were chosen carefully to assure that they were at the same tidal elevation and substrate, and that they receive the same exposure to wave energy and solar radiation.

Numbers and lengths of transects were determined in the field using explicit criteria for delimiting transect boundaries to ensure habitat homogeneity. For example, sampling of the barnacle habitat at Starfish Point was performed above the elevation of sand scouring but below the uppermost limit of barnacles, and the same criteria were used to establish transects at other sites. *Fucus gardneri* platforms at Cape Alava and Norwegian Memorial were selected based on tidal elevation and the presence of a fucoid canopy on sandstone substrate. Treatment and reference sites were chosen for similarity of physical features such as the horizontal slope of the surface, sandstone substratum, and level of wave exposure or protection. I sampled the mussel zone at only one site, Hole-in-the-Wall. As with other sites, treatment and reference sites were chosen for similarity of substrate, exposure and elevation.

3.6.3. Verification of Visitor-Use Levels

I observed of visitor use at all sites but only during times when I was in the area collecting biological data. Visitor counts at Starfish Point were made daily by ONP interpretive rangers during intertidal tours between July 7 and September 24 to determine the ratio of tour participants to non-participants, which they found to be roughly 1.8/1. However, these observations did not distinguish between high- and low-use areas, and observations were performed for a very small portion of the total time that the sites at Starfish Point were above water and able to be accessed by people (1-3 hours of ranger observation per day, for a total of 82 hours of observation in 46 days).

3.6.4. Sampling Methods

I established transects at each MA and LA area independent of any visible footpaths (i.e., not biased for or against dominant foot traffic patterns). I visually assessed habitat homogeneity at MA and LA sites prior to establishing transects using the pre-determined physical criteria of topography, elevation, exposure, presence of pools and crevices, and evidence of scouring. Two 10 m transects were established at each site, and 15 20x20 cm quadrats were placed randomly along each transect. Percent cover of algae and sessile animals, barnacle scars, and bare space, and counts of motile animals were estimated visually. Taxa were identified to the lowest taxonomic level possible, usually to genus or species. I focused on dominant plants and animals, and did not include counts of less obvious organisms such as polychaetes, amphipods, or erect coralline algae. Sampling was not performed in pools, crevices or areas that were inundated with or scoured by sand. To determine size-frequency distributions of barnacles and limpets, I measured the basal diameters of 10 randomly chosen barnacles (*Balanus glandula*) and grazing limpets (*Lottia strigatella and L. digitalis*) to the nearest millimeter using calipers.

3.6.5. Statistical Analyses

I performed statistical analyses using Systat 9.0 and Microsoft Excel 9.0. All quadrats were grouped by trampling level (MA vs. LA) within each site. Percent cover data were log transformed for normality (Log_{10} (x+1)) prior to performing analysis of variance (ANOVA, Ho: $U_{MA}=U_{LA}$, $\alpha=0.05$). Size-class data collected for barnacles (*Balanus glandula*) and limpets (*Lottia strigatella and L. digitalis*) were subjected to ANOVA to determine whether organism size varied with trampling pressure (Ho: $U_{MA}=U_{LA}$, $\alpha=0.05$).

3.7. Results

Results for four functional groups of algae (*Fucus gardneri*, pooled fleshy algae, algal turf and algal crust) did not support my hypotheses. I predicted that treatment areas would show lower cover of *Fucus* and fleshy algae, and greater cover of turf and crustose algae than their reference companions. However, I found these predictions to be true for Cape Alava only, where the MA site had significantly less Fucus (17%) and fleshy algae (10%), and more algal turf (8%) than its LA reference. While results at Cape Alava are consistent with my hypotheses, I did not find similar patterns for algal cover coastwide. Gastropod abundance and limpet size-frequency distributions were highly variable and not significantly different between most LA and MA sites.

I found more bare space in MA than in LA sites at Starfish Point (14%), Cape Alava (15%), and Hole-in-the-Wall (mussel zone) (18%) (Fig. 3.2). Although I found greater cover of bare rock in the MA area at Yellow Banks (6%), this result was only marginally significant (p=0.059).

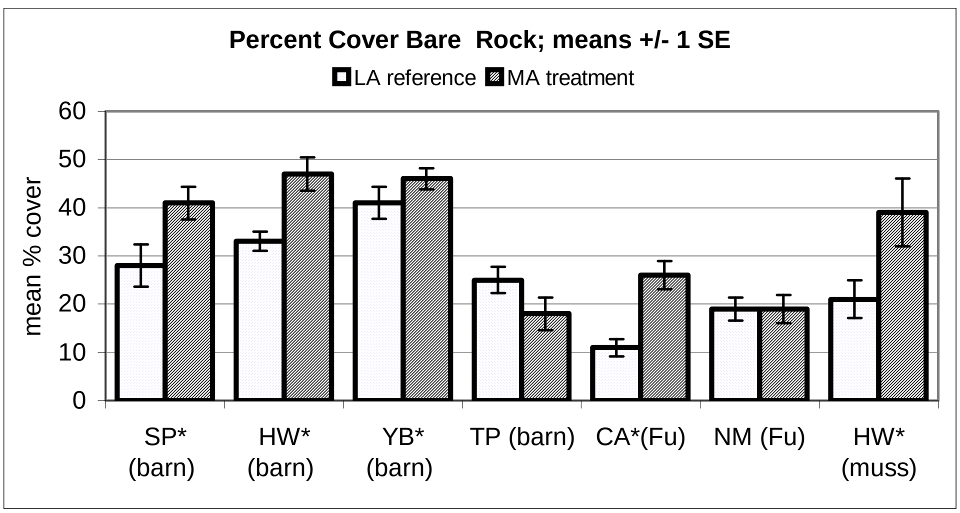

Figure 3.2. Mean percent cover (+/- 1 SE) of bare rock in LA reference and MA treatment sites at all study locations on the ONP coast. Treatment sites show greater percent cover of bare rock than do reference sites at five of the seven study locations. Results of ANOVA, α=0.05; All sites: n=30.

There are three common barnacle species on the Olympic coastline: *Balanus glandula, Semibalanus cariosus,* and *Chthamalus dalli.* Factors that affect barnacle settlement, recruitment and growth include substrate texture and topography (Chiba and Noda 2000), water flow (Crisp 1960Dayton, 1971 #115Leonard, 1998 #144) water temperature (Barnes and Barnes 1965), predation by birds and snails (Connell 1970, Irons 1986, Raimondi 1990), and mortality caused by logs in the surf (Dayton 1971). Barnacle "scars" are the calcareous basal plates that remain on the substrate when the barnacle *B. glandula* is removed from the rock. *B. glandula* is the dominant barnacle species in the upper mid-littoral zone of the Olympic coast, and the only species at Olympic that leaves this basal plate upon removal. *S. cariosus* is similar in appearance to *B. glandula* to the casual observer but it leaves no basal plate. While these two species are often found growing together, *B. glandula* dominates the upper margin of the barnacle zone, and *S. cariosus* dominates the lower (Dayton 1971 and personal observation). The third common barnacle species at Olympic, *C. dalli*, is an inferior competitor for space with the dominant *B. glandula* in the upper mid-littoral zone (Connell 1961). It finds "refuge" at the upper margin of the barnacle zone where its small body size is an effective defense against desiccation (Paine 1981). Barnacles in the upper intertidal are major space holders and high densities can ameliorate the effects of potentially limiting stresses such as desiccation (Bertness and Leonard 1997). On the Olympic coast, *B. glandula* settles in greater densities and grows faster than *C. dalli* (Dayton 1971). Like *S. cariosus*, *C. dalli* leaves no basal plate.

I compared the percent cover of barnacles and barnacle scars at the four study locations in the barnacle zone: Starfish Point, Toleak Point, Hole-in-the-Wall, and Yellow Banks. For living barnacles, I pooled *B. glandula*, *S. cariosus*, and *C. dalli*. I found that barnacle cover was variable among locations with lower total barnacle cover in MA sites at Starfish Point (13%) and Yellow Banks (7%), and higher cover at Hole-in-the-Wall (3%) and Toleak Point (2%). However, differences for the latter two were small, and results were not statistically significant for any of these locations ($p>0.05$) (Fig. 3.3). I found more barnacle scars in MA areas at three of the four paired sites: Starfish Point (10%), Yellow Banks (9%), and Toleak Point (7%) (Fig. 3.4).

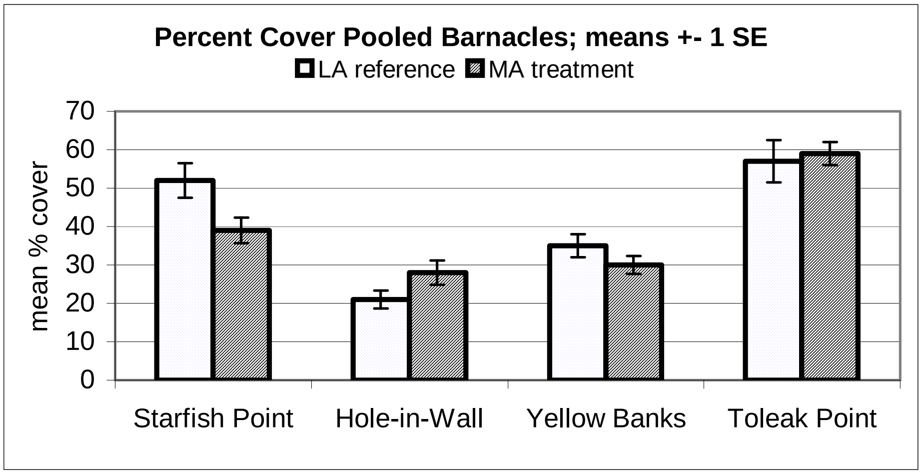

Figure 3.3. Mean percent cover (+/- 1 SE) of pooled barnacle species (*Balanus glandula*, *Semibalanus cariosus*, and *Chthamalus dalli*) in LA reference and MA treatment sites at the four study locations in the upper mid-littoral barnacle zone. Barnacle cover was variable between sites, but results were not statistically significant. Results of ANOVA, α=0.05; All sites: n=30.

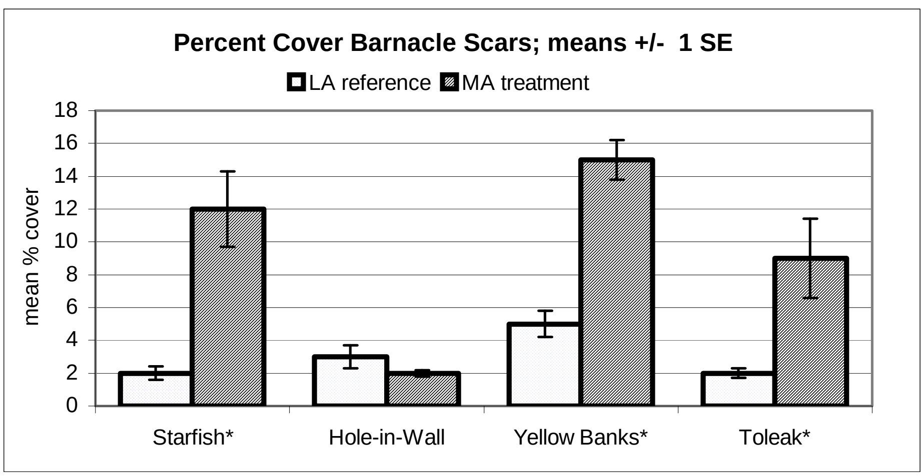

Figure 3.4. Mean percent cover (+/- 1 SE) of barnacle scars (basal plates of *B. glandula*.) in LA reference and MA treatment sites at all four study locations in the upper mid-littoral barnacle zone. I found greater percent cover of barnacle scars in treatment sites at three of the four study locations. Results of ANOVA, α=0.05; All sites: n=30.

I found that barnacles at all MA treatment sites in the barnacle zone were consistently smaller than barnacles in their reference sites ($p<0.05$) (Fig. 3.5). Size-frequency distributions for barnacles in areas that are exposed to trampling pressure are skewed toward smaller individuals; size-frequency distributions of barnacles in reference sites appear to be normally distributed (Fig. 3.6).

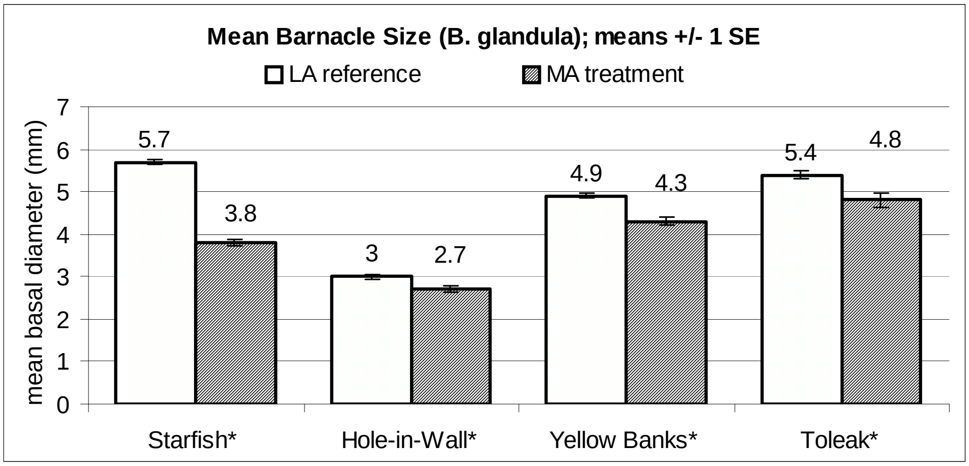

Figure 3.5. Mean basal diameter (+/- 1 SE) of *B. glandula* at reference and treatment sites in all study locations in the barnacle zone. Barnacle sizes were consistently smaller in areas that are more accessible to visitors. Results of ANOVA, α=0.05; All sites: n=150 to 300 measurements per site.

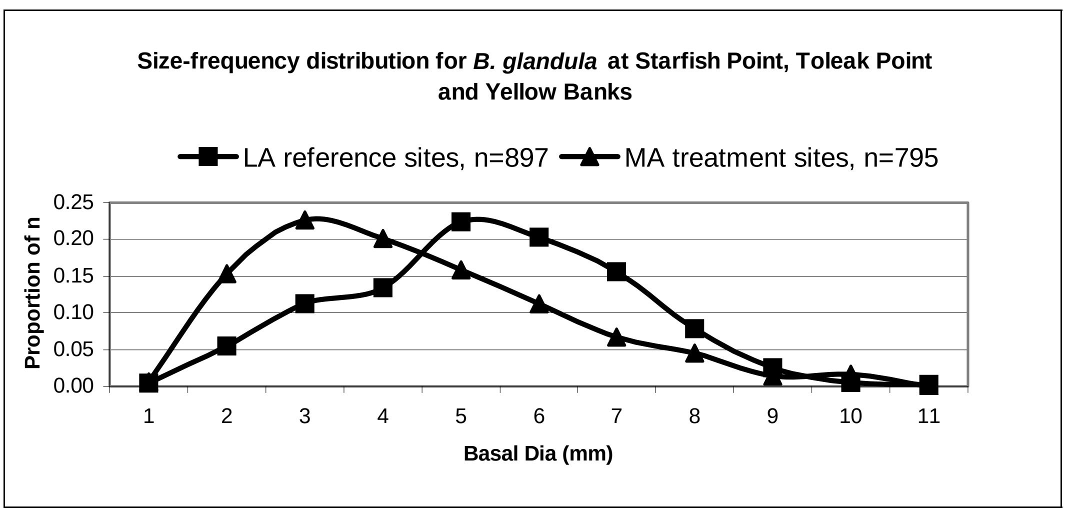

Figure 3.6. Size-frequency distribution for *Balanus glandula* pooled across locations (Starfish Point, Toleak Point and Yellow Banks). Hole-in-the-Wall was omitted from the graph because *B. glandula* is not the dominant barnacle at this location.

3.8. Discussion

Researchers previously have found that human trampling negatively impacts intertidal communities. Impacts are manifest in replacement of barnacles and mussels by trample-resistant “weedy” algal species on the Oregon coast (Brosnan 1993, Brosnan and Crumrine 1994), reductions in the natural abundance of invertebrates such as snails, limpets and worms on the coast of New Zealand (Brown and Taylor 1999), and a general reduction in species abundance and diversity on the California coast (Beauchamp and Gowing 1982). My results suggest that human visitation, and presumed associated trampling in the intertidal zone of the Olympic coast, has produced a detectable biological signal.

In a coastwide comparison of paired sites that differ in accessibility I found differences in algal abundance to be highly variable. Based on studies conducted by other researchers I predicted that most-accessible (MA, or treatment) sites would show a lower percent cover of fleshy algae and a higher percent cover of encrusting algae than their least-accessible (LA) reference sites. However, results for fucoids and encrusting algae were either inconsistent with these predictions, not statistically significant, or the differences were small regardless of their significance. I attribute these results to variation in the distribution of algal cover associated with intertidal zonation. Significant differences in percent cover of fleshy algae and *Fucus gardneri* in the mid-littoral *Fucus* zone were detected at Cape Alava, but not in any of the four upper-littoral sites located in the barnacle zone. I sampled the mid-littoral *Fucus* zone at only two paired sites: Cape Alava and Norwegian Memorial. I found no differences in cover of fleshy and fucoid algae between the MA and LA sites at Norwegian Memorial. Although both locations are popular camping areas, Park data show that campers visit Cape Alava more frequently than Norwegian Memorial (ONP 1999), possibly because it is located closer to visitor parking. Norwegian Memorial can be accessed via an unmarked way-trail, so day-use is possible. However, there are three factors that make Norwegian Memorial a less-visited day-use area: 1) the trail is not advertised or shown on maps, 2) visitors must navigate several miles of primitive logging roads through private forest lands to reach the unmarked trail, and 3) parking is severely limited at the unmarked access trail. It is therefore reasonable to assume that Norwegian Memorial experiences less day-use than Cape Alava.

Although Brosnan and Crumrine (1992) report that the presence of “weedy” turf algae is a signal of trampling pressure on the coast of Oregon, I found very little turf algae (*Endocladia muricata*, *Cladophora columbiana*) at any of the study locations. The only significant differences between MA and LA sites were observed at Cape Alava, Norwegian Memorial, and Toleak Point. This is likely due to differences in the algal communities between Washington and Oregon. On the Olympic coast *Cladophora columbiana* is commonly found in moist, low-lying areas, whereas *Endocladia muricata* grows in areas that are drier and highly sand-scoured (personal observation). Consequently, I found *Cladophora* to be the dominant species of turf alga at both Cape Alava and Norwegian Memorial, and in both locations I found more *Cladophora* in the MA sites. *Endocladia* was the dominant turf alga at Toleak, and I found more *Endocladia* in the MA site at this upper mid-littoral paired-site. While these results are consistent with my hypotheses and the results of researchers in Oregon, they do not hold for the entire coast. Similarly, results for encrusting algae (*Hildenbrandia spp*., *Petrocelis spp*., *Verrucaria spp*., other unknown crusts) were not consistent with my hypotheses or the work of other researchers.

I initially predicted that MA sites would have a greater abundance of grazing gastropods than their LA counterparts, but I did not find limpets to be significantly more abundant in the MA sites coastwide. I predicted that areas subjected to trampling would be cleared of canopy-forming algae and exhibit a growth of encrusting algae that would support grazing gastropods. I now believe that this hypothesis was too simplistic because it weighted food availability higher than direct mortality caused by recurrent human trampling. Limpets prefer areas of low algal cover (which theoretically corresponds with MA areas), but they may experience a higher rate of mortality from human trampling in these sites. In such a case, one would expect to see lower limpet densities in MA sites, particularly where human visitation is high. Yet, the only location in which limpets were more abundant in the MA site was at the highly-visited Starfish Point. My limpet hypothesis was guided in part by research performed by Keough and Quinn (1998) in which they observed that large limpets were less likely to be crushed by human trampling than small limpets, and that limpet densities in trampled areas increased when trampling ceased. However, many limpets in the southern hemisphere are larger and morphologically more robust than those on the Olympic coast. Additionally, this study measured the impacts and recovery of plots that were experimentally trampled repeatedly for only six summers. It is likely that people have visited my study locations every year for unknown decades. Still, my measurements of the limpets *Lottia strigatella* and *L. digitalis* reveal that these animals are largest in the MA sites of the Starfish Point, Norwegian Memorial and Yellow Banks locations. There were too few limpets at Toleak Point and Cape Alava to gather a meaningful sample, and limpets were smaller at the MA sites of both the barnacle and mussel paired sites at Hole-in-the-Wall. For these reasons, I cannon draw conclusions regarding the impacts of trampling on limpet densities and size-distributions on the Olympic coast.

I found littorine densities to be higher in the MA areas of three of the four paired-sites in the barnacle zone, although differences for Starfish Point were not statistically significant ($p=0.418$). This finding could be the result of my enhanced ability to detect littorines in areas where there was more bare space. However, I found littorines to be less abundant in the treatment than in the reference site at Yellow Banks. Exposure to wave energy may account for differences within and among sites, with littorine densities being higher in areas that are less exposed. I observed that Yellow Banks and Starfish Point are highly exposed to waves and that Hole-in-the-Wall and Toleak Point are protected by offshore rocks. Unlike limpets, littorine snails are easily dislodged from the substrate (personal observation), and one can reasonably assume that populations are less prone to disturbance in more protected areas of the coast.

I am uncertain about the effect of visitor traffic on barnacle cover, but I believe further investigation is warranted. Consistent with my hypothesis, I found lower barnacle cover at the MA sites at Starfish Point and Yellow Banks. However, percent cover of barnacles was higher but not significant (p>0.05) in the MA sites at Hole-in-the-Wall (both mussel and barnacle zones) and Toleak Point. I believe there may be species-specific differences in barnacle cover between sites. While my methods for determining barnacle cover included taxonomic identification to species, I had difficulty distinguishing between *B. glandula*, *S. cariosus* and *C. dalli* when individuals are smaller than 2 mm, as were many of the barnacles in my study quadrats during the months of June and July when this research was performed. Future efforts to study trampling on the ONP coast should identify barnacles to the species level, and should be performed at the end of the tourist season when barnacles that settle and recruit in the spring have matured.

I found that barnacle scars dominate MA sites in the barnacle zone at Olympic. I found greater cover of scars in MA sites at Starfish Point, Toleak Point, and Yellow Banks. Conversely, I found fewer scars in the treatment site at Hole-in-the-Wall. *S. cariosus* is the most dominant barnacle in the middle intertidal zone, and the barnacle zone at Hole-in-the-Wall is lower in elevation (6.0 ft. below MLLW) than the other three sites (7.0+ ft. above MLLW). Because *S. cariosus* was more common than *B. glandula* at Hole-in-the-Wall, and *S. cariosus* does not leave a scar when removed from the substrate, there were fewer barnacle scars in the MA site in this location.

Previous researchers have shown that rocky substrate exposed to human trampling is cleared of biota and dominated by bare space (Brosnan and Crumrine 1992, 1994, Schiel and Taylor 1999). With the exception of Toleak Point and Norwegian Memorial, MA sites across the coast in all three biological zones that I sampled exhibited more bare space than their LA reference sites. Areas determined to have high levels of visitation (Hole-in-the-Wall mussel and barnacle sites, Starfish Point, and Cape Alava) showed large, significant differences in bare space. Results for Yellow Banks, which experiences moderate levels of visitation, were marginally significant (p=0.059). Because Toleak Point and Norwegian Memorial experience low levels of visitation, bare space did not dominate the substrate in MA areas at these sites. Results for amount of bare space are consistently significant in areas of high visitation.

Barnacles on the Olympic coast settle and grow as solitary individuals (such as those that I measured) or in closely packed groups that display morphological modifications at high densities. Barnacles that are space limited often settle and grow on other barnacles, or in a columnar fashion in densely packed groups, called hummocks, where individuals can be 4-10 times as tall as they are wide (Bertness et al. 1998). This pattern of growth is the result of high settlement and recruitment, favorable environmental conditions, and substantial availability of food. Barnacles in hummocks minimize skeletal support costs because close neighbors provide support; this enhances the growth rate of individuals, which can lead to greater reproductive output (Bertness et al. 1998). Because large organisms are subjected to greater shear stress than small organisms in high wave-energy environments (Denny 1988), the strength of the barnacle basal attachment is crucial to its survival. Crowding in barnacles, therefore, represents a tradeoff between enhanced growth leading to higher fecundity and susceptibility to dislodgement.

Although *B. glandula* at my four study locations did not display hummock growth patterns, I did observe this phenomenon at Brown’s Point on the south coast, which was not a part of this study. Other sites displayed barnacles growing closely together, but packing was not tight and growth patterns did not produce hummocks. This suggests that either recruitment was lower at my study locations than at Brown’s Point, food was limited, or recruitment and growth were limited by disturbance. Barnacles growing in hummocks have thin wall plates and are easily crushed and dislodged by trampling (personal observation). For this reason, high visitation and associated trampling in some locations on the Olympic coast will preclude the development of barnacle hummocks, regardless of recruitment densities and food availability.

Because barnacles at my paired sites were growing almost exclusively as solitary individuals or in loosely aggregated groups, I was able to measure the basal diameters of *B. glandula* to determine if barnacle sizes varied by accessibility. This procedure revealed that barnacles were significantly smaller in MA sites located in the barnacle zone. This finding suggests that barnacles on the Olympic coast grow larger in the absence of human trampling pressure. Consequently, barnacle fecundity may be greater in areas that are less trampled.

3.9. Concluding Comments on Impacts

My analysis shows that the most highly visited locations on the coast have a higher percent cover of bare rock, more barnacle scars, and smaller barnacles in areas that are accessible to foot traffic, and that these biological signals are greatest in areas that receive the highest levels of visitation. For instance, the cover of fleshy algae was lower and bare space higher in the accessible area at Cape Alava, but there was little difference in alga cover and bare space in a comparison of accessible and inaccessible sites at the less-visited Norwegian Memorial. I found similar results for locations in the barnacle zone that receive varying levels of human visitation.

With the exception of the popular Cape Alava location, I observed the greatest number of detectable biological signals of trampling pressure in the upper mid-littoral barnacle zone. I've observed that most people who visit the coast prefer to walk in the upper intertidal zone, which is exposed for much of the day during the summer visitor season. Barnacles make good footing; they're much easier and safer to walk on than rockweed or crustose algae. Barnacles are not harvested on the Olympic coast, and if left undisturbed can live and grow for more than one summer season. This means that they can achieve a reasonably large size (up to 15mm in diameter for *B. glandula*) if left undisturbed. Accessible areas in the barnacle zone showed significantly more bare space, more barnacle scars and smaller barnacles than their inaccessible counterparts. Consistent with results for Cape Alava and Norwegian Memorial, differences between MA and LA areas in the barnacle zone were greatest in locations that I assumed to be more frequently visited.

It should be noted that there are several factors that could affect intertidal community structure that were not measured or monitored during this study. The research was performed during an El Nino year, which could alter water temperatures and weather on the Olympic coast. Such factors could affect the rates of invertebrate or algal recruitment, intertidal community structure and rates of predation, competition, and mortality. Although my sampling scheme did not measure any of these potentially confounding effects, the paired site design of the study should have compensated for variation due to interannual effects, if these effects are constant within sites and across the entire study area. While I did not document visitor use at study locations during the summer of 2002, I am confident that my visitor-use assessments are accurate. I used several criteria to assess the level of use at study sites: 1) ONP camping permit data; 2) proximity to parking areas; 3) use by ONP interpretive rangers; and 4) personal knowledge about the coastline and visitor activities, which I acquired during five years of employment as a coastal field biologist with the Park. Observations of visitor use were performed haphazardly, but my site selection was based on the criteria of water barriers that limit access. I therefore feel confident that reference sites are unvisited, or visited less frequently, than treatment sites.

4. An Application of Policy Science

In this chapter I present Park management goals, evaluative criteria, and management alternatives, or key policy variables, to be manipulated to address trampling impacts to intertidal resources. I first define these terms and describe methods for their development, then follow with an evaluation of the usefulness of the variables. I do not recommend a management strategy for the coastline, but leave strategy development to the Park. A complete description of definitions and methods can be found in Weimer and Vining (1999) and May (1980).

Policy goals, criteria for their evaluation, and alternatives, or variables, provide the analytical structure of a policy analysis. Policy goals are normative statements that reflect human values. Alternatives are tools used to achieve a goal. Goals and alternatives are easily confused, because the former are often erroneously stated with concrete means for their achievement (Weimer and Vining 1999). Goals are best stated broadly, because a goal described in detail offers no means for its evaluation. Criteria are the means used to evaluate goals. The establishment of criteria represents the first step to analyze competing management strategies designed to achieve policy goals. Yet criteria are not to be so specific that they offer quantitative means for evaluating strategies; rather, they are qualitative statements used to assess progress toward the achievement of a specific goal (Weimer and Vining 1999).

Policy variables are concrete actions that can be manipulated to address a management problem. The development of key policy variables that can be feasibly manipulated to achieve management goals is aided by an intimate knowledge of what can, and should, be done to solve the problem at hand (May 1980). It’s unlikely that any one variable will be sufficient to solve all dimensions of a management problem; it is therefore necessary to combine variables into a feasible strategy. Thus, strategies are combinations, or suites, of key policy variables “that address enough of the salient dimensions of a problem to make it of little concern” (May 1980).

4.2. Policy Goals and Criteria for their Evaluation

Based on the Park's legal mandates I have identified four primary goals for coastline management: 1) resource protection, 2) public access, 3) equitable distribution of Park resources, and 4) administrative feasibility. Each is described in more detail below.

Resource protection. The coastal lands in question are managed by the federal government in the public trust, and a review of the laws that guide Park management reveal that the first obligation of the Park is to preserve and protect its resources. Congress has clearly stated that to comply with the law, Park managers must protect resources from "impairment," which is defined as an impact so severe that it would affect park resources and values. "Resources and values" are defined, broadly, as the Park's natural and cultural resources and ecological and ecosystem processes, and the opportunity for the American public to enjoy them. An important distinction to make when evaluating the relative merit of a policy for the coastline is whether or not the lands in question have been designated wilderness. Standards for environmental quality in wilderness lands are higher than those for non-wilderness lands. Additionally, it is important to consider whether impacts are localized or broadly distributed, and whether localized impacts constitute an impairment of coastal resources in their entirety.

Congress and NPS directives clearly state that impacts which create impairment are to be left to the "professional judgement" of the NPS manager (NPS 2000). A primary policy goal, then, should be resource preservation in all its intended meanings. Although I make no determination of impairment, my research suggests that some rocky intertidal areas in the Park are impacted by use, and I have based my evaluation of resource preservation on these results. Primary criteria for measuring progress toward the goal of resource preservation are the ability to 1) address the most significant uncertainties about impacts, 2) minimize further impacts to intertidal areas in order to prevent impairment, and 3) preserve the wilderness nature of the coast.

Public access. ONP has an obligation to make the Park available to the public for recreation. The law states, however, that this use by the public shall be encouraged and allowed so long as resources will be “left unimpaired for the enjoyment of future generations” (Organic Act of 1916). Therefore, a secondary goal should be to provide public access, but only to the extent that Park resources and values are not being impaired. The primary criterion for measuring progress toward this goal is accommodation of the current types and levels of use on the coastline.

Equity. The Park is mandated to make resources available to all people, regardless of income or status. Under current management policies there are few restrictions on visitors. Fees are low or non-existent, and there are no permanent area closures to prevent the public from accessing any portion of the coastline (temporary closures are occasionally made for reasons of safety). However, the law specifically states that Park resources shall be left “unimpaired” for future generations of Americans, which means that the Park must consider how the quality of the coastal environment is likely to change given predictions for population growth in the state and increased demands for coastal recreation. Equitable distribution of the coastal recreational experience and environmental quality should be a policy goal. The criteria of 1) fairness to current users, and 2) fairness to future users, will be used to evaluate progress toward this goal.

Administrative feasibility. Finally, a policy must be administratively feasible to be effective in achieving intended benefits. If the Park chooses to change management policies for the coastal area, funding may be needed to support these changes. Additionally, the public may view management changes as unfair or unwarranted. For these reasons administrative feasibility should be a policy goal. The criteria of 1) public acceptance, 2) ease of enforcement, and 3) affordability, will be used to evaluate progress toward this goal.

4.3. Evaluation of the Current Management Policy

Preservation. Under the current policy, intertidal communities at the most visited locations of the Park (Cape Alava, Starfish Point and Hole-in-the-wall) show signs of damage from foot traffic. Starfish Point and Hole-in-the-Wall are interpretive sites used for resource education, but are also located near parking areas that accommodate several dozen vehicles each. Cape Alava is located within the wilderness boundary. Intertidal life at Yellow Banks also shows signs of impacts from trampling. While Yellow Banks does not experience the volume of campers that Cape Alava and other popular locations on the coast do, the area I sampled was a portion of the headland that provides access to passing hikers; it is the most obvious location for passage, and the only place where passage can be made during most tidal elevations. Accessible sites at these locations showed more cover of bare rock, more barnacle scars, and smaller barnacles than their less accessible reference sites. The intertidal habitats at Toleak Point and Norwegian Memorial were the least impacted of the seven study locations I examined on the coast during the 2002 season. Both are backcountry camping destinations but the volume of use is much less than at Cape Alava or Hole-in-the-Wall.

The current policy does not offer protection to intertidal resources in the most-visited portions of the coast. It is important to note that there is some level of uncertainty associated with these results. First, power analyses were not performed, so I cannot estimate the likelihood of Type II error in my analysis. Also, there may have been natural and human-caused factors that affected the results but were not measured. Further, this analysis includes seven locations on 65 miles of coastline; a more robust design would include more study locations and would confer greater power for statistical inference across the entire coast. While I cannot say definitively whether rocky intertidal areas have or have not been “impaired” by trampling, they have indeed been impacted, and these impacts vary directly with human visitation.

Access. The current Park policy places few restrictions on access. These are in the form of camping quotas on the north coast, implemented via a permit system, and temporary closures imposed for visitor safety. Hikers and campers who are able to make advance reservations and pay backcountry camping and parking fees can access this portion of the coast. Camping on the remaining wilderness coast is available to those who can afford nominal camping fees. There are no restrictions on day-use access in the Park. However, due to the dynamic nature of the coastline and the infeasibility of building permanent structures in the intertidal zone, wheelchair-bound persons cannot access rocky intertidal areas in the Park. Under the current policy, managers can expect that the use of the coast for wilderness camping and beachcombing will increase.

Equity. My study shows that trampling in high-use areas of the Park coastline has impacted intertidal resources. The impacts of trampling do not constitute a permanent condition—impacted areas could recover if human trampling were stopped. Studies show that recovery in areas that are repeatedly trampled can take 1-2 years for barnacles and algae (Povey and Keough 1991, Schiel and Taylor 1999) to several years for mussel beds (Brosnan and Crumrine 1994). However, the extent of recovery can be uncertain, and areas that are severely denuded can take many more years to recover. For the most accessible and highly visited locations on the coast, such as Starfish Point, Hole-in-the-Wall, and Cape Alava, neither current nor future visitors are able to enjoy untrampled intertidal resources under the current policy. If visitor use of the coastline increases with population growth, as is projected, managers can expect that these areas will be further impacted. My research suggests that rocky areas in the remote wilderness are less affected by trampling than areas that are not located in the wilderness. With the exception of Cape Alava, the current policy does an adequate job of protecting intertidal resources in the wilderness. It also does an adequate job of making resources available to current visitors to these popular non-wilderness areas, but it is questionable whether these visitors are having the highest quality experience at non-wilderness locations.

Administrative feasibility. Current management policies for the coast are well established and historically have presented few obstacles to implementation. In recent years, however, the Park has suffered from budget cuts, resulting in a diminished staff of full- and part-time employees. Future funding for visitor contact positions in both the Ranger and Education Divisions is uncertain. For these reasons, administrative feasibility of the current policy is marginally adequate. In the current season, for instance, coastal ranger district offices at Mora and Kalaloch are understaffed and relying on assistance from Student Conservation Association (SCA) volunteers.

4.4. Proposed Key Policy Variables

The key policy variables I propose for manipulation include trail markers, user-fees, quotas, closures, and education; these variables were analyzed under differing levels of manipulation. I selected these variables based on examples presented in the literature, communications with managers and scientists in other parks and recreation areas, and on personal knowledge about the Olympic coastline and its uses by the visiting public. In Table 4.1, I present ways in which the Park might consider applying these variables in their management strategy to address the impacts of visitor-related tramping. In this matrix I make few specific numeric prescriptions for the manipulation of variables. For instance, in the case of user fees I propose only that the Park consider raising fees or assessing fees at more locations. I propose that quotas be established that are more restrictive than those that are currently in place, and that the Park consider establishing a "no access" zone on the middle coast. In tables 4.2 to 4.6 I evaluate these five key policy variables by listing the variables on one axis and the policy goals and criteria on the other. I use these matrices to compare and contrast ranges of manipulation of variables in terms of their ability to meet management goals.

Table 4.1. Potential range of manipulation of policy variables. Evaluation of these variables is presented in tables 4.2 through 4.6.

Policy Variable	**Range of Manipulation**		
	Limited (current policy)	**Moderate**	**Intensive**
Trail Markers and Signage	No markers	Signs direct BC hikers to unmarked paths; educators direct visitor movements on-site; signs at trailheads and headlands	Bolts and flags mark BC and interpretive area trails and users urged to stay on trails at all times
User Fees	Camping $2/pers/nt + reg. of $5/grp/nt; limit $50/6/wk and $100/12/2wks; Ozette parking $2/car/d	Modest increase in BC camping, registration and Ozette parking fees; use fees to augment education/enforcement programs	Further increase fees; charge parking fee at Rialto and Oil City; continue directing fees to education and enforcement
Quotas	BC group limit 12/site/nt; use-quota for Ozette backcountry only	Apply quotas to all BC camping; limit tidal walks to half of maximum current participation (~25?)	Reduce BC party sizes and camping quotas; further reduce limit on tidal walk participation and enforce rules against informal hangers on (~15?)
Closures	No closures except for visitor safety	Closures in frontcountry, manipulative "adaptive management" experiments	Establish "no access" area(s) on middle, northern coast
Education	No policy to emphasize user impacts	Tidal walks include "impacts" education; develop brochures to educate people of unintended effects of human activity	Same as moderate, but develop NPS community outreach, particularly locally and regionally; use print media

BC=backcountry

I use ratings of “Excellent,” “Very Good,” “Good,” “Adequate,” “Fair,” and “Poor” to assign merit to the ability of each policy variable to address evaluative criteria (Tab 4.2). Descriptions in the cells of each matrix are predictions based upon the best available information about current conditions. It is not possible, given uncertainties in biological conditions and human behavior, to make completely accurate predictions about the ability of these variables to meet policy goals, or the magnitude of the change that will occur with their implementation.

Table 4.2. Ratings used to assign merit to the ability of each policy variable to address evaluative criteria.

Rating	Assessment
Excellent	Variable is currently being used with few difficulties, or it can be easily implemented. No additional resources are needed.
Very Good	Variable shows promise for the Olympic coastline, and resources for its implementation are either readily available, or easy to acquire.
Good	Variable has been useful in other areas and systems, but uncertainty about human behavior and biological systems may minimize its effectiveness.
Adequate	Variable clearly represents a tradeoff between cost and benefit. Or, although it has proven useful in small resource areas, it is unclear how effective it will be on the large and remote Olympic coastline
Fair	Ability of variable to meet criterion is unproven, or there are known funding and staffing insufficiencies; if these can be met through fee imposition, inter-agency coordination, use of volunteers, the assessment could be improved to adequate.
Poor	The variable does not address the criterion. Or, Lack of revenues, staff, and information about its usefulness would hinder implementation. Addressing insufficiencies could be problematic.

Land managers have used combinations of the variables presented in Table 4.1 to minimize the effects of human use in terrestrial and marine environments. Each variable will succeed at addressing some aspect of trampling effects, but each has drawbacks and limitations in terms of its utility for the unique intertidal environment of the Olympic coast, its cost outlay, and its political or logistic feasibility. In these matrices I offer predictions about how changes in the use of management tools may or may not be successful in meeting Park goals for coastal management. I expressly avoid recommending a management strategy that combines these tools. I leave that task to coastal managers.

Trail Markers and Signage. Under the current policy the Park does not use trail markers or signage to direct foot traffic in the intertidal zone. The Park might consider establishing pathways in high-use areas to minimize further damage by concentrating foot traffic and by informing visitors of places they should avoid walking for the sake of intertidal life. This might consist of placing highly visible bolt markers in the rock with arrows and signs along pathways that have already become established on rocky benches and headlands. It might also include posting small signs at the places that are most likely to be accessed by backpackers passing over rocky headlands in the wilderness backcountry. Signs could include concise directions for hikers to watch their footing and to choose pathways that have clearly been used in the past. They might be of a pictorial nature—such as those used at Yaquina Head, Oregon, (personal observation) which discourage inappropriate behavior in the intertidal zone and inform tourists of how and where to place their feet in order to minimize damage to intertidal life (Figs. 4.1, 4.2). Similar signage is used at other locations on the Oregon coast. Pictorial signage, or signage with very little text, could be useful in the backcountry where hikers often diligently watch their footing for personal safety. I have observed areas on the wilderness coast that lend themselves to this type of signage. Rocky headlands at Yellow Bank and South Ozette, for instance, clearly show trails in the upper intertidal zone (personal observation). Backcountry hikers are reluctant to stop and linger in an area when fully loaded with a heavy backpack. Therefore, any signage placed at wilderness headlands should be clear and concise.

Figure 4.1. Signs at beach access point; Yaquina Head, Oregon.

In addition to concentrating use by backcountry hikers in the intertidal zone, this approach could be useful at the heavily visited day-use areas and interpretive sites at Hole-in-the-Wall and Starfish Point. Because many Park visitors on the southern coast use trails that depart from parking areas to access the intertidal zone (personal observation), signage at trailheads could be useful for informing visitors of appropriate behaviors toward intertidal habitats and life forms (Fig. 4.2). Additionally, it would be a simple matter for interpretive rangers to guide visitor movements during educational sessions while informing them of the unintended consequences of their enjoyment of the intertidal area. Interpreters could avoid walking or standing on rocky outcrops during educational sessions, and emphasize the reason for doing so.

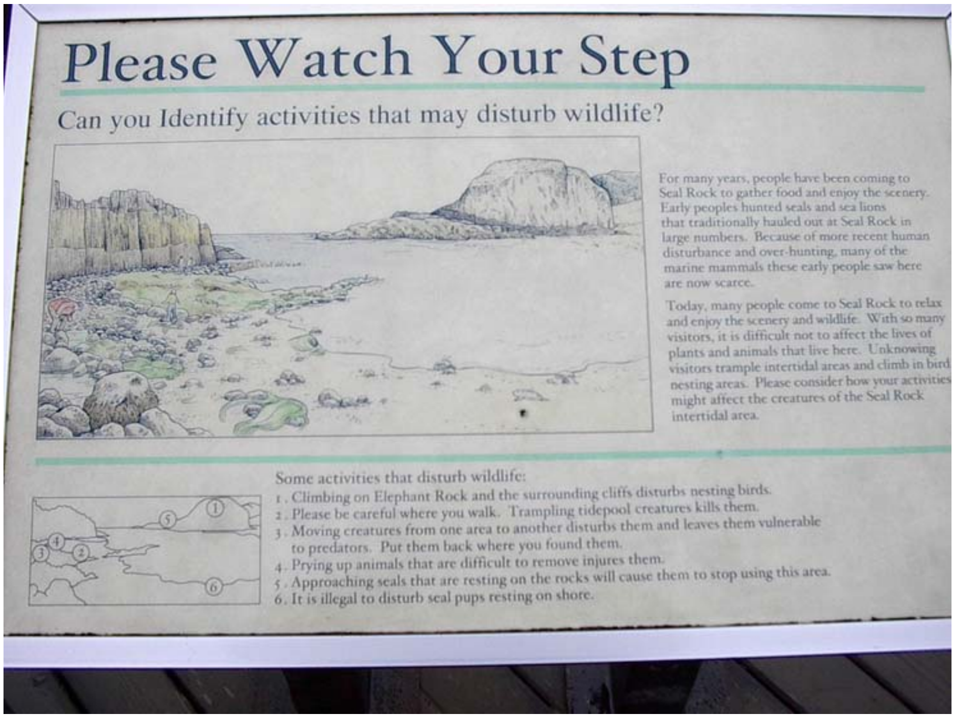

Figure 4.2. Informational sign at beach entrance; Yaquina Head, Oregon.

Trail markers have been used successfully to mark subtidal snorkeling trails in the Virgin Islands (Brosnan 1993) and have been effective at managing trampling-related impacts in terrestrial environments (R. Rochfort, pers. comm.). Because the intertidal zone on the Olympic coast is a high-energy, highly dynamic system, boardwalks and other permanent structures are infeasible options for directing foot traffic in this environment. Infrastructure of this sort is likely to be destroyed during the winter storms that commonly strike the coast. However, small bolts to mark paths and walkways are feasible and could be combined with signage at interpretive sites and frequently visited day use areas

Although this variable appears to contradict the Park’s policy against signage and permanent structures (bolts, markers and signs) in the wilderness, and may diminish the wilderness experience of backcountry visitors, it should be considered as a feasible option for balancing resource protection with visitor access. A summary evaluation of this policy variable is presented in table 4.3.

Table 4.3. Evaluation of trail markers and signage under varying levels of manipulation.

Goals	Criteria	Trail Markers and Signage		
		Current Policy: No markers	**Moderate:** Signs direct BC hikers to unmarked paths; educators direct visitor movements on-site; signs at trailheads and headlands	**Intensive:** Bolts and flags mark BC and interpretive area trails and users urged to stay on trails at all times
Resource Preservation	**Address uncertainty**	Poor; variable does not address uncertainty	Poor; variable does not address uncertainty	Poor; variable does not address uncertainty
	Prevent further impacts	Poor; no signage or markers used	Good; if visitors follow signage	Good; if visitors follow trail markers
	Preserve wilderness	Poor; rate of trampling impacts will likely increase	Good; signage will inform visitors without impacting resource; may detract from wilderness experience	Good; but bolts could detract from "wilderness experience" in BC
Public Access	**Maintain current use**	Excellent; no restrictions on access	Very good; educators can explain need for policy. Backcountry trails already established in some areas	Fair; unguided users are likely to resent bolted directions
Equitable Distribution	**Fairness to current users**	Fair; most can access, but information asymmetry problem	Adequate; may diminish wilderness experience, but provide higher quality environment	Adequate; may diminish wilderness experience, but provide higher quality environment
	Fairness to future users	Poor; will rob future user of undamaged resource	Good; will enhance resource quality	Good; will enhance resource quality
Administrative Feasibility	**Public acceptance**	Very good--unless public observes and objects to damage	Good; Oregon signage has been effective, but effectiveness unproven on Olympic coast	Fair; mgrs can expect some non-compliance with markers
	Ease of enforcement	Excellent; no action necessary	Fair; for day use and education sites. Poor; for backcountry	Poor; ranger staff insufficient to enforce
	Affordability	Excellent; no action necessary	Fair; because revenues are needed for signage, but could be secured through user fees and interagency coordination	Fair; revenues needed for bolts, but could be secured through user fees and interagency coordination

User Fees. Fees can be a means of both discouraging human activities that have proven to negatively impact resources, and of ascribing economic value to goods and services that are not recognized in the traditional marketplace (Bergstrom and Cordell 1991, Font 1999, Davis and Gartside 2001, Nunes and Bergh 2001). One benefit for ONP management is the revenue-generating potential of fees in light of diminishing resource management budgets. Fees collected on the coast could be directed toward coastal research activities and educational programs. This approach is currently being used on the southern coast of the Park, where a $3 room charge is assessed at Kalaloch Lodge and used to support coastal interpretive rangers (M. Gurling, pers. comm.). Similarly, a portion of Park entrance fees is used for research.

Under the current management policy nominal fees are being collected for camping throughout the wilderness and for parking at the Ozette ranger station. In 1998 the Park instituted wilderness camping fees of $2/person/night, a registration fee of $5/group/night for all coastal wilderness areas, and parking fees of $1/car/night at the highly used Ozette Ranger Station parking area.

Access fees have been imposed for day-use at some state parks in Washington and are being collected at some public beaches on the heavily-visited Oregon coast. A daily parking fee of $3 is charged at Ecola, Nehalem, Cape Lookout, Fogarty Creek, Heceta Head, and Shore Acres on the Oregon coast. In most cases, visitors self-pay at the entrance of the parking area and receive a ticket which is to be displayed on the dashboard of the car. During a recent winter visit to the Oregon coast, I observed that all who approached park entrances paid the fee and entered the park. I don't know how the revenue generated by this fee is used by Oregon State Parks, or whether it discourages people from visiting the parks. While access fees are usually charged for entry to National Parks, including Olympic, fees do not currently apply to the ONP coastline. National parks on the coast of California, such as Point Reyes, Channel Islands, and Cabrillo, charge fees for access.

Fees for overnight camping on the coast could be increased from the $2 per person that is now being charged. A camping fee of $4 per night per individual is assessed for primitive campsites on the Oregon coast at Fogarty Creek, Beachside, Umpqua, Tugman, Sunset Bay, Bullard's Beach and Cape Blanco. Fees could be considered for participation in interpretive programs, although this variable would be difficult to implement since people often join interpretive sessions on the beach. Parking fees could be charged at Oil City at the mouth of the Hoh River, and at Rialto Beach near

LaPush. Parking fees may not be logistically feasible for the south coast because the highway is adjacent to the beach and there are pullouts and road shoulders that can serve as alternative parking locations.

Increasing user fees and extending their application to more types of recreation and more areas on the coast could be an effective but politically unpopular way of generating funds to implement other management variables such as signage and education (Tab. 4.4). If fees are collected, the ways in which they are used should be made explicit to Park visitors at the time of collection. Adding cost to the price of parking, camping, or participation in interpretive sessions could discourage some people from visiting the coast. While this might reduce trampling impacts and could be a source of revenue for coastal research and education activities, it could also discriminate against those with low incomes. Intensive use of fees does not meet the criterion of fairness to current users, but could meet the criterion of fairness to future users if managers are successful in incorporating fees into research and education activities that change visitor behaviors to benefit intertidal resources.

Table 4.4. Evaluation of user fees under varying levels of manipulation.

Goals	Criteria	User Fees		
		Current Policy: Camping $2/pers/nt + reg. of $5/grp/nt; limit $50/6/wk and $100/12/2wks; Ozette parking $1/car/night	**Moderate**: Modest increase in BC camping, registration and Ozette parking fees; use fees for research, education and enforcement programs	**Intensive**: Further increase fees; charge parking fee at Rialto and Oil City; continue directing fees to research, education and enforcement
Resource Preservation	**Address uncertainty**	Poor; some park-wide fee-demo monies used for coastal research, but there is no stable funding source	Adequate; because expenses are unknown. Research fees are used in other programs	Good; expenses still unknown, but additional fees would be helpful
	Prevent further impacts	Poor; fees not used on coast, except Kalaloch Lodge assessment	Good; if fees support research and education to manage coast and change visitor behavior	Very Good; if fees are redirected to protect intertidal resources and provide education
	Preserve wilderness	Poor; fees not changing visitor behavior	Good; if research and education are funded	Very Good; if research and education are funded
Public Access	**Maintain current use**	Excellent; fees established, will not impact current use	Good to fair; may keep some visitors from the coast	Fair; fees could be prohibitively high for low income people, and may deter visitation
Equitable Distribution	**Fairness to current users**	Excellent; fees are few, and affordable	Good to fair; may keep some visitors from the coast	Fair; fees could be prohibitively high for low income people
	Fairness to future users	Excellent; if rates remain the same	Good to fair; may keep some visitors from the coast	Fair; fees could be prohibitively high for low income people
Administrative Feasibility	**Public acceptance**	Very good—few complaints about coastal fees	Fair; Some visitors may view as excessive or unnecessary	Poor; mgrs can expect non-compliance
	Ease of enforcement	Very Good; fee collection mostly through Park HQ	Good; use Park policies in place for fee collection	Adequate; will likely be some non-compliance with parking fees
	Affordability	Very Good; fee collection mostly through Park HQ	Good; if honor system or current policies used. Some fees could offset collection costs	Adequate; additional efforts will be necessary to collect and monitor parking fees

Quotas. Quotas to limit camping have not been established for most of the coastal backcountry, with the exception of the Cape Alava and Sand Point areas, which have been managed by a pre-registration quota system since 1996. High demand for recreational camping at these sites was causing congestion and use-related impacts, such as expansion of campsites, soil compaction, loss of forest vegetation, problems with human waste disposal and the development of social trails, and growing populations of forest scavengers such as crows and raccoons. On the remaining wilderness coast, quotas and pre-registration are not used; rangers assign permits in such a way as to minimize congestion in the backcountry, but since backpackers can self-register at the trailhead at the start of their hike Park managers cannot be sure that hikers are evenly distributed along the coast.

Quotas can be particularly useful for protecting the wilderness backcountry where visitors must travel many miles to access fragile intertidal systems. To minimize impacts from backcountry camping and tidepooling, the Park might consider implementing quotas and a pre-registration system for the entire coastal wilderness area. Although the coast accounts for only 20% of the wilderness landmass in the Park, wilderness camping on the coast comprised 45% of the total volume of wilderness camping in years 1988-1997, and much of this use was from people from the Puget Sound basin (ONP 1999). A moderate, year-round climate and close proximity to the metropolitan areas of Seattle and Tacoma make the coast attractive and accessible to campers from these cities. Park managers can expect the demand for coastal camping to increase in proportion with population growth in the state, and eventually it may be necessary to impose quotas for the entire coast to preserve park resources and values.

Limits on participation in interpretive sessions may not be a workable option for ONP. Quotas are being considered, but are not currently used, for educational programs at Channel Islands National Park (D. Richards, pers. comm.). This park is unique in that visitors must access the islands by boat, so limits on access would be relatively easy to establish and enforce. Participation in educational sessions currently ranges from 100-700 individuals per month. Park scientists have proposed that limits be set at 100 per day and 500 per month (D. Richards, pers. comm.) to minimize the impacts of human visitation. Due to the remote location of Channel Islands National Park, interpretive session quotas are a reasonable option to minimize human impacts. Quotas on participation in educational sessions at ONP would be difficult to implement and enforce because the beaches are highly accessible and stragglers commonly join sessions in progress. Under the current policy the Park does not limit participation in these sessions, believing that it is best to introduce as many as possible to the unique environment of the Olympic coast. However, it is questionable how much information individual participants gain during the course of one two-hour session in which several dozen individuals are crowded around one interpretive ranger. It could be valuable to establish participation quotas for these walks. However, this change may have limited usefulness for minimizing impacts at Hole-in-the-Wall and Starfish Point, since unguided visitor activities may exceed participation in ranger-guided walks. On the Olympic coast, quotas could minimize trampling impacts in the wilderness, but this variable will be most useful if combined with research (Tab. 4.5).

Table 4.5. Evaluation of quotas under varying levels of manipulation.

Goals	Criteria	Quotas		
		Current Policy: BC group limit 12/site/nt; use-quotas for Ozette backcountry only	**Moderate:** Apply quotas to all BC camping; limit tidal walks to half of maximum current participation (~25?)	**Intensive:** Reduce BC party sizes and camping quotas; further reduce limit on tidal walk participation and enforce rules against informal "hangers-on" (~15?)
Resource Preservation	**Address uncertainty**	Poor; no effort made to minimize uncertainty	Fair; if combined with research and adaptive management	Fair; if combined with research and adaptive management
	Prevent further impacts	Poor; predicted increase in coastal recreation	Adequate; because extent of coastwide impacts are currently unknown	Adequate; because extent of coastwide impacts are currently unknown
	Preserve wilderness	Poor; impacts will continue	Adequate; quotas cap use in the BC. Still, effect will only be know by performing research	Good; lower quotas may protect wilderness, but real understanding will require monitoring to track biological changes
Public Access	**Maintain current use**	Excellent; few restrictions on use	Fair; if BC quotas set at current levels of use. Adequate in frontcountry; most education sessions do not now exceed 25	Poor; reduces visitation on the coast
Equitable Distribution	**Fairness to current users**	Very Good; available access. Good; some areas impacted	Good; if BC quotas set at current levels. Minimal effect on education sessions	Fair; may exclude some from using the coast, but those who do may experience greater environmental quality
	Fairness to future users	Poor; no change in policy will result in damaged resources	Good, especially BC; Future users could see higher quality environment	Fair in frontcountry; because day use is likely greater than educational programs. Good in BC; quotas provide protection for wilderness
Administrative Feasibility	**Public acceptance**	Very Good; public accepts current policy	Fair; if reasons for quotas explained. Some will object	Poor; visitors will object to quotas. Intensive use of quotas will damage agency reputation and public approval for management decisions
	Ease of enforcement	Very Good; but may be some non-compliance	Adequate; will be a lengthy adjustment period. Educational sessions are generally below 25 now	Poor; turning visitors away from educ. programs will be unpleasant, perhaps infeasible, while performing instructional duties
	Affordability	Good; current system is well established	Fair; additional funding will be needed	Fair; additional funding will be needed

Closures. Marine protected areas (MPAs), marine reserves, and no-access zones are a commonly used and effective means of protecting valuable and fragile coastal resources and ecological systems (Castilla and Bustamante 1989, Cole et al. 1990, Hunt and Scheibling 1997, Lasiak 1998, Murray et al. 1999, Castilla 2000). Area closures are being used at Cabrillo National Monument near San Diego, California, to minimize trampling impacts on a portion of this park's small rocky intertidal area. Because the park is within an urban area it is highly visited by the public and managers are able to use volunteers to keep people out of the closed area (B. Becker, pers. comm.). Use of volunteers is possible in a small park like Cabrillo, but not likely to be feasible for the large and remote ONP coast, particularly in the wilderness. Signage to close small areas of rocky habitat is used successfully at Yaquina Head in Oregon, which has been known to have as many as 1,000 people on the beach during the busy summer tourist season. Managers at Yaquina post closure signs near rocky areas to prevent public access and protect intertidal life (Fig. 4.3). A nearby visitor center provides educational exhibits that describe the reasons for these closures. In a recent winter trip to Yaquina Head I noticed complete compliance with the signage by visitors, despite the fact that closed areas were located in the immediate vicinity of the heavily used portion of the beach.

Figure 4.3. Signs at Yaquina Head that limit public access to sensitive intertidal areas.

Exclusions could be considered for interpretive areas. Rangers could alternate the location of their educational sessions to allow the most heavily impacted sites to recover before foot traffic is resumed. It is questionable whether this variable, alone, could minimize impacts at Park interpretive sites because day-use may produce a greater impact than guided walks on the intertidal biota at Starfish Point and Hole-in-the-Wall. Both areas are currently being managed as “sacrificial areas” in which restrictions on use are non-existent (although they are not officially designated as sacrificial areas). Starfish Point is highly accessible, much more so than Hole-in-the-Wall, which borders the wilderness boundary just north of Rialto Beach. It may be acceptable to designate Starfish Point, but not Hole-in-the-Wall as a “sacrificial area.” Allowing unlimited use of accessible areas of Starfish Point could be balanced by protecting relatively inaccessible platforms nearby (such as my reference site at Starfish) by posting “access restricted” or “wilderness protection area” signage at the sites or at the trailhead. In addition to protecting some of the rocky habitat, this manipulation would have the added benefit of preserving reference areas for future research.

Alternatively, visitor use at either rocky location could be manipulated experimentally using closures. Managers could close and open areas, then monitor biological degradation and recovery. Insights gained could be used to alternate openings and closures of rocky intertidal areas in the front country. Use of this variable should include an educational component to inform visitors of the reason for closures and research results. Exhibits at trailheads and visitor centers could explain the research in progress as well as include up-to-date information about the status of biological decline and recover in experimental areas.

Most of the Olympic coast is accessible to Park visitors. The southern coast, from the Hoh River to the southern park boundary, is adjacent to the highway and presents few barriers to access. Rocky intertidal areas on the mid and northern coast are accessible to visitors who choose to hike along the coast. Exceptions are rock walls and small pocket beaches in the vicinity of Hoh Head on the middle coast and Point of the Arches on the north. Much of the rocky intertidal area near Point of the Arches is comprised of vertical cliffs and course gravel beaches. Vertical surfaces differ from horizontal surfaces in rates of settlement, recruitment and predation of intertidal organisms (Frank 1982, Brosnan and Crumrine 1992, Glasby and Connell 2001). In order to protect rocky beaches from trampling impacts, the Park may wish to establish one or two “no access” areas on the northern and middle coast that include a variety of habitat types.

Closures may be a feasible option for management of the Olympic coastline (Tab. 4.6). However, the public is likely to view any closure as discriminatory, particularly if the reason for the closure is not made clear. For this reason, there may be some non-compliance and continued impacts in some areas. Any use of closures should be combined with research and visitor education.

Table 4.6. Evaluation of closures under varying levels of manipulation.

Goals	Criteria	Closures		
		Current Policy: No closures except for visitor safety	**Moderate:** Closures in frontcountry, manipulative "adaptive management" experiments	**Intensive:** Establish "no access" area(s) on middle, northern coast
Resource Preservation	**Address uncertainty**	Poor; no closures	Good; resources not secured for research; Very Good; with fee-generated resources	Poor; unless combined with research and fee-based funding, then Good
	Prevent further impacts	Poor; no closures	Good; if visitors obey signage	Excellent; closed areas
	Preserve wilderness	Poor; no closures	Very Good; manipulations can guide wilderness mgt	Excellent; closed areas
Public Access	**Maintain current use**	Excellent; use level maintained or increased	Fair; some excluded in frontcountry	Fair; some excluded in backcountry
Equitable Distribution	**Fairness to current users**	Excellent; unlimited access, but could be info asymmetry	Adequate; some exclusions in frontcountry	Adequate to Fair; depending on locations for closures
	Fairness to future users	Poor; resource will likely sustain further damage without intervention	Very Good; Mgt can incorporate experimental evidence into mgt policies	Very Good; closed areas protected for future enjoyment
Administrative Feasibility	**Public acceptance**	Excellent; no closures, so no reason for objection	Acceptable; if reason for closures made explicit and combined with education	Poor; public will likely object to closures
	Ease of enforcement	Excellent; currently no closures	Good; expect some non-compliance	Good; expect some non-compliance
	Affordability	Excellent; currently no closures	Good; if revenues secured for signage, or cost-share with OCNMS	Good, if revenues secured for signage, or cost-share with OCNMS

Education. The coastal resource education program has been administered thoughtfully and with genuine concern for intertidal resources, and is provided to Park visitors at no cost. Advanced registration is not required for participation in interpretive walks, and anyone may join a group while the session is in progress. The primary objective of the Park's Resource Education Division has been to instill the public with a love of nature that will be manifest in a desire to protect the Park's natural resources. The motto of this Division is "stewardship through education." For this reason, rangers prefer to practice a policy of inclusion and allow all interested individuals to participate in educational tours. While education may foster stewardship in some individuals, the conservation message could be translated more directly. Managers and educators assume that knowledge about coastal ecosystems and life forms will compel visitors to be stewards of this system. Researchers on Vancouver Island have discovered that intertidal education can increase damage in the intertidal zone (L. Alessa, pers. comm.). After becoming informed about intertidal life, knowledgeable people wander onto the exposed beach to observe their study objects. Trampling damage is not malicious or intentional; it's merely a consequence of human presence. On the other hand, behavioral instructions provided by park rangers have consistently proven to be more effective at changing visitor behavior in the intertidal zone than either printed materials or visitor center exhibits (L. Alessa, pers. comm.). Not all coastal tourists visit information centers or read trailhead signs. Personal instruction will be required to change their behavior.

Because the Park is mandated to protect resources from impairment, educational programs that focus on the intertidal zone should always inform visitors of the impacts caused by their experience with this unique ecological system. Park visitors should leave these sessions informed and with a desire to change damaging behavior. Educators could teach visitors to avoid trampling fragile intertidal life by carefully placing their feet on bare patches of rock whenever possible, and by wearing soft-soled running shoes. Explicit instructions should be given to stay on paths, whether they be marked trails or areas that have clearly been worn down by previous foot traffic. Visitors should be instructed to avoid walking on all intertidal life, including rockweed, barnacles, and mussels. Interpretive rangers should lead by example, instructing visitors while standing on gravel or sand rather than rocky substrate.

These messages could also be contained in brochures made available at ranger stations and visitor centers, through the print media, through trailside message boards, and through signage at coastal access points. Signage is being used to inform visitors of the effects of their actions at Yaquina Head, where signs are posted in the visitor center and at the sole beach access point. Most signs contain little text, and focus visitor attention on pictographs of intertidal life and ways in which visitors should, and should not, interact with habitats and organisms in the intertidal zone. Trampling impacts, specifically, are addressed in coastal access signage and visitor center exhibits at Yaquina Head. Signage and exhibits are combined with personal instruction provided by the interpretive rangers that are commonly on the beach.

Finally, the Park might consider exporting lessons about the beauty and vulnerability of the intertidal system by speaking to groups in the community and the region. Although educational activities are offered at Park headquarters, the Park could reach more people by taking lessons to the public rather than expecting the public to come to the Park. Obvious audiences include public and private schools, visitor and tourism boards, recreational clubs, scouting groups, economic development councils, and business organizations. This approach would also be valuable to inform the public of important and timely research being conducted in the Park by the Natural Resources Division, OCNMS, and other researchers. This type of information may go a long way in fostering good will toward the Park, particularly among people who reside near the Park or in the region.

Contact with interpretive rangers will be the most effective means of immediately changing the behavior of Park visitors. Although ranger funding has been reduced in recent years, the Park can direct coastal user fees to support coastal interpretive staff. This would be an appropriate and practical way of using these fees. A summary evaluation is presented in table 4.7.

Table 4.7. Evaluation of education under varying levels of manipulation.

Goals	Criteria	Education		
		Current Policy: No policy to emphasize on user impacts	**Moderate:** Tidal walks include "impacts" education; develop brochures to educate people of unintended effects of human activity	**Intensive:** Same as moderate, but develop NPS community outreach, particularly locally and regionally; use print media
Resource Preservation	**Address uncertainty**	Poor; no research implemented	Good; education, especially combined with research, is an important component of adaptive mgt	Good; as with moderate, research
	Prevent further impacts	Poor; no focus on visitor impacts	Very Good; ed session participants informed. Fair; non-participant/day use damage continues	Very Good; ed session participants informed. Good to Fair; brochures and community talks can change behavior
	Preserve wilderness	Poor; no focus on visitor impacts	Not likely to affect wilderness users	Good to Fair; brochures and community talks can change behavior
Public Access	**Maintain current use**	Excellent; no limitations	Excellent; use not affected by providing more information	Excellent; use not affected by providing more information
Equitable Distribution	**Fairness to current users**	Poor; no impact ed means resources are damaged by use	Good; ed participants. Poor; unguided users still damage resources	Good; if message eventually changes behavior, generally
	Fairness to future users	Poor; resource damage	Good to Fair; if behaviors are changed	Good to Fair; if behaviors are changed
Administrative Feasibility	**Public acceptance**	Excellent; no cause for objections	Excellent; visitors benefit from useful, in depth science instruction	Excellent; visitors benefit from science instruction. Community involvement is especially valuable for Park PR
	Ease of enforcement	Excellent; nothing to enforce	Adequate; if fees, volunteers, interagency coordination used to increase staffing	Adequate; Education program would be considerably more large and complex.
	Affordability	Fair; limited funding	Adequate; if funded with fee revenues. Good; responsibilities shared with OCNMS	Fair; fee revenues may be insufficient. Good; responsibilities shared with OCNMS

5. Conclusion

Although people from around the world visit the coastal area of ONP, it is perhaps most valued by residents of the Pacific Northwest region. The population of Washington is growing, and recreational use of the coastal area will increase proportionately. While the public commonly believes that ONP was established to provide recreational opportunities for people, a review of enabling and management legislation reveals that the Park's primary obligation is protection of its resources. If high levels of human use are found to jeopardize intertidal resources, the Park is mandated to address and remedy the problem. NPS guidelines define "impairment" as an impact so great that it diminishes park resources and values, but do not provide explicit criteria with which to determine the level of impacts that constitute impairment; rather, this determination is left to the "professional judgement" of the NPS manager. I leave the determination of impairment to the Park; however, I have shown empirically that human trampling has negatively impacted some intertidal areas in the Park.

The PCA consists of 65 miles of coastline that are comprised of acres of complex and highly variable intertidal habitat. For the purpose of this policy analysis, I performed an empirical study of the effects of human trampling on rocky platform habitat. I examined platforms located at three tidal elevations in exposed and protected habitats, at six locations within the ONP boundary: Starfish Point, Hole-in-the-Wall, Cape Alava, Yellow Banks, Toleak Point, and Norwegian Memorial. These locations experience levels of human visitation that range from high to low in the order in which I've listed them. My data indicate that trampling associated with visitation has impacted intertidal areas on the coast, and that this impact is evident in proportion to human visitation.

At the two most frequently visited locations on the "non-wilderness" coastline, Starfish Point and Hole-in-the-Wall, sites that are accessible to human foot traffic (treatment sites) have more bare space, more barnacle scars and smaller barnacles than sites that are less accessible to foot traffic (reference sites). Because I have no pre-study visitation data, it is possible that even my reference sites have been affected by trampling and that the overall impact to rocky habitats at Starfish Point and Hole-in-the-Wall is greater than my study indicates. It's important to note that these are only two beaches on the non-wilderness coast. Analyses of additional locations could reveal that other areas are impacted by trampling or not affected.

Of the four "wilderness" locations I sampled, Cape Alava and Yellow Banks showed significant impacts from trampling. Biota at the less-visited locations of Norwegian Memorial and Toleak Point showed fewer and smaller differences between treatment and reference sites. The treatment site at Yellow Banks is on a major access trail over the headland south of Sand Point. I attribute trampling impacts there to hiker traffic crossing the headland, rather than exploration of the headland. Cape Alava is the most popular camping location on the wilderness coast (ONP 1999), and I believe impacts there can be attributed to visitor exploration of the intertidal zone. Although Cape Alava is within the wilderness boundary, it is closer to the nearest trailhead than either Norwegian Memorial or Toleak Point; many visitors to Cape Alava are day hikers. I established wilderness study locations near the most frequently used camping areas on the coast (ONP 1999), but Cape Alava, the only location close enough to a trailhead to facilitate day use, was the most impacted of the wilderness locations I sampled.

The prescriptions for management of non-wilderness locations are less restrictive than those for wilderness areas in national parks (NPS 2000). Although no benchmarks have been established for intertidal resource "integrity" (integrity is not, but perhaps should be, defined in park policies), it is clear that Congress intended for wilderness lands to receive greater protection from human activities than non-wilderness lands. The Cape Alava location shows significant effects from human use that may be caused by unregulated day use. The current policy of pre-registration and quotas for camping, then, is inadequate to protect this location from trampling impacts. Distances from the trailheads will be an important consideration in designing management policies for the coast and for scientific studies to monitor visitor-use impacts—particularly in the Ozette area.

Ecological systems are continually evolving. Natural systems progress through a series of changes of increasing complexity and connectedness to reach a "climax" state of development. This state, however, is not an endpoint. Rather, it is a condition in which nutrients, energy, and biomass have become consolidated to form a complex organization of maximum developmental potential (Gunderson and Holling 2002) (Fig. 5.1). Inevitably, a climax or “K-phase” system will succumb to disturbance that causes the release of its components, followed by a system reorganization (Berkes et al. 2003). In short, ecological systems are inherently nonlinear, unpredictable, and prone to uncertainties and multiple stable states.

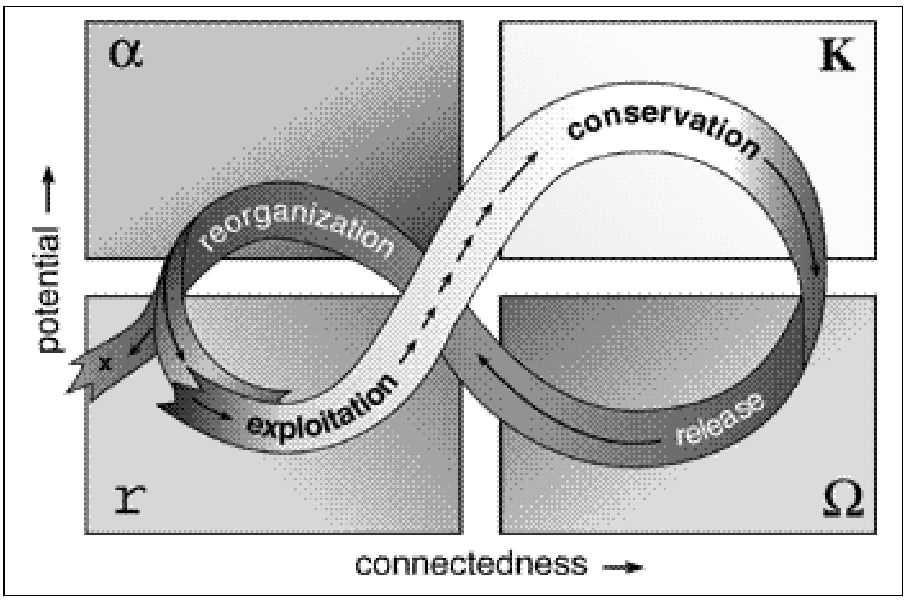

Figure 5.1. A model of the adaptive renewal cycle that illustrates natural functions and transitions in ecological systems. The model presents the classic “r- to K-phases” of rapid growth to a “climax” state of ecological development. The “backside” of the loop depicts the release of ecosystem components through disturbance (Ω), followed by a reorganization (α) of the ecological community and return to the r-phase of growth where the cycle repeats itself (Graphic: Resilience Alliance 2003).

Examples of this renewal cycle in nature are numerous. A classic example is the decline of a mature forest (at K-phase) through fire or insect infestation (release, or Ω-phase), and the rebirth of a new forest through the reorganization (α-phase) of components of the old system (e.g., nutrients in ash and soil, seeds, and the survival, growth, and reproduction of disturbance tolerant individuals). In benthic intertidal communities, large, mature barnacles (K-phase) invite predation by shorebirds and predatory snails, and are susceptible to removal by wave-borne drift logs or trampling feet (Ω-phase). If large quantities of barnacles are removed, the established benthic community declines and then transitions into an alternative state (α-phase), and the cycle repeats itself. Of critical importance, then, is the ability of the system to "self-organize" following disturbance—a trait common to all complex and biologically diverse ecological systems. Biodiversity is a key element in the process of self-organization (Berkes et al. 2003).

Transitions from Ω to α, and r to K represent periods of maximum growth in organizational potential, but the latter transition has a slow evolution time, while the former can occur quite rapidly. While the transition from r to K is generally steady and predictable, the progression from Ω to α can be turbulent and full of surprises—a time of critical developmental importance to the system to follow. During this transition the resilience of the system, or its likelihood of maintaining its form and function following disturbance, is low (Gunderson and Holling 2002). It is now that an ecological system is at greatest risk of loosing critical components, which can result in species extinctions, exotic species invasions, and reorganization into an undesirable state. Yet, in most instances of resource management the dynamics of the temporally dominant r to K phase catch the attention of researchers and managers, particularly at a regional scale (Walker et al. 2002). An emerging and widely accepted concept in resource management is the recognition that complex, nonlinear systems are best managed by engaging in interdisciplinary research and flexible, adaptive management practices (Walters 1986, Constable 1991, Lee 1993a, Castilla 2000, Walker et al. 2002, Habron 2003, Rodgers et al. 2003).

There are several factors common to ecological research that hinder the ability of managers to understand, and therefore manage, natural areas (Hilborn and Ludwig 1993, Ludwig et al. 1993). A lack of controls and replicates in ecological research slows the pace of learning (Ludwig et al. 1993). Researchers in the fields of physics, chemistry, and toxicology, among others, have the luxury of performing laboratory experiments under controlled conditions. Consequently, the knowledge base in these fields is large and growing rapidly. It is difficult to tease out anthropogenic sources of disturbance in ecological systems because these systems possess a naturally high level of variability and are complex enough to preclude a reductionist approach to learning (Ludwig et al. 1993). Our understanding of natural systems is limited and growing slowly, which has led to the overexploitation of many organisms—especially those that are long lived. Examples abound in the field of fisheries management where stocks of fish are depleted or collapsing around the world. The overexploitation of fisheries has been aided by uncertainty. Responsible management of fishery and other resources would entail acknowledgement of the uncertainty inherent in ecological research, but would embrace management prescriptions that err on the side of protecting ecological systems (Hilborn and Ludwig 1993).

Applied research must consider human systems when performing resource management studies and making management prescriptions. Managed natural systems and the human systems that interact with them are inherently unknowable and unpredictable (Holling 1993). Managing resources sustainably is not a simple matter of selecting a course of action and following through. Both natural and human systems are continually evolving, and prescriptions for their management must be flexible enough to adapt with our understanding of them (Holling 1993). Applied research that does not acknowledge and involve the social systems of the dominant and most rapidly growing population on the planet (humans) is unscientific (Ludwig 1993) and unproductive. Lee (1993b) attributes overexploitation of resources to a mismatch between the scale of human responsibility and the interaction of the environment with human activities, drawing parallels to Garret Hardin's description of moral and institutional failure in the management of common property resources. This mismatch can be observed when those who benefit from the exploitation of a resource are different from those who pay the cost for the exploitation. Uncertainty and misinformation make it difficult to match the scales of human desire and the ability of the environment to meet these desires. Ludwig (1993), emphasizes the need limit human extractive activities relative to the boundaries of biological production and accuses policy makers who fail to accept biological limits of wishing to “invent magical theories in an attempt to reconcile the irreconcilable.” Lee (1993b) concludes that the burden of proving “no harm” lies with those who would exploit, rather than those who would refrain from exploiting resources, and that if mismatches are to be remedied they must first be understood. Learning is paramount.

Uncertainties about natural ecological processes and the impacts of natural phenomena and human activities on intertidal biota slow the development of management policies for the Olympic coast. The most rational approach to managing intertidal resources, then, is to develop a flexible, adaptive management strategy that is informed by scientific and social research and can evolve with changes in natural conditions and human desires and activities. Habron (2003) presents a nonlinear model of adaptive management with a focus on research to address the uncertainties inherent in watershed management. This model emphasizes the development of “active adaptive policies” proposed by Walters (1986). Active policies are designed for the purpose of learning. They are based on hypotheses or predictions about biological responses to management actions, and subsequent monitoring and evaluation of the system as policies are implemented. Adaptive management is nonlinear, and not predicated on rigid policy prescriptions. Its strength lies in its ability to embrace change and adapt as necessary. I suggest that such a model be applied to management of the Olympic coastline (Fig. 5.2).

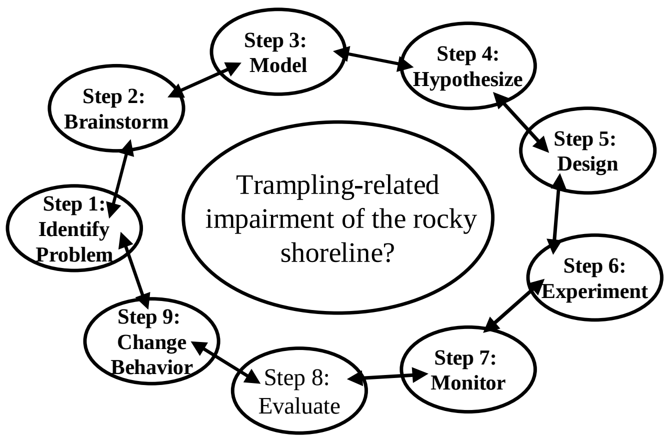

Figure 5.2. Model for adaptive management of natural systems that are affected by uncertainties. Adapted from Habron (2003).

In Chapter 4, I introduced five key policy variables to be considered by the Park to manage trampling impacts: trail markers and signage, user fees, quotas, closures, and education. I provide examples of how these variables might be manipulated (Tab. 4.1) and evaluate each with criteria that I developed to assess progress toward meeting the goals of resource preservation, public access, equitable distribution of park amenities to current and future visitors, and administrative feasibility (Tabs. 4.3 through 4.7). I suggest that the Park combine these variables in a manner that minimizes the uncertainty regarding impacts and impairment, changes the behavior of Park visitors, protects the most biologically diverse areas of the coast, and minimizes damages that are likely to accompany population growth in the State.

I believe the use of quotas, signage, and some closures will be valuable for protecting wilderness resources from future damage. Trailhead signs, trail markers, and personal contact with interpretive rangers will be effective means of minimizing impacts in non-wilderness areas, and research-related closures at the most heavily visited locations will aid managers in addressing biological uncertainty. Research results should be incorporated into coastal management policies, as well as presented to visitors in informational exhibits and ranger talks (Fig 5.3). In doing this, the Park will meet two management mandates: It will 1) protect resources by determining the level of impacts that constitute impairment, applying research results to management decisions as they become apparent, and 2) enhance the visitor experience by providing information about timely research through exhibits and personal contacts. Rodgers et al. (2003) propose a similar closure-and-education strategy to manage trampling impacts to coral reefs in the Hawaiian Islands, and stress the value of research in supporting unpopular management decisions. The use of education, to include outreach, will be agreeable with the public and will benefit coastal resources by shifting attitudes about intertidal life from complacency to concern.

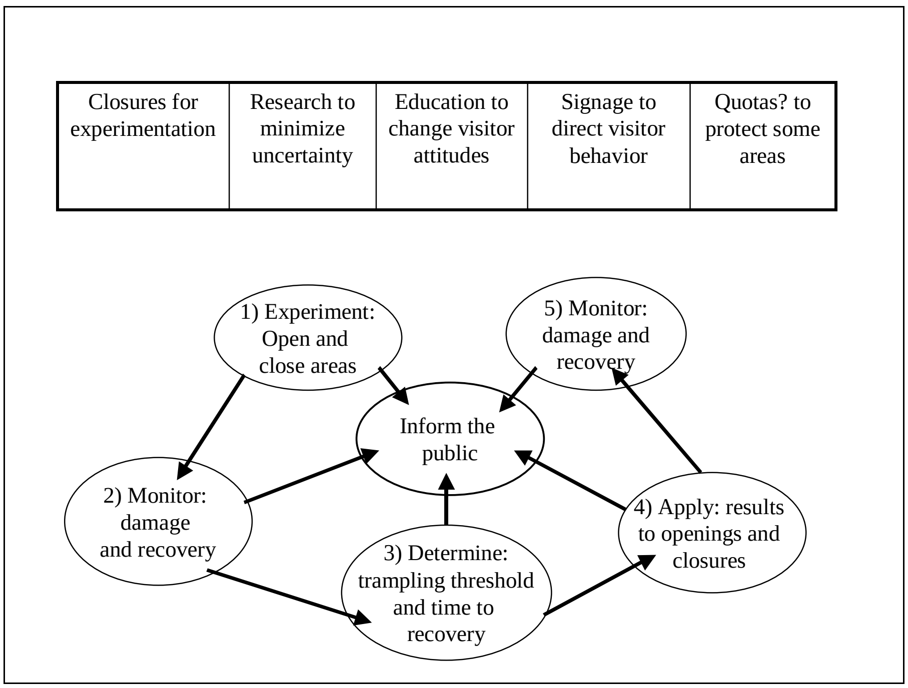

Figure 5.3. Model for managing the coast in the face of uncertainties.

I suggest that the Park make extensive use of education that incorporates a strong element of “intertidal stewardship,” which emphasizes the unintended affects of human activities in the intertidal zone and instills visitors with a sense of responsibility for these resources. This will be aided by informational signage, but clearly there should be a larger ranger presence on the coast to interact with Park visitors. Coastal education should also include an outreach component. Education and research are costly, and it will be necessary to rely on user fees, volunteers, and additional interagency coordination to implement these variables. However, a strategy that includes both, and emphasizes behavioral education, will provide the Park with a good balance of resource protection and public access.

Finally, Park managers must fully investigate, and continue to monitor as visitation increases, the extent to which resources are being impacted on the coast. This should include an element of experimentation in association with area closures, to determine rates of recovery, and, alternatively, rates of degradation on rocky platforms. To determine coastal impairment, managers should consider the intertidal zone in its entirety by examining many more locations along the coast. Empirical information about the location, level, and density of human activity in the intertidal area should be gathered to correlate visitor activity with biological signals of trampling effect, and to determine the nature of the response of the biological resource to varying levels of visitation. These types of analyses will provide more comprehensive information about the impacts of human trampling on this coast. Further study will reduce the uncertainty surrounding trampling impacts, and aid managers in determining impairment of coastal resources. It will also foster the development of a flexible, adaptive management strategy that can evolve in response to the Park's understanding of changes in the biological condition and human use of the intertidal zone.

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