Marine Sanctuaries Conservation Series MSD-05-3

The Impacts of Coastal Protection Structures in California's Monterey Bay National Marine Sanctuary

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean and Coastal Resource Management
Marine Sanctuaries Division

February 2005

National Marine Sanctuaries

About the Marine Sanctuaries Conservation Series

The National Oceanic and Atmospheric Administration's Marine Sanctuary Division (MSD) administers the National Marine Sanctuary Program. Its mission is to identify, designate, protect and manage the ecological, recreational, research, educational, historical, and aesthetic resources and qualities of nationally significant coastal and marine areas. The existing marine sanctuaries differ widely in their natural and historical resources and include nearshore and open ocean areas ranging in size from less than one to over 5,000 square miles. Protected habitats include rocky coasts, kelp forests, coral reefs, sea grass beds, estuarine habitats, hard and soft bottom habitats, segments of whale migration routes, and shipwrecks.

Because of considerable differences in settings, resources, and threats, each marine sanctuary has a tailored management plan. Conservation, education, research, monitoring and enforcement programs vary accordingly. The integration of these programs is fundamental to marine protected area management. The Marine Sanctuaries Conservation Series reflects and supports this integration by providing a forum for publication and discussion of the complex issues currently facing the National Marine Sanctuary Program. Topics of published reports vary substantially and may include descriptions of educational programs, discussions on resource management issues, and results of scientific research and monitoring projects. The series facilitates integration of natural sciences, socioeconomic and cultural sciences, education, and policy development to accomplish the diverse needs of NOAA's resource protection mandate.

The Impacts of Coastal Protection Structures in California's Monterey Bay National Marine Sanctuary

Rebecca Stamski

Monterey Bay National Marine Sanctuary
Monterey, CA

U.S. Department of Commerce
Carlos M. Gutierrez, Secretary

National Oceanic and Atmospheric Administration
VADM Conrad C. Lautenbacher, Jr. (USN-ret.)
Under Secretary of Commerce for Oceans and Atmosphere

National Ocean Service
Richard W. Spinrad, Ph.D., Assistant Administrator

Marine Sanctuaries Division
Daniel J. Basta, Director

Silver Spring, Maryland
February 2005

DISCLAIMER

REPORT AVAILABILITY

Electronic copies of this report may be downloaded from the National Marine Sanctuaries Program web site at www.sanctuaries.nos.noaa.gov. Hard copies may be available from the following address:

National Oceanic and Atmospheric Administration
Marine Sanctuaries Division
SSMC4, N/ORM62
1305 East-West Highway
Silver Spring, MD 20910

COVER

Upper Left:	Coastal armoring in Capitola, CA. MBNMS
Center Left:	Erosion warning sign, Santa Cruz, CA. MBNMS
Lower Left:	Riprap along Westcliff Drive, Santa Cruz, CA. MBNMS
Upper Right:	Riprap along Westcliff Drive, Santa Cruz, CA. MBNMS
Center Right:	Seawall in Capitola, CA. MBNMS
Lower Right:	Seawall in Santa Cruz, CA. MBNMS

SUGGESTED CITATION

Stamski, Rebecca. 2005. The impacts of coastal protection structures in California's Monterey Bay National Marine Sanctuary. Marine Sanctuaries Conservation Series MSD-05-3. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Marine Sanctuaries Division, Silver Spring, MD. 18 pp.

CONTACT

Rebecca Stamski
California Sea Grant Fellow
Monterey Bay National Marine Sanctuary
299 Foam Street
Monterey, CA 93940
(831) 647-4228
Becky.Stamski@noaa.gov

ABSTRACT

This report outlines the potential impacts of coastal protection structures on the resources of the Monterey Bay National Marine Sanctuary. At least 15 miles of the Sanctuary's 300-mile shoreline are currently armored with seawalls and riprap revetments. Most of these coastal protection structures are placed above the mean high tide line, the official boundary of the Sanctuary, yet some influences of armoring impinge on the marine realm and on recreational use. In addition, continued sea level rise and accompanying coastal retreat will force many of these structures below the high tide line over time. The Monterey Bay National Marine Sanctuary staff has recognized the significance of coastal armoring, identifying it as a critical issue in the Coastal Armoring Action Plan of the draft Joint Management Plan.

This summary is intended to provide general background information for Sanctuary policies on coastal armoring. The impacts discussed include: aesthetic depreciation, beach loss due to placement, access restriction, loss of sand supply from eroding cliffs, passive erosion, and active erosion. In addition, the potential biological impacts are explored. Finally, an appraisal of how differing armor types compare in relation to impacts, expense and engineering is presented. While the literature cited in this report focus predominantly on the California coast, the framework for this discussion could have implications for other actively eroding coastlines.

KEY WORDS

Coastal erosion, armoring, coastal protection structures, seawall, riprap revetment, geology, sanctuary, California, Monterey Bay

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Eighty-six percent of California's 1,100 miles of coastline is eroding (Griggs 1999), yet now more than ever, people want to live at that retreating boundary between land and sea. Erosion of the coast has been occurring for the past 18,000 years, when the last glacial period ended and sea level began to rise. Coastal cliffs are retreating at an average rate of 10 to 30 centimeters per year across the state (Griggs and Patsch 2004a), although erosion rates can be as high as 4.5 meters per year (Griggs and Patsch 2004b). Extreme variability in the rates and severity of coastal erosion, particularly in relation to El Niño storm patterns and local geomorphic conditions, complicates property protection decisions. In addition, the politics of public and private land ownership in the coastal zone make coastal armoring a contentious issue for Californians.

Several alternatives have been recognized to deal with the confluence of coastal development and eroding shorelines, none of which are a panacea. In the extreme case, property owners can demolish the building or relocate it landward, either on the same parcel or on an entirely different inland location. Neither of these choices is ideal for property owners, though they should be considered as serious, long-term solutions to this inevitable dilemma, given the rising costs of other alternatives (Griggs 1986). For example, Stillwell Hall, built in the 1940's as the Fort Ord soldier's club in Seaside, California, was torn down in March 2004 because the cost of both coastal armoring and relocating were too high (Figures 1a and b).

Figure 1a: Oblique aerial photograph of Stillwell Hall in 2002 in Marina, CA. Coastal protection structures placed at the base of the aged building were neither effective nor efficient enough keep up with intense coastal erosion of adjacent bluffs. Photograph copyright © 2002 Kenneth & Gabrielle Adelman (http://www.californiacoastline.org/).

Figure 1b: Oblique aerial photograph of the former Stillwell Hall location after the building and associated coastal protection structures were removed in March 2004. Photograph copyright © 2002 Kenneth & Gabrielle Adelman (http://www.californiacoastline.org/).

Beach nourishment has been highlighted recently as a solution to coastal erosion; proponents of this alternative maintain that increasing beach width by physically adding sand to a beach buffers wave energy and slows retreat rates. Federal, state and local government agencies are pursuing this method as a way to protect property from erosion damage, but the costs are generally very high and the net, long-term benefits of beach nourishment will vary greatly depending on local conditions (Leonard et al. 1990).

A survey of west coast beach nourishment projects determined that only 27% survived more than 5 years and 18% lasted less than 1 year (Leonard et al. 1990). In some cases, sand that was placed on a beach during summer was completely washed away the following winter. This is not unexpected given the high littoral drift rates that characterize most of the coast of California. A cost-benefit analysis of proposed nourishment projects should include site-specific evaluations of littoral budgets. In addition, the availability of an appropriate, cost-effective sand source and potential interference between beach users and sand transportation equipment should be addressed. As an alternative, beach width might be increased by removing dams that impound significant amounts of sand in coastal streams (Willis and Griggs 2003).

By far the most popular option to manage shoreline retreat in California has been the construction of coastal protection structures (also referred to as coastal armoring). Approximately 10% of California's coastline is currently armored (Griggs in press-a). The complexity and significance of coastal armoring in California are evidenced by numerous scientific studies, involvement of non-profit organizations, such as the Sierra Club and the Surfrider Foundation, and media coverage of the issue, such as KQED's *Coastal Clash* documentary (http://www.kqed.org/w/coastalclash/home.html). The costs of armoring can be significant; millions of federal, state and private dollars have been expended annually on shore protection, which can cost anywhere from $1800 to $7600 per linear foot of coast (Griggs in press-a).

Armoring varies widely in type of material, degree of engineering, and relative success in preventing coastal erosion and providing property protection (Griggs and Fulton-Bennett 1988). Riprap and seawalls are the most common armoring structures used in central California. Riprap can be defined as any large (1 to 6 ton) rocks used for coastal protection, with varying degrees of engineering; seawalls are continuous, rigid structures with vertical or concave faces. To clarify a common misconception, it is important to note that armoring is emplaced to protect buildings and infrastructure, not beaches (Kraus and McDougal 1996). Groin fields and beach nourishment are the common methods by which beaches are expanded, both of which are fundamentally different than armoring, which is constructed to halt erosion of cliffs, bluffs or dunes that have buildings behind or on top of them, or to protect a building built on the backshore (above the high tide line).

Public concern over use and regulation of the California coastline was aired in the early 1970s, the result of which was the establishment of the California Coastal Act in 1976. This act created the California Coastal Commission (Commission), which is tasked with regulating development in the coastal zone. Under the Coastal Act, new armor is only allowed to protect existing structures and new buildings must be setback enough to ensure that erosion will not threaten the house within its projected lifespan. The Commission, in coordination with local coastal planning agencies, provides permits for the emplacement and maintenance of coastal protection structures. Unfortunately, ambiguous language within the Coastal Act has been exploited and there is a need to design more specific long-range plans to limit the extent of coastal armoring (Griggs et al. 1992).

The Monterey Bay National Marine Sanctuary (Sanctuary), which encompasses 276 miles (444.2 km) of coastline from Marin to Cambria, was designated in 1992 to protect the resources of this unique marine environment. As of 1998, 15.1 miles (24.3 km) of the Sanctuary’s coastline have been armored (Griggs et al. in press-b). Various physical and biological impacts of coastal armoring may affect the resources of the Sanctuary both directly and indirectly. Most coastal protection structures are placed above the high tide line, the official boundary of the Sanctuary; yet some influences of armoring may impinge on the marine realm, and continued sea level rise and the accompanying coastal retreat will force many of these structures below the high tide line over time. The Sanctuary recognized the significance of protection structures on the shoreline and has identified it as a critical issue in the Coastal Armoring Action Plan of the Joint Management Plan.

The impacts of coastal protection structures are of great concern to local governments, private property owners, and the public. The most commonly recognized impacts (as outlined in Griggs (in press-a)) are: visual effects, placement loss, access issues, loss of sand supply from eroding cliffs, passive erosion, and active erosion. In addition, there are potential impacts to the biological communities that utilize the coastal zone. The following is a discussion of these impacts, including an appraisal of how differing armor types compare in relation to impacts, expense and engineering. This report is intended to provide general background information for regional coastal armoring plans for the Sanctuary.

IMPACTS OF COASTAL ARMORING STRUCTURES

Visual Impacts

Public outcry over armoring is largely the result of visual impacts, because coastal protection structures often look unnatural or unsightly and can negatively affect recreational beach experiences. In the past, emergency armor has been emplaced with no regard to aesthetics or long-term engineering standards. Slabs of concrete have been dumped at the bases of cliffs, as is the case near Lighthouse Point in Santa Cruz (Figure 2), and several different kinds of structures have been haphazardly used on the same stretch of coast, such as is the case at Opal Cliffs in Capitola (Figure 3).

Figure 2: Concrete blocks used as riprap near Lighthouse Point in Santa Cruz, California.

Figure 3: An unplanned assemblage of coastal armoring at Opal Cliffs in Capitola, California can have a visual impact on the beach user.

There are ways to mitigate visual impacts. New seawall engineering, with faces crafted of gunite or shotcrete, can be sculpted and colored to resemble the surrounding cliff or bluff face. Such walls are already used extensively in cliff stabilization on roadways and are gaining further use in the coastal zone, including a new, natural-looking wall protecting the cliff behind Cowell's Beach in Santa Cruz (Figure 4).

Figure 4: Photograph of cliff stabilization built to fill a seacave at Cowell's Beach in Santa Cruz. The 2004 gunite wall, outlined by the black dashed line, mimics the shape and color of the natural cliff.

The Commission, in compliance with section 30253 of the Coastal Act (2005), requires that a licensed civil engineer, who has experience in coastal processes, design new armoring structures. This has helped to reduce the number of shoddy, unregulated structures. One solution to the problem of unattractive, incongruent armoring being considered by the Commission is to plan a continuous, uniform coastal protection structure that spans across several parcels to ameliorate a regional erosion problem (Griggs and Fulton-Bennett 1988).

Placement Loss

Coastal armoring structures will inevitably cover up some portion of the beach in front of the structure they are built to protect; this impact is referred to as impoundment or placement loss. As with visual impacts, this is a tenuous issue with the public who lose beach area in order to benefit private property owners. The amount of beach that will be lost from construction of new armor can be easily calculated for inclusion in engineering plans and environmental impact statements.

In terms of impoundment, seawalls are almost always more favorable than riprap structures. Most seawalls are only a few feet (~6') thick and are built flush with the cliff or bluff, impounding a minimal amount of backshore area. Engineered riprap, on the other hand, should have a width (cross-beach) to height ratio of at least 1.5:1 or 2:1 to maintain structural integrity during strong storms (Griggs and Fulton-Bennett 1988). Thus, riprap that is designed to be 20 feet high could cover up to 40 feet of beach (in the shore-perpendicular direction); multiplying by the shore-parallel length of the riprap yields the square feet of beach lost by impoundment. In this case, if a 20-foot stretch of coast needed to be armored, an average seawall would impound 120 ft^2 of beach (6 ft wide x 20 ft long), while riprap would cover 800 ft^2 of beach (40 ft wide x 20 ft long). Westcliff Drive in Santa Cruz, for example, has had extensive beach loss because of riprap emplacement (Figure 5).

Figure 5: Riprap covering up significant amount of beach area in Santa Cruz, California, near the intersection of Westcliff Drive and San Jose Avenue.

Access Issues

In conjunction with impoundment, access to beaches can be lost when armor is installed. Lateral access is restricted when armoring bisects the shore-parallel continuity of a beach; the time frame of access-loss will depend on tidal and seasonal changes in beach width. As with the issue of impoundment, riprap tends to cover up a wider section of beach than a seawall, and would therefore be more likely to cut off lateral access. Yet in instances when the beach is narrow, especially during high tides and/or winter months, seawalls can also impair lateral access.

Vertical access, the ability to get to a beach from behind or above, can also be affected when armoring is placed on the coast. Riprap and seawalls can cover up paths or trails that lead to the beach. However, in most cases, a protection structure is placed against a near-vertical cliff or bluff face where vertical access was most likely difficult prior to armoring. As a mitigation measure, stairs or paths can be integrated within coastal protection structures to facilitate vertical access to the beach, though maintenance of these paths can become a safety issue over time if the armoring is structurally compromised (Figure 6).

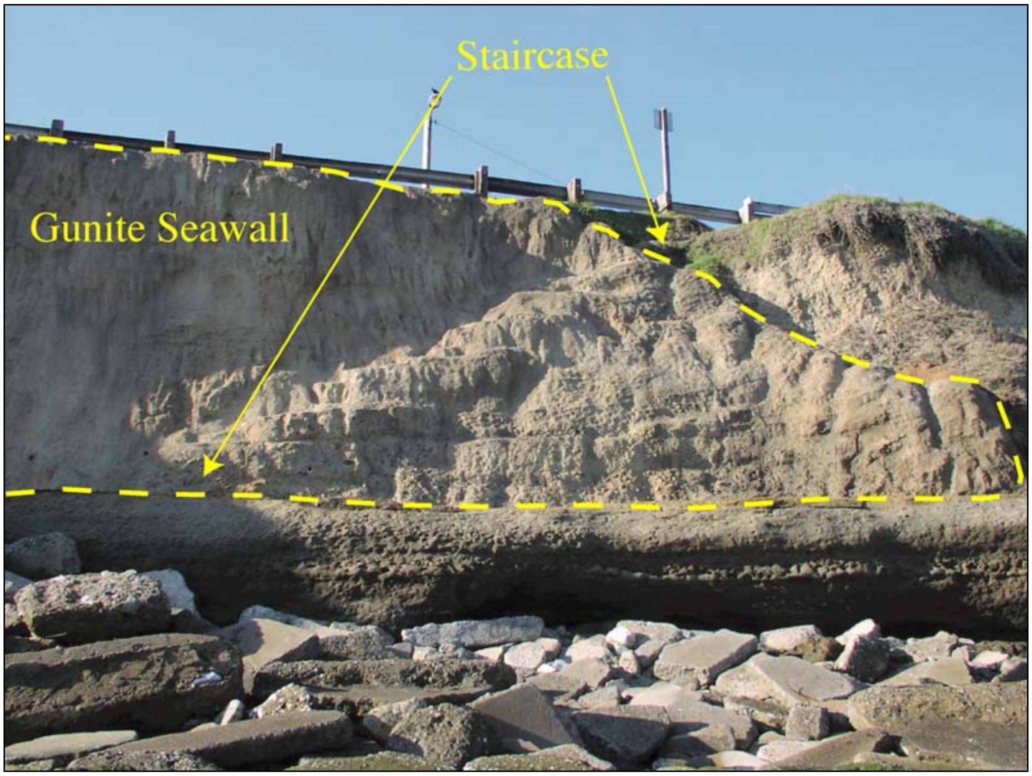

Figure 6: In this bluff stabilization project at Pleasure Point in Santa Cruz, the protective gunite (outlined with dotted line) was colored and textured to match the existing bluff materials, and access steps were built into the structure (Photograph by Gary Griggs).

Reduction of Sand Supply from Armoring of Cliffs

Comprehensive approaches to understanding coastal erosion include an assessment of anthropogenic reductions in sand supply. The breakdown of rocks and sediment in cliffs, bluffs and dunes creates sand that constitutes some fraction of the littoral budget. Armoring coastal landforms covers up those erosion-prone surfaces and may therefore reduce sand supply. These reductions can make downcoast beaches narrower, allowing more wave energy to erode cliffs, bluffs and dunes downcoast of the armored area.

The relative contribution of cliff erosion to sediment budgets will vary based on local geology and erosion rates. Thus, understanding the effects of coastal armoring on sand supply needs to be addressed on a littoral cell by littoral cell basis. For example, a recent study found that less than 1% of sand supply was contributed from seacliff erosion in the Santa Barbara littoral cell, while 12% of the sand in the Oceanside littoral cell originated from eroding cliffs (Runyan and Griggs 2003).

Mitigation measures for sand supply reduction from armoring include the replacement of sand, via beach nourishment, in equal volume to that which is lost by the emplacement of armoring structures. Yet, as noted above, the success and longevity of beach nourishment projects is debatable.

Passive Erosion

Passive erosion is perhaps the most significant and the most misunderstood impact of coastal armoring. Eighty-six percent of California's coastline is eroding, the result of which is a landward retreat of beaches, cliffs and other coastal landforms. Yet when a structure, such as riprap or a seawall, is constructed in front of a building to halt erosion, the shoreline is essentially fixed at that location. Adjacent landforms (beaches, cliffs, etc.) will continue to retreat landward, creating an artificial headland out of the armored segment of coast. If armor is placed at the base of a cliff that has a beach in front of it, the beach will continue to migrate landward on either side of the armored area, but there will be no beach in front of the armor, as depicted in Figure 7.

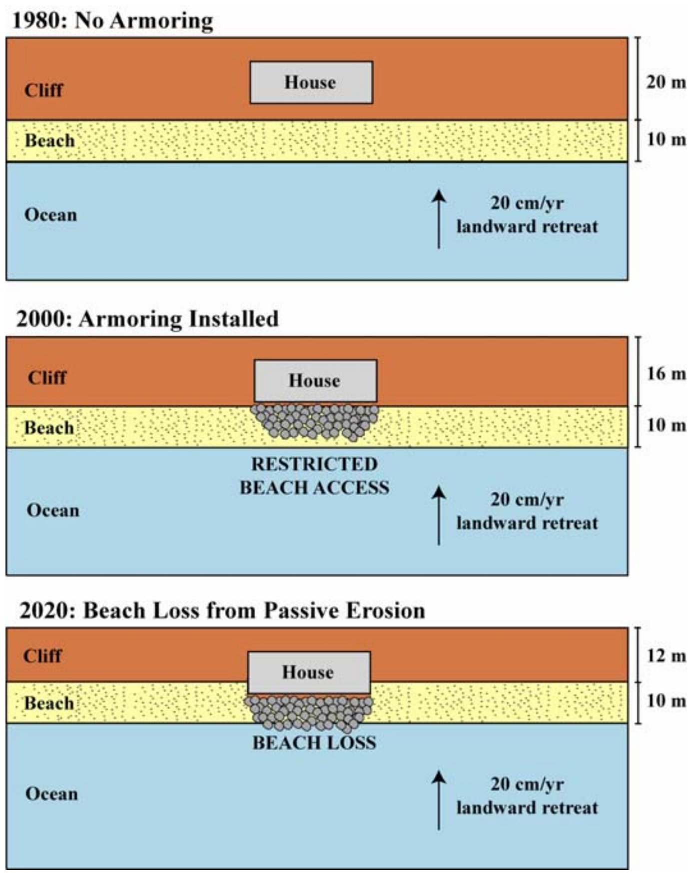

Figure 7: Aerial-perspective, schematic diagram depicting beach loss over time due to fixing the coastline with armor when coastal erosion rates are 20 cm/year, a realistic rate for California. Prior to its removal, Stillwell Hall in Marina, California, was a classic example of passive erosion (see Figure 1).

Passive erosion occurs regardless of the type of structure used; riprap and seawalls both fix the coastline and prevent the landward migration of beaches, cliffs, bluffs and dunes. One way to mitigate passive erosion is to nourish beaches with sand from other locations, though this is only a temporary solution to an incessant problem. As an alternative, removing dams from rivers will increase the sediment supply to beaches along much of the California coast (Farnsworth and Milliman 2003; Willis and Griggs 2003).

Active Erosion

Localized, accelerated erosion that might occur because of interactions between armoring structures and waves is referred to as active erosion. This type of erosion includes scour at the base of a protection structure or on adjacent segments of shoreline, and changes in overall beach morphology. Many people feel that seawalls initiate active erosion and are therefore detrimental to coastal environments, yet recent investigations may suggest otherwise.

A summary of over 40 scientific studies on the interactions between beaches and coastal armoring structures (including seawalls and riprap) found that active erosion may not be as prolific a problem as was once thought (Kraus and McDougal 1996). The review determined that reflection of wave energy off of coastal armor (waves bouncing off perpendicular to a structure) generally does not cause changes in beach profiles or scour in front of the armor. In addition, they ascertained that beach profiles in front of armoring retained the same amount of sand as non-armored beaches during storm events.

In an eight-year study by Griggs et al. (1994; 1997), over 2000 beach profiles were collected and analyzed across armored and non-armored beaches around northern Monterey Bay. In this exhaustive investigation, scour was documented in front of an armoring structure only during extreme storm events and the imprint of that scour was ephemeral. The study did find that, as winter approached, the summertime beach berm migrated landward slightly faster in front of coastal protection structures when compared to beaches without armoring. However, once typical, narrow winter beaches were established, there was no significant alongshore difference in the shape of armored and non-armored beaches. In winter months, Griggs et al. (1994) did document some scour on the downcoast end of the structure, extending in an arc-shaped zone for as much as 50 to 150 m. Yet, as summer advanced, the beach width widened and there was no trace of scour or berm erosion caused by the armor.

This study served to dispel, or at least bring into question, many common assumptions concerning interactions between armoring and beaches. First, seawalls are often perceived to cause more active erosion than other structures, such as riprap, because the former is less permeable than the latter. However, the 8-year study by Griggs et al. showed that there were no significant differences in beach profiles in front of a seawall versus riprap. Second, in contrast to the general sentiment that coastal armoring causes excessive erosion, there was no appreciable, long-term active erosion caused by seawalls or riprap on the Monterey beaches highlighted in the Griggs et al. study (1994; 1997). The real problem is passive erosion, which is an inevitable part of California coastal dynamics; beaches are eroding in front of armoring structures because the coastline is fixed at that spot, while the adjacent beaches are migrating landward.

Biological Impacts

While a significant amount of attention has been given to the physical effects of placing hard armoring structures on the coast, relatively little consideration has been focused on potential biological impacts. Armoring can be emplaced both above and below the high tide line. It is important to recognize that this is an extremely dynamic environment; passive erosion, for example, ensures that much of the armor placed above the high tide line will end up below that line as the coast retreats. The habitats most impacted by armoring are the beach, above the highest high tide line, and the intertidal zone, between the highest high tide and lowest low tide lines.

Riprap placed against a cliff to slow erosion can cover up extensive portions of the beach, which serves as habitat for many species of invertebrates and birds. The endangered Snowy Plover (*Charadrius alexandrinus*), for example, nests and feeds on beaches in the Sanctuary (USFWS 2005). Armoring in the intertidal zone can also cover up vital, natural habitats for fish, algae and invertebrates (MBNMS 2004). Organisms can also be directly smothered or killed during the construction phase of these coastal protection devices.

In addition to physically removing or disturbing habitats, armoring also adds hard substrate that can have implications for populations in the area (McGuinness 1989; Osborn 2002). If riprap is placed on top of a beach, the new substrate may attract different algae species that would otherwise not have had an appropriate attachment medium at that location (Figure 8). Different species, which can capitalize on armoring surfaces, may compete with species that had previously occupied those regions.

A recent study in northern Monterey Bay found that rock type can have an impact on colonization and subsequent recruitment of other organisms (Osborn 2002). The rocks used for riprap revetments are usually foreign to the area in which they are emplaced; therefore physical properties of the riprap will vary from local conditions. In this study, community structure was documented on basaltic riprap and on sandstone, the natural cliff material. Significant differences in intertidal communities were found living on the two rock types. Rock properties, such as porosity and color, affect the dampness and heat of the substrate upon which intertidal organisms settle and may impact population dynamics.

Figure 8: Algae growing on basaltic riprap in Santa Cruz, California. This riprap has covered up a beach, creating an artificial substrate for species recruitment.

In Sydney, Australia, a comparison between organisms living on rocky shores versus seawalls found that seawalls supported only half the diversity of mobile organisms when compared to nearby natural rocky substrates (Chapman 2003). The study found that the types of algae and sessile organisms were similar on both substrates, but that rocky shores were home to more rare species than seawalls. The paucity of mobile and rare organisms may have been due to the steep slopes and lack of rugosity, or microhabitats, used for conventional seawalls. Sculpting coastal armoring structures so that they mimic surrounding landforms may help avoid loss of community diversity.

Armoring may also have influences on large-scale biogeography. A review of intertidal systems in the northeast Pacific suggested that there is a substantial biogeographic break at Monterey Bay (Foster et al. 1991). This discontinuity in populations to the north and south of the Bay may be due to the extensive sandy shoreline that stretches from Aptos to Monterey. This area lacks hard substrate, upon which many intertidal organisms rely. If and when armoring is added to this area, it may provide settlement sites for species that otherwise could not live in the Monterey Bay intertidal zone. In this manner, the biogeographic break may be crossed and species from the north may be able to migrate south and vise versa. Similarly, armoring structures may provide habitat for species that are brought into harbors by boats, facilitating the spread of invasive species.

ENGINEERING OF COASTAL ARMORING STRUCTURES

With the exception of passive erosion, all of the impacts described above can be influenced by the design and type of armoring used. Methods for constructing and repairing coastal protection structures are not standardized and poor engineering can lead to failure and additional costs (USACE 1981; Griggs and Fulton-Bennett 1988; Chenault 2000). To be sustainable and effective, armoring must survive the following forces: overtopping by large storm waves, undermining by scour at the base, outflanking by erosion on either side, and battering by waves, sediment and debris. The following is a brief description of some of the engineering considerations in building riprap and seawalls.

Riprap

Engineered riprap must have several elements to efficiently protect the coast, as outlined in a study of the effectiveness of riprap in central California (Griggs and Fulton-Bennett 1988):

- Excavation of sand, if built on the beach
- Filter cloth at base
- A trench at the seaward edge of structure (referred to as a "toe trench") below maximum scour depth, with large stone (4-6 tons) in toe trench
- Stable slope angles of at least 1.5:1 (width across the beach: height), 2:1 is more successful
- Small core stones placed down first on top of filter cloth
- Large cap stone (3-5 tons) on top, positioned in an interlocking pattern
- Height great enough to prevent overtopping

In addition to these engineering specifications, riprap generally requires regular maintenance by adding rocks every 5 to 10 years. These structures can cost over $1500 per linear foot (in 2003 dollars), with annual maintenance costs of 2-15% of the initial cost. Riprap that is built on top of bedrock platforms generally lasts longer than those placed on beaches, because a significant amount of settling and burial can occur in active beach environments (Figure 9).

Figure 9: Riprap boulders commonly settle into deep sandy beaches or get buried, as seen here near the intersection of Westcliff Drive and David Street in Santa Cruz, California.

Seawalls

Seawalls have different engineering criteria. In general, due to their durability, concrete or gunite walls outlive timber seawalls and fare better than riprap, in terms of costs and benefits (Griggs and Fulton-Bennett 1988). Some recommended elements for seawall longevity include:

- Concrete mix with a low water to cement ratio
- Epoxy coated rebar with at least 3 inches of concrete between steel and seawater to prevent rusting of steel
- Deep (8-15 ft below MLLW) interlocking sheet piles in sandy areas
- At least 12” of thickness for the wall
- Wide, seaward sloping apron shoreward of the wall to prevent overtopping, when appropriate
- Holes drilled through entire width of the seawall (referred to as “weep holes”) to provide drainage and to prevent ponding behind the wall
- Maintenance of weep holes to prevent loss of fill from behind, around or underneath the wall
- Filter blanket (filter cloth and gravel) positioned behind seawall to reduce loss of fill

Seawalls, if constructed and maintained properly, can endure for decades. The O’Shaughnessy Seawall on San Francisco’s Ocean Beach, for example, has survived over 75 years without major repair. Despite their durability, seawalls are often not used because they can be expensive. Recent extensions of the massive O'Shaughnessy structure have cost over $7,000 per linear foot, while smaller-scale seawalls can cost upwards of $3,000 per linear foot, depending on their design and size (Griggs 1999). However, seawalls can fail, even with good engineering, because of severe, unpredicted storms, such as those that occurred during the 1982-83 El Niño events. Thus, no seawall should ever be considered to provide permanent protection.

CONCLUSIONS

Over 900 miles of actively eroding coastline, encroaching coastal development and crumbling bluffs pose an immense challenge to resource management agencies in California. The construction of coastal protection structures, such as riprap and seawalls, has been the most widespread solution to prevent loss of property, yet armoring has many impacts that reach far beyond the individual parcels they are designed to protect. Because armoring is built to save buildings, not to protect beaches, the public can be negatively affected by these coastal protection structures in terms of visual impacts, lateral and vertical access, and beach loss due to passive erosion.

Beach nourishment has been promoted as a solution to ameliorate the impacts of coastal armoring, yet the sustainability and cost-effectiveness of these projects has yet to be proven and is highly site-specific. Adding sand to beaches in an area with high littoral drift rates, as is true along most of the California coast, may be imprudent. Compensating for sand supply losses, by removing coastal dams, for example, may be a more logical, and more sustainable, solution for increasing beach widths. The State of California has recognized the need for a more holistic approach to sediment issues and is working to restore balance to littoral cells through the California Coastal Sediment Management Master Plan (CCSMW 2004).

There are alternatives that allow property owners to protect their assets, while mitigating some of the negative impacts. Regional-scale protection, for example, utilizes continuous, uniform armor to protect a stretch of coast that spans many parcels with similar erosion problems. These structures, such as gunite bluff stabilization, can mimic the natural cliff face and replace a mismatched array of protection devices. This type of large-scale structure may also improve structural integrity because weak points can be created at the junction between two different types of armoring. In addition, comprehensive armoring can include sufficient vertical public access and can ensure that the least amount of beach is covered up to improve coastal access.

A long-term, regional-scale erosion response and armoring plan could be evaluated for alternatives that may save costs over time. Under such a plan, prediction of erosion hotspots could alleviate many of the problems that occur from the construction of emergency structures, which are often less thorough in their impact analysis and mitigation. In addition, relocation of threatened structures could be considered a realistic and economically-viable option. Through the Coastal Armoring Action Plan, the Sanctuary is initiating a regional plan of this nature to protect the resources of the Monterey Bay and to help California's coastal development be flexible and progressive in the face of an incessantly eroding shoreline.

LITERATURE CITED

California Coastal Act (2005). Public Resources Code, Division 20. Section: 30253.

CCSMW (2004). "California Coastal Sediment Management Workgroup: Sediment Master Plan." State of CA. http://dbw.ca.gov/csmw/sedimentmasterplan.htm.

Chapman, M. G. (2003). "Paucity of mobile species on constructed seawalls: effects of urbanization on biodiversity." Marine Ecology Progress Series 264: 21-29.

Chenault, C. D. (2000). Shore protections structures in Oregon: An analysis of demand and the implementation of engineering recommendations. Masters Thesis in Marine Resource Management, Oregon State University: 74.

Farnsworth, K. L. and J. D. Milliman (2003). "Effects of climatic and anthropogenic change on small mountainous rivers: the Salinas River example." Global and Planetary Change 39: 53-64.

Foster, M. S., A. P. De Vogelaere, J. S. Oliver, J. S. Pearse and C. Harrold (1991). Open coast intertidal and shallow subtidal ecosystems of the northeast Pacific. Ecosystems of the World 24: Intertidal and Littoral Systems. Ed. A. C. Mathieson and P. H. Nienhuis. New York, Elsevier: 235-272.

Griggs, G. B. (1986). "Relocation or reconstruction: Viable approaches for structures in areas of high coastal erosion." Shore and Beach 54(1): 8-16.

Griggs, G. B. (1999). "The Protection of California's Coast: Past, Present and Future." Shore and Beach 67(1): 18-28.

Griggs, G. B. (in press-a). "Impacts of Coastal Armoring." Shore and Beach.

Griggs, G.B., K.B. Patsch, and L. Savoy, Eds. (in press-b). Living with the Changing California Coast. Berkeley, CA, University of California Press.

Griggs, G. B. and K. W. Fulton-Bennett (1988). "Rip rap revetments and seawalls and their effectiveness along the central California coast." Shore and Beach 56: 3-11.

Griggs, G. B. and K. Patsch (2004a). "Cliff erosion and bluff retreat along the California coast." Sea Technology September: 36-40.

Griggs, G. B. and K. B. Patsch (2004b). "California's Coastal Cliffs and Bluffs." Formation, Evolution, and Stability of Coastal Cliffs-Status and Trends USGS Professional Paper 1693: 53-64.

Griggs, G. B., J. E. Pepper and M. E. Jordan (1992). "California's Coastal Hazards: A Critical Assessment of Existing Land-Use Policies and Practices." Special Publication of California Policy Seminar Program: 224.

Griggs, G. B., J. F. Tait and W. Corona (1994). "The Interaction of Seawalls and Beaches: Seven years of monitoring, Monterey Bay, California." Shore and Beach 62: 21-28.

Griggs, G. B., J. F. Tait, L. J. Moore, K. Scott, W. Corona and D. Pembrook (1997). "The Interaction of Seawalls and Beaches: Eight years of field monitoring, Monterey Bay, California." U.S. Army Corps of Engineers, Waterways Experiment Station Contract Report CHL-97-1: 34.

Kraus, N. C. and W. G. McDougal (1996). "The effects of seawalls on the beach: Part I, an updated literature review." Journal of Coastal Research 12(3): 691-701.

Leonard, L., K. Dixon and O. Pilkey (1990). "A comparison of beach replenishment on the U.S. Atlantic, Pacific and Gulf coasts." Journal of Coastal Research Special Issue(6): 127-140.

MBNMS (2004). "Monterey Bay National Marine Sanctuary Site Characterization." MBNMS. http://www.mbnms.nos.noaa.gov/sitechar/welcome.html.

McGuinness, K. A. (1989). "Effects of some natural and artificial substrata on sessile marine organisms at Galeta Reef, Panama." Marine Ecology Progress Series 52(2): 201-208.

Osborn, D. A. (2002). "The effects of geology on intertidal community ecology." Conference Proceedings: California and the World Ocean '02, Santa Barbara. American Society of Civil Engineers.

Runyan, K. and G. B. Griggs (2003). "The effects of armoring seacliffs on the natural sand supply to beaches in California." Journal of Coastal Research 19(2): 336-347.

USACE (1981). Seawalls - Their Applications and Limitations, CENT-III-8. Coastal Engineering Research Center, Fort Belvoir, VA. 7 p.

USFWS (2005). "Snowy Plover Critical Habitat." Sacramento Fish and Wildlife Office. http://sacramento.fws.gov/ecosystems/coast/wsp_crit_hab_units.htm.

Willis, C. M. and G. B. Griggs (2003). "Reductions in fluvial sediment discharge by coastal dams in California and implications for beach sustainability." Journal of Geology 111: 167-182.

ACKNOWLEDGEMENTS

I would like to thank Dr. Gary Griggs, Professor of Earth Sciences and Director of the Institute of Marine Sciences at the University of California Santa Cruz, for providing his expertise and review of this report. Dr. Andrew DeVogelaere and Brad Damitz of the Monterey Bay National Marine Sanctuary also provided thoughtful evaluation and advice. In addition, I would like to thank Dr. Steve Gittings and Kathy Dalton, of the National Marine Sanctuaries Program, for assistance with review and publication.