California Coastal Commission

Improved Valuation of Impacts to Recreation, Public Access, and Beach Ecology from Shoreline Armoring

- Administrative Draft -

Not Approved by the Coastal Commission

Principal Authors:
Jonna Engel, Ph.D., Lesley Ewing, Ph.D.,
Michelle Jesperson, Jeannine Manna, Mary Matella, Ph.D., and Elena Perez

Developed with Input from:
Jenny Dugan, PhD, Karen Martin, PhD, Dave Hubbard,
Phil King, PhD, and Chad Nelson, PhD

September 28, 2015

This report was prepared with financial assistance from National Oceanic and Atmospheric Administration, as a FY 2012 Project of Special Merit (NA12NOS4190026)

(This page left intentionally blank.)

TABLE OF CONTENTS

EXECUTIVE SUMMARY **1**
1. INTRODUCTION **6**
- **Background** **6**
- **Project Scope** **9**
- **Valuation Method Development** **10**
- **Grant Deliverable** **12**

2. SANDY BEACHES (Task 2) **13**
3. REVIEW OF ECONOMIC VALUATION METHODS **25**
4. ECOSYSTEM VALUATION (Task 3) **28**
- **Characteristics of Beach Ecosystems** **28**
- **Effects of Coastal Armoring** **28**
- **Academics' Recommended Ecosystem Valuation Method for Beaches** **29**
- **Commission Staff Beach Ecosystem Valuation Conclusions** **33**

5. RECREATION AND ACCESS VALUATION (Task 4) **36**
- **Consumer Surplus/Day-Use Value and the Academics' Recommendations** **36**
- **Academics' Recommendations about Beach Attendance** **37**
- **Hypothetical Case Studies Prepared by the Academics (Task 5)** **41**
- **Commission Staff Recreation Valuation Conclusions** **44**

6. MITIGATION (Task 6) **47**
- **Guiding Principles for Mitigation** **47**
- **Current Commission Mitigation Approach** **48**
- **Implications for Mitigation Based on Academics' Recommendations** **50**

7. DEVELOPMENT OF GUIDELINES (Task 7) **52**
- **Addressing Major Data Gaps and Procedural Limitations** **52**
- **Recommendations** **54**
- **Summary and Next Steps** **58**

Appendix A. Deliverable from Academics **A-1**
Appendix B. Scope of Work for Academic Assistance **B-1**

List of Figures

Figure 1. Total economic value conceptual diagram. 25
Figure 2. Recreational demand curve with consumer surplus 36

List of Tables

Table 1. Task list for NOAA Project of Special Merit: Improving Valuation of Impacts to Recreation, Public Access and Beach Ecology from Shoreline Armoring.................................. 12
Table 2. Examples of costs for restoration of beach ecosystems in California 31
Table 3. Consultant Recommendations for Day Use and Attendance Density 39
Table 4. Recreational value case study parameters and results 44

EXECUTIVE SUMMARY

Beaches form the transition zone between marine and terrestrial ecosystems and face the brunt of coastal storms and extreme events. Beach and bluff erosion are natural responses to these events and with climate change and sea level rise, increased erosion of both beaches and bluffs is expected. When erosion threatens inland development, humans often respond with "hard armoring," such as seawalls, revetments and other rock, wood, and concrete structures. When erosion is persistent, hard shoreline armoring results in the direct loss of beach sand and impacts the sandy beach ecosystem as well as beach access and recreation. As the Coastal Commission aims to protect and enhance California's coast and ocean resources through the implementation of the California Coastal Act, the challenges of preserving beaches will increase over time and require new innovative approaches to balancing resource and development needs.

This project builds upon ongoing efforts by the Coastal Commission to fully mitigate the adverse impacts of shoreline armoring to beach recreation, access, and ecology where those impacts are not feasibly avoided. Commission staff worked with beach ecologists and economic valuation academics to document and evaluate beach resources and to explore beach valuation methods that might better account for the impacts of permitted shoreline armoring. The overarching goal of this project was to better assess and determine the true costs to the public resulting from installation of shoreline armoring projects using improved methodologies that could be carried out by staff using information typically received from permit applicants.

To apply the latest and most appropriate economic modeling of recreational use and access value and beach ecosystem value, the Coastal Commission entered into a contract with academic experts on beach recreational use economics and beach ecology: Dr. Philip King, Associate Professor at San Francisco State University in Applied Microeconomics and Environmental Economies; Dr. Chad Nelsen[1], independent consultant; Dr. Jenny Dugan, Associate Research Biologist with the Marine Science Institute at the University of California at Santa Barbara; David Hubbard, Assistant Research Specialist at the Marine Science Institute, University of California, Santa Barbara and founding principal of Coastal Restoration Consultants, Inc.; and Dr. Karen Martin, Professor of Biology at Pepperdine University. These academic consultants (academics) provided expert review of the most current economic and ecological literature to recommend methods for Coastal Commission staff potentially to use in valuing shoreline armoring impacts for purposes of specifying mitigation for such impacts. Their final report is provided as Appendix A of this report.

In setting the context for the beach valuation and mitigation strategies proposed, this report presents a characterization of California beaches, with special attention given to southern California. This section identifies and categorizes recreation, access, and ecological aspects of California beaches according to significant natural processes (i.e. geologic processes, storm events) and anthropogenic factors (coastal development and sand supply interruptions). It also

[1] During the completion of the contracted work, Dr. Nelsen took a position as the Executive Director of Surfrider Foundation; this was not his affiliation at the start of the contract.

presents detail on the historical management of beaches in two littoral cells: Oceanside and Monterey Bay.

This report presents a general overview of economic methods. Since beach recreation, access and ecology are not goods that are bought and sold through normal market activities, it is not easy to fit these services into a traditional market framework. The total economic value model provides a more comprehensive framework for quantifying the benefits associated with a non-market resource, including direct use, indirect use, and non-use values. Use value refers to those values associated with current or future use of an environmental resource by an individual. The use can either be consumptive (e.g. recreational fishing) or non-consumptive (e.g. surfing). Direct use is most relevant for the Commission's quantification of sand supply and beach recreation values. Indirect use values apply when an environmental resource provides benefits which are more difficult to measure but still apparent, such as flood control or beach habitat. The use of beaches by future generations and their existence value (a non-use value) are not included in this evaluation; and as a result the beach value estimates will be a lower bound for total economic value.

The academics reviewed the impacts of shoreline armoring on sandy beach ecosystems, laying the groundwork for developing an ecosystem valuation method. Ecological impacts due to armoring result from direct loss of beach due to the physical footprint of the structure, from erosion and scour resulting from the armoring, and from reduced sediment supply as a result of fixing the back beach. These physical changes to the beach environment have ecological impacts such as the loss of sandy beach zones/habitat and the concomitant loss of infaunal biomass and biodiversity (upper beach zones are most heavily impacted), loss of sandy beach area currently or potentially used for feeding, roosting, nesting, or reproduction of wildlife, and loss of sandy beach ecosystem services and functions (flood protection, nutrient cycling, etc.). The highly dynamic nature of the ecological components and functions of sandy beaches (beaches change on daily, weekly, seasonal, yearly, and decadal time periods) make quantitatively evaluating the sandy beach ecosystem expensive, time-consuming, and difficult.

The literature quantifying ecosystem service values for sandy beaches is limited. The economists and ecologists together reviewed the possible methods for assessing monetary value for beach ecosystems and framed a conceptual model for valuing ecological resources. Rather than quantitatively assessing what ecological components and functions may be altered or lost on a given stretch of sandy beach due to shoreline armoring, the academics recommend using the cost of restoring comparable sandy beach habitat (replacement value), as a simple and defendable proxy valuation method for mitigating the ecological impacts of coastal armoring. The academics' recommended method uses the length of a new shoreline armoring project and the cost per linear foot for a beach ecosystem restoration project (that includes removal of obstacles to beach migration) to derive a sandy beach ecology value. The academics recommend that the Commission adopt a no-net loss policy for beaches, as some state agencies have applied to wetlands, and a 4:1 mitigation ratio for the beach ecology mitigation fee. [2] Commission staff

[2] The Coastal Act requires the avoidance of wetland fill and impacts except for certain specific allowable uses. Thus, while the Commission's regulatory approach is supportive of a "no net loss" policy when impacts need to be

concluded that the ecological framework presented by the academics is promising, though it would benefit from additional data development and analysis concerning beach ecosystem restoration project costs (beach nourishment is not considered restoration by the academics) to facilitate its application statewide.

In addition to deriving a method to quantify ecological impacts, the academics reviewed the economic literature and identified analytical steps to derive values for recreation and access impacts due to armoring. The academics recommend using the value of a day at the beach (consumer surplus) and attendance density to determine a beach recreation value. They presented a set of studies from which a benefit transfer approach could be used to apply average consumer surplus and beach attendance values to new sites. The economists proposed one consumer surplus value (value of a beach day) for the state, and two averages for beach attendance density (for northern and southern California). They also developed two case studies to examine application of the recreation valuation method—for hypothetical projects at Del Monte and San Elijo Beaches. Commission staff recognize that the recreation valuation method is at the forefront of economic science applied to quantifying recreation use values. Implementation of this method would also benefit from additional peer review and local data collection to support its application in specific places.

Finally, the report lays out mitigation strategies for shoreline armoring impacts on beach ecology and recreation and access. While the proposed methods may not be completely actionable in all cases due to limited data, they point to additional next steps as well as recommendations on how to better mitigate the impacts of shoreline armoring. Ideally, the recommendations contained in the academic report will ultimately be useful to the application of a common methodology for reviewing shoreline armoring permit applications case-by-case, including identification of appropriate mitigation based on the specific impacts of each case. In addition, this report will support the development of policy guidance for use in Local Coastal Programs (LCPs) (updates or new certifications). The project resulted in eight recommendations pertaining to LCP updates, reviewing permit applications, and agency-wide efforts, summarized below.

LCPs provide a mechanism to better refine data and identify opportunities for mitigation to improve project implementation at the local level regardless of mitigation methodology. Commission staff recommends that local governments:

1) Identify potential mitigation projects for recreation and ecological losses. Local governments should also prioritize potential areas for public access and recreation improvements and beach ecology restoration that meet criteria based on consideration of potentially-impacted resources in each LCP jurisdiction.
2) Include in LCPs a mechanism for collecting and applying mitigation fees. Managing in-lieu mitigation fees and allocating them to appropriate projects could be streamlined in advance of new valuation methods, in preparation for a potential increase in the collection of mitigation fees.

---

mitigated, the Coastal Act doesn't allow for approving the loss of wetlands simply because they may be proposed to be offset elsewhere. See *See Bolsa Chica Land Trust v. Superior Court* (1999)

3) Generate local attendance density data and other relevant recreational use data for use in the recreation valuation method. Variation in recreation use and access patterns along the California coast could be better accounted for with local, long-term attendance and use data.

Just as LCPs provide opportunities to improve mitigation approaches, coastal development permits (CDPs) provide a mechanism for integrating some of the results of this project and preparing for eventual changes in mitigation strategies. Commission staff recommends that CDPs:

4) Identify mechanisms for how applicants/permittees can mitigate for recreation and ecosystem impacts identified and mitigated by collection and application of in-lieu fees.
5) Consider and integrate into findings as relevant analytic discussions derived from this report detailing information gathered from the beach valuation project literature reviews explaining the impacts to recreation, sand supply and ecology that result from shoreline armoring.

Lastly, peer review and local data collection for validation would support eventual potential application of the methods recommended by the consulting experts of this project. Commission staff should also continue to collect new information on beach recreation and ecosystem valuation as the state of the science progresses. Commission staff recommends the agency:

6) Obtain peer review of the academics' recommended value for state-wide consumer surplus as well as suggestions for ways to update this value as new, peer-reviewed research becomes available.
7) Continue to research and collect data on beach restoration projects as they occur throughout the state. These data could be potentially used at a later date to update/refine the restoration cost estimates for the ecology valuation method.
8) Establish a Beach Valuation Task Force within Commission staff to continue work on development, refinement, and application of beach valuation methods, including data collection that could support their future implementation, and evaluation of application of these methods in the context of the Coastal Act.

In summary, the goal of this project was to provide new methods to better assess the true costs of shoreline armoring to the public. The results, based on the academic consultant recommendations, provide a potential method for valuing recreational use of beaches. This report is also an important first step at developing the framework for accounting for the impacts of shoreline armoring on beach ecosystems and translating this into a mitigation value for these impacts. Thus, this effort sets the stage for a more comprehensive valuation of shoreline armoring impacts on beaches, but it does not attempt to value all aspects of beaches. It does not quantify people's existence value of beaches. Not all use values are estimated either, such as revenues related to surfing, fishing or visitor spending contributing to local economies. The recommended methods focus on value related most specifically to uses or components of the beach that support human recreation and provide ecological habitat. As a result, the mitigation recommended in this study is conservative and most likely continues to undervalue to true value of California's beaches. However, this beach valuation project provides a good starting basis for eventually adopting new methods for fully mitigating armoring impacts to beach recreation, access, and ecology.

1. INTRODUCTION

Background

Beaches are dynamic landforms altered by wind and waves in a continual process of accretion and erosion, as well as habitat for a myriad of life forms. They are recognized as valuable socioeconomic, recreational, and cultural resources worldwide. Coastal communities attract ever increasing numbers of people, as they offer a wide array of experiences for residents and visitors. California's 1,100 miles of coastline are varied and diverse and represent several different types of beaches and geological features with long stretches of wide sandy beaches, long stretches of rocky and high cliffed shoreline, and numerous small pocket beaches.[3] California beaches, both wide sandy beaches and pocket beaches, are significant financial assets to coastal communities and the state. In recent years, beach recreation alone accounted for about $3.8 billion in revenue annually and all coastal tourism brought in $12 to 14 billion annually[4], more than twice the value of the state's agricultural output. Beaches are also a yearly recreational destination for 67% of Californians, a higher percentage than any other outdoor activity destination.[5]

A man takes advantage of the King Tides to dig for clams during low tide on the beach in Crescent City. Photo Credit: Amanda Hennessy

[3] Scholar, D.C. & G.E. Griggs 1998. "Coastal Processes within a Small Pocket Beach" in Proceedings from Ca. Coastal Hazard Conference, Santa Barbara, CA, Nov 12 – 14, 1997, USC Sea Grant Urban Ocean Program.
[4] Kildow, J. & C. Colgan. 2005. "California's Ocean Economy: Report to the Resources Agency, State of California" prepared by The National Ocean Economics Program; and
King, P. 1999. "The Fiscal Impact of Beaches in California." *Public Research Institute*, San Francisco University, Report Commissioned by California Department of Boating and Waterways.
[5] Scripps Institute, http://coastalchange.ucsd.edu/st3_basics/beaches.html.

At first glance, beaches may appear as nearly barren landscapes, largely absent of life. In fact, beaches provide significant habitat for multitudes of species of plants and animals. They also serve as breeding grounds for many species of marine mammals and birds that are not permanent beach residents. Additionally, beaches provide habitat for listed species such as western snowy plovers and least terns as well as spawning habitat for a very unique fish, the grunion, that comes out of the water to breed and deposit its eggs in the sand. The sand supports both microscopic and macroscopic organisms including algae, polychaete worms, bivalves, and crustaceans. This community of infaunal species attracts predators such as fish and seabirds, which depend on sandy beaches for their foraging activities. In addition to their remarkable biological and physical diversity, beaches provide unique and important ecological services. These services include filtering water, recycling nutrients, buffering the coast from storm waves, and providing critical habitats for hundreds of species.

An issue of major concern facing California today is the fast pace of disappearing beaches due to natural processes (i.e. geologic processes, storm events) and anthropogenic factors (coastal development and sand supply interruptions). Since much of the coast is developed, beach loss puts development at risk from erosion and inundation. Future accelerated sea level rise and extreme storm events will further increase beach losses and risks, and the demand for protective options such as beach nourishment, seawalls, rip rap or other structures is likely to increase.

Seawalls, revetments, and other types of hard armoring have long been used to protect backshore development from erosion and flooding, but have deleterious effects on beach ecosystems. Yet, these protective options often have unintended ecological and public access consequences such as loss of biodiversity and ecosystem services and replacement of recreational beach area with armoring structures. Confounding the immediate impacts, these structures cause continuing loss of sand due to erosion, scour, and reductions in sand reaching the coast. With that loss of sand, there may be a corresponding loss of recreational area and habitat important for a wide range of species that use the land/sea interface provided by the beach for foraging and reproduction.

The Coastal Commission has long grappled with the tension between the human desire for stable shorelines and recognizing the dynamic nature of the beach environment. Understanding the interaction of coastal processes and shoreline development, such as armoring, is critical to addressing this tension. In addition, as discussed in the Coastal Commission's 2013-2018 Strategic Plan, the agency's fundamental goals of maximizing public access and recreation and protecting coastal resources such as beaches are often challenged by proposals for shoreline armoring.

Seashore armoring blocks public access at high tide on Faria Beach Park in Ventura.
Photo Credit: Lesley Ewing

Coastal Act Section 30235 states:

> *"Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fishkills should be phased out or upgraded where feasible."*

Accordingly, Section 30235 only requires the Commission to authorize the construction of shoreline protective structures when the structures are required to serve coastal dependent uses or protect existing structures or public beaches in danger from erosion. The Coastal Act provides these limitations because shoreline armoring can have a variety of impacts on coastal resources, including effects on sand supply, public access and recreation, coastal views, natural landforms, marine resources, and overall shoreline beach dynamics on and off site. While the Coastal Act allows for shoreline armoring as outlined above, it also provides for the protection for public access, recreation and beach resources, such as habitat and visual quality. Therefore, the Commission always considers options that will avoid adverse impacts to coastal resources to the maximum extent possible. When these impacts are unavoidable, it seeks to fully mitigate them.

While the Coastal Act allows for the construction of shoreline armoring in certain situations, it requires mitigation for adverse impacts to local sand supply and protection of coastal resources. Over the years, the Commission has developed a method to quantify several impacts from shoreline armoring: (1) physical encroachment onto the beach from constructing the structure, (2) future loss of beach that will occur when the nearshore beach continues to erode and the back beach remains fixed, and (3) future loss of beach sand that would have been contributed to the littoral cell from back shore erosion. The first two of these factors represent physical losses of beach area and these losses have significant consequences to beach access and recreation opportunities. The third factor has direct effects to available sand supply and the ability of beaches to form and expand. The Commission has been proactive in requiring that projects mitigate for both the direct losses of beach area and the losses of beach sand. The Commission's mitigation for direct beach losses, however, does not directly assess impacts to recreation, nor does it address any of the ecological impacts from shoreline armoring. This project aims to identify a way to more accurately value the recreational losses related to the beach loss and to also value the ecological losses that result from shoreline armoring. The valuation does not address or recommend modification to the Commission's method for mitigating the losses of beach sand.

Project Scope

This project builds upon ongoing efforts by the Coastal Commission to fully mitigate the adverse impacts of shoreline armoring to beach recreation, access, and ecology. Commission staff worked with beach ecology and economic academics to document and to evaluate beach resources and develop a beach valuation method to better account for the impacts of permitting hard shoreline armoring. "Hard" shoreline armoring is a broad term for most engineered features such as seawalls, revetments, cave fills, and bulkheads that block the landward retreat of the shoreline. "Soft" armoring solutions to address erosion and flooding, such as beach nourishment, were initially included in the scope of work. However, Commission staff quickly recognized that soft armoring poses vastly different recreational and ecosystem valuation questions than does hard armoring and so soft armoring was removed from the project scope.

Beaches provide and evoke many different values, some quite general and some quite specific. People, of course, get tremendous value from their use of beaches, and there is a significant literature on valuing this use based on, for example, consumer willingness to pay for a day at the beach. For beach communities, there are direct market benefits from tourists who rent hotel rooms, buy meals, buy or rent beach equipment, etc. Tourism also generates indirect market impacts, resulting from the spending by the people whose employment depends upon the tourist economy. These economic impacts are often measured by the tax dollars paid directly or indirectly through tourism activities. Beach value, however, extends beyond tax revenues, and contributes to the overall value to society that comes from there being a beach. Such values can include an existence value (the value that comes from knowing that a beach exists, even if people do not visit it), the value it can provide for future generations, values for erosion and flood protection, or values due to proximity to surfing and fishing resources. This project focuses only on beach access, recreation and habitat values. Thus, this effort sets the stage for a more comprehensive valuation of shoreline armoring impacts on beaches, **but it does not attempt to value all aspects of beaches**.

The wide, sandy beaches of Huntington Beach draw large crowds in the summer. Photo Credit: Lesley Ewing

Valuation Method Development

The use of economic valuation in quantifying benefits of natural resources (like recreational use and beach habitat) is an area of emerging science.[6,7] The use of economics is highly anthropocentric and assumes that humans can meaningfully measure these values. However, the array of standard techniques that economists have developed has been widely accepted in public policy debates and legal proceedings. In addition, in practice, providing no economic (dollar) value for non-market goods/services such as natural resources often leads others to assume that the good/service has no value. By assessing beach recreation and access and ecological impacts of shoreline armoring, important dimensions of cumulative impacts to beaches are better captured than current mitigation practices allow.

This project required access to expert knowledge of beach ecology and economic valuation techniques to propose valuation methods for recreational, public access, and ecological losses

[6] Naeem, S., et al. "Get the science right when paying for nature's services." *Science* 347.6227 (2015): 1206-1207.
[7] Costanza, Robert, et al. "The value of ecosystem services: putting the issues in perspective." *Ecological economics* 25.1 (1998): 67-72.

due to shoreline armoring projects. The Commission hired a team of qualified academic academics with the combined technical expertise needed for this grant: Dr Philip King, Associate Professor at San Francisco State University in Applied Microeconomics and Environmental Economies; Dr. Jenny Dugan, Associate Research Biologist with the Marine Science Institute at the University of California at Santa Barbara; David Hubbard, Assistant Research Specialist at the Marine Science Institute, University of California, Santa Barbara and founding principal of Coastal Restoration Consultants, Inc.; and Dr. Karen Martin, Professor of Biology at Pepperdine University. Dr. King requested and was given permission to augment the teams' economic valuation expertise by adding Dr. Chad Nelsen as a non-academic sub-contractor, to the initial scope of work Task 1 of the NOAA grant. A description of the academic academics' qualifications and their CVs are included in Appendix B.

The Commission wrote the scope of work for the academics to identify a way to assess values that could be carried out by staff with information typically received from permit applicants and not be a significant new complex tool for applicants or staff to use. The economic academics (Drs. King and Nelson) proposed a simple method for valuation of beach recreation and access. This method is based on the value of a beach day, visitor attendance, and the loss of beach over time due to shoreline armoring. Given the complexity and dynamic nature of sandy beaches, the ecology academics (Drs. Dugan and Martin and Mr. Hubbard) found that currently there is not a simple economic model for valuing ecological losses due to shoreline armoring that would adequately capture the ecological value of beach ecosystems. Instead, the ecology academics developed a conceptual rationale to initiate the development of an ecological valuation method based on offsets for California beaches.

Grant Deliverable

Commission staff has prepared this report as fulfillment of NOAA Contract NA12NOS4190026. Some tasks have been prepared by staff exclusively, while other tasks have been informed by and developed from information and analysis provided by the academics. Table 1 summarizes the NOAA tasks, the report sections addressing each task, and the relevant sections of the academics' report (Appendix A) that inform the entire grant deliverable. Throughout the report, grant tasks are referenced in paranthesis next to the headers of applicable sections.

Table 1. Task list for NOAA Project of Special Merit: Improving Valuation of Impacts to Recreation, Public Access and Beach Ecology from Shoreline Armoring

TASK	TASK NAME	CCC REPORT SECTION	ACADEMICS' REPORT SECTION (Appendix A)
1	Create Scope of Work and Solicit Consultant/Academic Assistance	Section 1 and Scope of Work	
2	Categorization of Beaches across Southern California	Section 2	
3	Baseline Ecological Resources, including beach ecology valuation methodology and ecosystem valuation method guidelines	Section 4	Section 4
4	Development of Recreation and Access Valuation Methodology	Sections 3 and 5	Section 2
5	Case Study – Review Beach Nourishment Project (revised to address examples of armoring)	Section 6	Sections 3.6, 3.7 and 5.4
6	Development of Appropriate Mitigation (Criteria and Strategies)	Section 7	Sections 3.1 – 3.5 and 5
7	Development of guidelines and list or relevant materials for reviewing permit applications	Section 8	Sections 3.4, 5.2 and Appendix I

2. SANDY BEACHES (Task 2)

Beaches are unique and dynamic ecosystems that link marine and terrestrial environments and are found on all continents of the world. Yet, sandy beaches, one of the most threatened global ecosystems and, are under severe pressure from the combined impacts of sea level rise, coastal development, and management actions to protect coastal properties.

The unique geomorphology of the California coast, along with swell direction, shoreline orientation, wave exposure, and geological processes occurring inland, all play a role in shaping California beaches. The variable geology along the California coast accounts for the different beach types from northern California to southern California. The Northern and Central California shoreline is known for its rocky coast, with occasional beaches occurring where rivers cut through erosive rock material, delivering the necessary sediment to form sandy beaches. Southern California, on the other hand, is known for its long, sandy beaches, which were formed as a result of crust downwarping, or depression of the earth, that was then filled with sediment. Pocket beaches, which consist of narrow strips of sand bounded by rocky headlands, occur along the entire California coast. A few beaches in California are comprised of small cobbles or rocks, rather than sand, but these are the exception.

The coast is divided into distinct zones or compartments called littoral cells where complete cycles of sedimentation occur including sources, transport paths and sinks. Sediment sources such as rivers, streams and eroding coastal bluffs provide sand to the shoreline; wind, currents and waves transport sand; and sand sinks such as coastal dunes and submarine canyons are where sand is deposited.

The physical and biological characteristics of beaches are driven largely by physical attributes such as exposure, orientation, wave energy regime, currents and tides, and material type. While beaches come in all shapes and sizes, a key feature that distinguishes beaches is the material they are made of, which is typically sand (some beaches are made of gravel, cobble, or boulders). Sand is a granular material composed of rock or mineral particles. It is defined by size, being finer than gravel and coarser than silt. The overall shape of a sandy beach is affected by the grain size and type of sand, the typical wave energy regime, and the influence of nearby rocky reefs, headlands and man-made structures on wave exposure and water circulation.[8]

Surf regime and sand grain characteristics allow beaches to be described in terms of morpho-dynamic state or type, ranging from dissipative to reflective conditions. Beach slope, sand grain size, and the wave-breaking and nearshore circulation patterns differ along the gradient from dissipative to reflective beaches. Dissipative beaches have wide, high energy surf zones that dissipate large amounts of incoming wave energy before it reaches the intertidal swash zone. These wide flat beaches typically have very fine sand and laminar, long period swash climates.[9]

[8] Orme, A.R., J.G. Zoulas, G.B. Griggs, C.C. Grandy, D.L. Revell, & H. Koo. 2011. Beach Changes along the Southern California Coast during the 20th Century: A Comparison of Natural and Human Forcing Factors. Shore & Beach, v. 79 (4): 38-50.

[9] McArdle, S. B. & A. McLachlan. 1992. Sand beach ecology: Swash features relevant to the macrofauna. Journal of Coastal Research, V.8:398–407.

Reflective beaches have very narrow surf zones where waves break near or directly on the shore and some wave energy is reflected seaward. Reflective beaches generally have coarse sediments, steep slopes, and short period, turbulent swash climates. The majority of beaches in California and across the globe are intermediate type beaches that lie within the broad spectrum between dissipative and reflective types and represent a wide range of sizes and shapes as well as sand grain sizes.[10] Sandy beaches, particularly intermediate types, can exhibit seasonal shifts in morpho-dynamic state in response to storm and swell conditions. However, a beach of coarse sediments may remain reflective and a fine-sand beach may remain dissipative regardless of wave conditions.[11]

Grain size also strongly affects the structure and diversity of benthic invertebrate communities[12] including those on open coast sandy beaches.[13,14,15] Burrowing performance of benthic animals is strongly influenced by grain size with subsequent effects on their distribution and abundance in different habitats. In addition to grain size and material type, sand color, angularity, and level of sorting are also key factors impacting the physical and biological character of respective beaches.

Southern California sandy beaches can support some of the most diverse invertebrate communities ever reported for this coastal habitat.[16] According to Dugan & Hubbard:

> *Recent comparisons have shown that California's sandy beaches support some of the most diverse intertidal invertebrate communities ever reported for beach ecosystems with >45 species found in single surveys on a variety of beaches and >105 species recorded in southern and central regions (Straughan 1983, Dugan et al. 2000, 2003, Schooler et al. 2013, in prep.). Crustaceans, polychaete worms and mollusks are major intertidal invertebrate groups on California beaches and elsewhere. Endemic insects, including a number of flightless beetles, form an important element of the diversity of California's beaches. It is highly likely that numerous additional species are present on California beaches but identification of several important taxa, including infaunal polychaete worms and wrack-associated insects are presently limited by taxonomic knowledge.*[17]

The abundant invertebrates of beaches provide prey for a remarkably rich assemblage of shorebirds averaging > 100 birds per kilometer year-round for some southern California

[10] Dugan, J. E. and D. M. Hubbard. 2014. Sandy Beach Ecosystems. in: Ecosystems of California – A source book. Mooney, H. and E. Zavaleta, eds. University of California Press.
[11] Bryant 1982
[12] Johnson, R. G. 1971. Animal-sediment relations in shallow water benthic communities. Marine Geol., V.11: 93-104.
[13] McLachlan, A. & A. Dorvlo. 2005. Global patterns in sandy beach macrobenthic communities. Journal of Coastal Research, V.21(4), 674–687.
[14] Rodil, I.F. & M. Lastra. 2004. Environmental factors affecting benthic macrofauna along a gradient of intermediate sandy beaches in northern Spain. Estuarine, Coastal and Shelf Science, V. 61 (1): 37-44.
[15] Peterson et al. 2014. Op. Cit.
[16] Dugan, J.E., Hubbard, D.M., Engle, J.M., Martin, D.L., Richards, D.M., Davis, G.E., Lafferty, K.D., and R.F. Ambrose. 2000. Macrofauna communities of exposed sandy beaches on the Southern California mainland and Channel Islands. Fifth California Islands Symposium, OCS Study, MMS 99-0038: 339-346.
[17] Dugan & Hubbard. 2014. Op Cit.

beaches[18]. Shorebird use of beaches has been positively correlated with the availability of invertebrate prey and wrack as well as beach type, width and condition.[19] A number of nearshore fish species feed on beach invertebrates providing a trophic link to subtidal food webs. The threatened western snowy plover and California least tern nest and rear their chicks on open coast and sheltered beaches in the region.

The high intertidal zone of southern California beaches are home to a remarkable diversity of invertebrates, many of which are associated with stranded kelps and algae. These animals make up an average of 40% of the intertidal species of beaches in the region that are not subject to grooming or nourishment or other impacts.[20]

Development and Sandy Beaches

Unfortunately, development along the California coast often has not taken natural coastal processes into consideration, affecting sand supply to beaches and ultimately leaving coastal development vulnerable to the ever-changing conditions along the shoreline. Rapid erosion shifts sand, leaving previously stable homes at the precipice of worn away bluffs. Roads and other development that back dunes restrict the natural landward migration of these sand reserves, allowing waves to scour away at a natural shoreline that protects the coast from intense wave energy.

Human activities have greatly influenced sand supply, which has also played a role in altering beaches. On- and offshore sand mining depletes sand from beaches, while the construction of dams and shoreline armoring trap sediment, significantly reducing the amount of sand delivered to the coast by rivers and bluff erosion, respectively. Harbors, jetties, and groins trap sand causing sand accumulation upcoast and sand depletion downcoast of the respective structure. Moreover, drought can reduce the river flow of the small fraction of remaining rivers and streams that properly function to deposit sand to the beaches.

---

[18] Hubbard, D.M., and J.E. Dugan. 2003. Shorebird use of an exposed sandy beach in southern California. Estuar. Coastl. Shelf Sci. 58S: 169-182.

[19] Dugan, J.E., D.M. Hubbard, D.L. Revell, and S. Schroeter. 2008. Ecological effects of coastal armoring on Sandy Beaches. Marine Ecology, v. 29: 160-170

[20] Dugan, J.E., Hubbard, D.M., McCrary, M., and M. Pierson. 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuar. Coastl. Shelf Sci. 58S: 133-148.

Development on Broad Beach in Malibu abuts the sea and is particularly vulnerable to beach erosion. Photo Credit: Lesley Ewing

Sediment supply has dropped significantly in Southern California, particularly Los Angeles, since the flat, coastal plain that characterizes the region has enabled rapid urban development without planning for maintenance of natural sediment supply to replenish beaches. Paved riverbeds, dams, and shoreline armoring abound in the urban landscape, interrupting natural sediment transport that would otherwise feed the coast. Ongoing beach erosion coupled with an insufficient sediment supply to replenish lost sand has resulted in narrowing beaches. Man-made structures protruding along the coast, such as jetties or harbors, interfere with longshore transport of sand, starving beaches of sand delivery farther down the coast, which has resulted in increased beach erosion and, in some instances, the complete loss of beaches.[21]

Many coastal communities have constructed shoreline armoring, such as seawalls and revetments, in an effort to protect existing properties from coastal erosion and sea level rise. Coastal armoring, however, can reduce sand supply from naturally eroding seacliffs, compounding shoreline erosion. While this may not have a large impact in areas where streams and rivers continue to deliver sediment, it can greatly impact regions where the majority of sand comes from seacliff and terrace erosion, such as the Oceanside littoral cell.[22] Such coastal protection devices have been found to accelerate erosion, since wave energy, which usually dissipates over the shore, reflects off the wall and back towards the sea, scouring the beach in the

[21] Griggs, G.B., et al. 2005. *Living with the Changing California Coast*. University of California Press. Berkeley and Los Angeles, California.

[22] Runyan, K. & G.B. Griggs 2003. "The Effects of Armoring Seacliffs on the Natural Sand Supply to the Beaches of California." *Journal of Coastal Research*, 19(2): 336-347.

process.[23] Potentially negative impacts, such as accelerated erosion and reduced sediment delivery, need to be carefully considered prior to coastal development, including shoreline protection.

Coastal communities have responded to the disruption of sediment transport with beach nourishment projects. Some nourishment projects have been ineffective, with coastal erosion processes too great to maintain the long-term stabilization of beaches. Others, such as the nourishment project on Silver Strand Beach in San Diego, have been more successful, creating wide, stable beaches that attract visitors.[24] Coastal armoring and beach nourishment are of particular interest to coastal municipalities because they want to stabilize and protect properties along the coast while simultaneously providing a place of recreation for residents and tourists alike.

Recreation and Sandy Beaches

California is known for its beautiful coastline, drawing tourists from the state, nation and around the world. The geomorphology along the California shoreline has largely determined the extent of coastal development and the type of recreation available to visitors. In Southern California, the flat plains that abut the wide, sandy beaches facilitate the development of amenities and attractions while the beaches themselves are easily accessible, drawing many visitors. Southern California has a higher percentage of urban waterfront areas than does Northern California, highlighting the ease of developing along relatively flat coastline. The flat beaches and urban waterfronts accommodate an array of recreational activities, including sun-bathing, volleyball, and cycling.

Developing along rugged coastal terrain has proven more difficult and accounts for fewer public amenities in such areas. Rocky beaches tend to be more hazardous for visitors as well, which reduces the number of people who visit rocky beaches. On the other hand, undeveloped, rugged coastlines often provide significant habitat for marine organisms, and as a result, draw visitors interested in observing marine wildlife, which contributes to local economies. The San Luis Obispo and Santa Cruz shorelines, for example, are known for their elephant seal populations, which draw millions of visitors each year.[25]

Residents and visitors also enjoy a number of cultural and recreational activities, such as fishing, birding, snorkeling, diving and grunion viewing. Many of these activities are low or no cost, allowing low income visitors the benefits provided by healthy coastal ecosystems. California's

[23] Griggs, G. & J.F. Tait 1988. "The Effects of Coastal Protection Structures on Beaches Along Northern Monterey Bay, California." *Journal of Coastal Research,* Special Issue (4). The Effects of Seawalls on the Beach: 93-111.

[24] Griggs, G.B., et al. 2005. *Living with the Changing California Coast*. University of California Press. Berkeley and Los Angeles, California.

[25] Griggs, G.B., et al. 2005. *Living with the Changing California Coast*. University of California Press. Berkeley and Los Angeles, California.

marine life and beach ecosystems hold significant recreational and economic value, and it is important to preserve the physical and biological complexity that sustains these benefits.

Sandpipers forage for food in the sand in Bodega Bay. Photo Credit: Kathleen Scavone

Management Practices and Public Access and Sandy Beach Ecology

Beach management practices and public access goals sometimes conflict with goals to preserve natural beach ecosystems. Management practices, from beach grooming to beach nourishment, can alter natural environments, disrupting beach ecosystems. Public access and recreation likewise tend to disturb the very environments that provide services and benefits to the public.

Southern California has a history of grooming its beaches to remove trash and wrack in order to enhance the recreational beach experience. Unfortunately, this practice results in decreased species richness, abundance, and biomass of species associated with macrophyte wrack.[26] Beach grooming also significantly decreases the ability of coastal strand vegetation (a component of incipient dunes) to establish, converting coastal strand habitat to stretches of bare sand.[27]

[26] Dugan, J. E., D.M. Hubbard, M.D. McCrary, and M.O. Pierson 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. *Estuarine Coastal and Shelf Science* 58 (S): 25-40.

[27] Dugan, J. E., and D.M. Hubbard 2010. Loss of coastal strand habitat in southern California: the role of beach grooming. *Estuaries and coasts* 33(1): 67-77.

Beach nourishment is intended to increase beach width and therefore expand suitable beach habitat, but management strategies do not necessarily take crucial ecosystem processes and beach organisms into consideration. Sand retrieved from an ocean or land source is placed on the beach, burying the original sand and subsequently smothering organisms. Sand may also be delivered at times that clash with important life stages of sensitive organisms.[28] Changes in sand composition may affect an organism's ability to dig in the sand – a behavior commonly used by burrowing invertebrates or foraging shorebirds; organisms evolutionarily adapted to dig or burrow in a particular grain size may be affected by sand that is much finer, much coarser, or with more shell particles, impeding organisms from performing functions necessary for survival. Grain size also affects the sand's moisture-retaining ability and oxygen levels, which can affect species that live on the beach. A study by McLachlan (1996) found that just increasing sand particle size changes the beach morphological state and decreases species richness and abundance.[29]

Sandy beach ecosystems are typically more accessible to visitors, which consequently increases the amount of degradation to the beach. Increased foot traffic may scare birds away, decreasing their ability to forage or nest. Recreational impacts from off-road vehicle use and pedestrian trampling can negatively impact beach infauna or destroy vegetation that secures sediment, advancing erosion. One study has concluded that beaches frequented by off-road vehicles, such as at Oceano Dunes, have both a smaller number of beach species and a lower abundance of individual beach organisms than beaches not used by off-road vehicles.[30]

Beach armoring has both direct and indirect impacts to sandy beach ecosystems. The footprint from seawall armoring directly impacts biological resources, effectively removing a segment of the sandy beach from the shoreline habitat. Armoring on sandy beaches indirectly impacts beach ecology by interrupting sediment supply from bluff erosion while on eroding shoreline, armoring can simultaneously cause passive beach erosion. Reduced sediment delivery and increased beach erosion contribute to the narrowing of the beaches, which reduces vital habitat. Furthermore, hard armoring prevents the beach from moving landward, limiting its ability to respond to sea level rise, and potentially reducing beach habitat, which ultimately affects the beach ecology.

Finding a balance between recreation and the preservation of beach ecology is necessary to sustain beach ecosystems and their associated environmental benefits. Many communities have changed management practices and now over 90% of previously groomed beaches are groomed

[28] Speybroeck, J., D. Bonte, W. Courtens, T. Gheskiere, P. Grootaert, J.P. Maelfait, M. Mathys, S. Provoost, K. Sabbe, E.W.M. Stienen, V. Van Lancker, M. Vincx, S. Degraer 2006. Beach nourishment: An ecologically sound coastal defense alternative? A review. *Aquatic Conservation: Marine and Freshwater Ecosystems* 16:419-435.

[29] McLachlan, A. 1996. Physical factors in benthic ecology: effects of changing sand particle size on beach fauna. *Marine Ecology Progress Series*, 131: 205-217.

[30] Schlacher, T. A., D. Richardson, and I. McLean 2008. Impacts of off-road vehicles (orvs) on macrobenthic assemblages on sandy beaches. *Environmental Management* 41: 878-892.

only above the wrack line.[31] Dune restoration conducted in Monterey aims to create distinct paths that enable public access while limiting the amount of trampling on dune ecosystems. Understanding the potential impacts development can have on sandy beach ecosystems enables planners to better protect the ecology that makes the development so valuable.

A Closer Look at Specific Littoral Cells

Beach geologies and morphologies vary up and down the coast of California. Neighboring beaches can have completely different characteristics and ecologies, and therefore armoring can have different impacts on different beaches. Looking at the unique characteristics of specific littoral cells provides a better understanding of the distinct physical and ecological processes involved.

Oceanside Littoral Cell

The Oceanside Littoral Cell is one of three littoral cells in San Diego. It extends from Dana Point Harbor to the La Jolla Submarine Canyon.[32] Strong waves from the Pacific Northwest create longshore currents that transport sediment southward within the Oceanside Littoral Cell, transporting a net total of 100,000 to 250,000 cubic yards of sediment per year.[33] The north jetty in Oceanside Harbor blocks the southward transport of sediment past the jetty, isolating the northern part of the cell from the southern portion.[34] Though coastal processes can restore sediment to the beach, some severe storms can draw sediment beyond the closure line and out of the system. The La Jolla Submarine Canyon is a natural "sink" where sediment is transported and then lost from the littoral cell; the Oceanside Littoral Cell loses 60,000 cubic yards of sand per year.[35]

Eroding seacliffs are found along 73% of the Oceanside Littoral Cell shoreline and seacliff erosion constitutes a significant portion of sand supply for the littoral cell. Erosion of these seacliffs and terraces contribute between 51 and 57% to coastal sediment, whereas streams only deposit 27.9% of sand to the beaches of the Oceanside Littoral Cell.[36] Coastal armoring,

---

[31] Dr. Karen Martin, personal communication, 2011

[32] Runyan, K. & G.B. Griggs 2003. "The Effects of Armoring Seacliffs on the Natural Sand Supply to the Beaches of California." *Journal of Coastal Research*, 19(2): 336-347.

[33] USACE 1991. State of the Coast Report San Diego Region, Volume I Main Report, Final, Coast of California Storm and Tidal Waves Study. US Army Corps of Engineers, Los Angeles District, Los Angeles, California.

[34] SANDAG and the California Coastal Sediment Management Workgroup 2009. Coastal Regional Sediment Management Plan for the San Diego Region. Prepared by Moffatt & Nichol; In Association with Everest International Consultants and Science Applications International Corporation.

[35] Patsch, K. & G. Griggs 2006. Littoral cells, sand budgets and beaches: understanding California's shoreline. Institute of Marine Sciences University of California, Santa Cruz. California Department of Boating and Waterways. California Coastal Sediment Management Workgroup.

[36] Runyan, K. & G.B. Griggs 2003. "The Effects of Armoring Seacliffs on the Natural Sand Supply to the Beaches of California." *Journal of Coastal Research*, 19(2): 336-347.

therefore, significantly reduces sediment delivery and plays an important role in narrowing beaches of this particular littoral cell. Patsch and Griggs (2006) report that bluff armoring reduces sand supply from bluff erosion in this littoral cell by 18 percent.[37]

Urbanization along the San Diego coast has significantly depleted the sediment supply, with some estimating an annual loss of 400,000 cubic yards of sediment as a result of regional development, flood control works and harbors.[38] Reduced sediment delivery coupled with increased wave energy and rising seas has accelerated erosion rates, narrowing San Diego beaches. Several beaches within the Oceanside Littoral Cell have been identified as Beach Erosion Concern Areas (BECAs), including Moonlight Beach, Encinitas Beach, South Carlsbad State Beach and South Oceanside.[39]

San Diego coastal planners have relied on beach nourishment projects to address sediment losses, combat severe erosion and maintain beach widths. Routine maintenance dredging is performed where sediment is trapped at most of the San Diego lagoons and harbors, and then redistributed to beaches. Such efforts do not add new sediment to the region, but rather by-pass sand along the system. Many coastal communities in San Diego County have also participated in regional beach nourishment. Unfortunately, ongoing monitoring has determined that five years after the first 2.1 million cubic yard beach nourishment project, natural processes eroded beaches to their original widths.[40] A second regional nourishment project was undertaken in 2012 and planners now are investigating sediment management devices to retain sand.

Beach armoring and nourishment projects change the beach ecology and may potentially impact a number of species, particularly threatened and endangered species. Armoring reduces the width of the beach and may expedite passive erosion of beaches, impacting California least terns and snowy plovers, which rely on the upper portion of these beaches for nesting and wintering. The beaches within the Oceanside Littoral Cell are also important breeding grounds for the California grunion and home to the organisms that comprise the diet of many sea birds. Projects that alter a seemingly small portion of the coast may have much larger impacts than one realizes. Coastal dunes, for instance, are rare in California, so development that disturbs the vegetation that stabilizes the dunes may accelerate dune erosion. Armoring within the Oceanside Littoral Cell, in

---

[37] Patsch, K. & G. Griggs 2006. Littoral cells, sand budgets and beaches: understanding California's shoreline. Institute of Marine Sciences University of California, Santa Cruz. California Department of Boating and Waterways. California Coastal Sediment Management Workgroup.

[38] SANDAG and the California Coastal Sediment Management Workgroup 2009. Coastal Regional Sediment Management Plan for the San Diego Region. Prepared by Moffatt & Nichol; In Association with Everest International Consultants and Science Applications International Corporation.

[39] California Coastal Sediment Management Workgroup 2010. Coastal Erosion & Beach Nourishment Needs. "Selected Sites of Important Coastal Erosion in California." http://www.dbw.ca.gov/csmw/PDF/TABLE1TASK1CSMW.pdf

[40] SANDAG and the California Coastal Sediment Management Workgroup 2009. Coastal Regional Sediment Management Plan for the San Diego Region. Prepared by Moffatt & Nichol; In Association with Everest International Consultants and Science Applications International Corporation.

particular, reduces sediment delivery to the coast, exacerbating beach erosion and subsequent impacts to crucial beach habitats and beach ecosystems. Since the Oceanside Littoral Cell relies heavily on seacliff erosion for sediment supply to beaches, armoring greatly impacts the region, but coastal armoring has major effects on littoral cells up and down the coast.

The Southern Littoral Cell of Monterey Bay

Monterey Bay is a large embayment that is divided into two littoral cells by the Monterey Submarine Canyon and the Salinas River.[41] [42] The coastline consists of weaker sandstones and siltstones and is therefore prone to erode more quickly, but the Monterey Bay coast is also more sheltered from the northwest winter waves, which bend as they enter the bay, reducing wave energy. The net transport of sand moves southward along the coast, and though the Monterey Submarine Canyon acts as a sink for the northern littoral cell, the main source of sand comes from streams and rivers ensuring the southern littoral cell still has plenty of sand.[43] This littoral cell also has significant sand contributions (42 percent of the sand budget) from dune recession.[44]

The southern littoral cell is made up of broad coastal lowlands, with wide sandy beaches that formed as a result of sediment delivery from the Salinas and Pajaro rivers.[45] Strong onshore winds have, over time, formed the dunes that line this section of the coast, providing added protection to the sheltered embayment.[46] The sandy beaches and protection from intense wave energy draw many visitors to the beaches and dunes within this littoral cell for recreation.

Monterey Bay is still vulnerable to waves from the west or southwest, such as waves generated during El Niño events; and beaches in the center of the bay, such as Marina and Fort Ord, are more vulnerable to western swell. Wave refraction over the Monterey Submarine Canyon focuses the wave energy at Fort Ord, resulting in the largest waves, coarsest sand, steepest beach and highest erosion rates along the Monterey Bay coastline.[47,48] Although the refraction of wave

---

[41] Dingler, J.R., T.E. Reiss 2002. Changes to Monterey Bay beaches from the end of the 1982-83 El Niño through the 1997-98 El Niño. *Marine Geology* 181:249-263.

[42] Thornton, E.B., A. Sallenger, J.C. Sesto, L. Egley, T. McGee, R. Parsons 2006. Sand mining impacts on long-term dune erosion in southern Monterey Bay. *Marine Geology* 229: 45-58.

[43] Griggs, G. & J.F. Tait 1988. “The Effects of Coastal Protection Structures on Beaches Along Northern Monterey Bay, California.” *Journal of Coastal Research*, Special Issue (4). The Effects of Seawalls on the Beach: 93-111.

[44] Patsch, K. & G. Griggs 2006. Littoral cells, sand budgets and beaches: understanding California’s shoreline. Institute of Marine Sciences University of California, Santa Cruz. California Department of Boating and Waterways. California Coastal Sediment Management Workgroup.

[45] Griggs, G.B., et al. 2005. *Living with the Changing California Coast*. University of California Press. Berkeley and Los Angeles, California.

[46] Thornton, E.B., A. Sallenger, J.C. Sesto, L. Egley, T. McGee, R. Parsons 2006. Sand mining impacts on long-term dune erosion in southern Monterey Bay. *Marine Geology* 229: 45-58.

[47] Thornton, E.B., A. Sallenger, J.C. Sesto, L. Egley, T. McGee, R. Parsons 2006. Sand mining impacts on long-term dune erosion in southern Monterey Bay. *Marine Geology* 229: 45-58.

energy has contributed to natural erosion events at Fort Ord, other anthropogenic impacts have been linked to the erosion of the Monterey shoreline as well.

A boy lunges to catch a Frisbee at Oceana Dunes. Frisbee is just one of the many recreational activities the public can partake in along the coast. Photo Credit: Randy Krauch

Dune recreation and walking paths on the dunes enable dune vegetation to be trampled, which destabilizes the dunes and contributes to increased erosion.[49] In the face of erosion and sea level rise, communities along Monterey Bay have built shoreline armoring, which has been found to accelerate shoreline erosion, though beaches with rip-rap revetments did not erode as rapidly as beaches with vertical seawalls.[50] Sand has been mined from the nearshore zone, beaches and dunes in Monterey Bay since the turn of the last century. Dragline mining from the nearshore area stopped in the 1970s; however beach mining still continues. All of the sand mining activity is thought to have exacerbated erosion rates, not only by drawing sediment from the littoral cell to fill the dredged area, but also by potentially reducing shoals that attenuate wave energy and deter erosion.[51]

---

[48] Dingler, J.R., T.E. Reiss 2002. Changes to Monterey Bay beaches from the end of the 1982-83 El Niño through the 1997-98 El Niño. *Marine Geology* 181:249-263.

[49] Thornton, E.B., A. Sallenger, J.C. Sesto, L. Egley, T. McGee, R. Parsons 2006. Sand mining impacts on long-term dune erosion in southern Monterey Bay. *Marine Geology* 229: 45-58.

[50] Griggs, G. & J.F. Tait 1988. “The Effects of Coastal Protection Structures on Beaches Along Northern Monterey Bay, California.” *Journal of Coastal Research*, Special Issue (4). The Effects of Seawalls on the Beach: 93-111.

[51] Thornton, E.B., A. Sallenger, J.C. Sesto, L. Egley, T. McGee, R. Parsons 2006. Sand mining impacts on long-term dune erosion in southern Monterey Bay. *Marine Geology* 229: 45-58.

These examples highlight the vast differences between beaches along the coast and the unintended consequences that result from practices that do not incorporate the physical and biological beach processes into planning and development efforts. Sandy beach environments hold an abundance of life and provide a host of ecological services that benefit coastal communities. Though many differences can be found among the beaches that line the California coast, these beaches hold great value and distinct attributes only add to their value.

3. REVIEW OF ECONOMIC VALUATION METHODS

In order to mitigate, proportionally and appropriately, the adverse impacts of shoreline armoring on beach recreation, access, and ecology, agencies need a quantitative way to value these resources. The field of economics provides methods for doing this and can help frame the tradeoffs presented by permitting shoreline armoring. Economic value is generally defined as a measure of the maximum amount an individual is willing to forego to obtain some good, service, or state of the world.[52] In a market economy, many goods and services are sold through a market, so the market price is generally considered to be an appropriate measure of value. However, economists also recognize that not all goods and services are provided by markets. These are generally referred to as non-market goods; most environmental services are normally considered to be non-market goods.

California's beaches represent examples of such non-market goods and services since beaches (seaward of the mean high tide line at least) are legally open to all and much of the coastline is public property. The total economic value (TEV) model provides a framework for valuing the full range of economic values associated with a resource, incorporating direct use, indirect use, and non-use values. None of these values are easily quantifiable in traditional monetary terms (dollars), though the emerging science of ecosystem services is harnessing the expertise of economists and ecologists in better accounting for value of natural resources. Figure 1 shows a schematic of TEV components, and references the core of the recommended valuation methods from the academics.

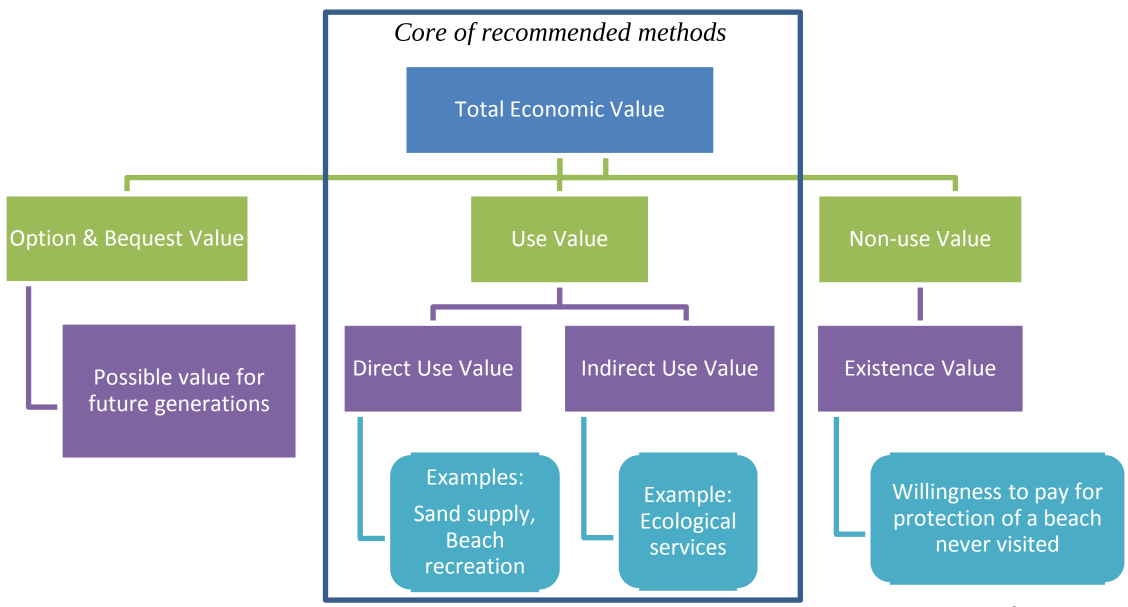


Figure 1. Total economic value conceptual diagram (based on Nelsen 2012). Only a select number of direct and indirect use values are addressed in this valuation effort.[53]

[52] Haab, T.C. & McConnell, K.E. (2002). Valuing Environmental and Natural Resources: The Econometrics of Non-Market Valuation (p. 326). Northhampton, MA: Edward Elgar Publishing Limited, Inc.
[53] Nelsen, C. (2012). Collecting and using Economic Information to Guide the Management of Coastal Recreational Resources in California. University of California, Los Angeles.

Use value refers to those values associated with current or future use of an environmental resource by an individual. The use can either be consumptive (e.g. recreational fishing) or non-consumptive (e.g. surfing). Direct use is most relevant for the Commission's quantification of sand supply and beach recreation values. Indirect use values apply when an ecosystem provides benefits which are more difficult to measure but still apparent, such as flood control or habitat on a beach. Additional components of the TEV framework--option and bequest and existence value--are not assessed by this project. Option and bequest values describe the value of preserving the option for use of services in the future either by an individual (option value) or by future generations (bequest values). Existence value represents the willingness to pay for the resource to exist (e.g. willingness to pay for the protection of a beach you will never visit). While estimating existence value is outside the scope of this project, existence value is still an important component of total valuation. This valuation does not include the use of beaches by future generations and their existence value, nor does it account for the fact that increased scarcity of beaches will inherently increase beach value; therefore the beach value estimates will be a lower bound for total economic value.

Despite the lack of a market to place a monetary value on beaches, several basic non-market methods are available, including:

- Revealed preference,
- Stated preference,
- Cost-based, and
- Benefit transfer approaches.

Revealed Preference approaches attempt to determine a minimum value for an amenity, such as a beach, through surveys of use patterns of market resources or resource uses. The Travel Cost method is perhaps the best known of these revealed preference methods, but others include Random Utility Models and Hedonic Models. The Travel Cost method collects information on parameters such as demographics, visitation patterns, transportation mode, travel time, travel distance, beach activities, and beach substitutes to develop consumers' travel costs and 'willingness-to-pay' for beach recreation. Random Utility Models add beach characteristics to the input parameters used in the Travel Cost Method. With the addition of beach characteristics, the models compare visitor choices and attempt to determine how consumers value different site characteristics, based on the added travel costs to access or avoid various beach characteristics. Hedonic models use market values, often real estate values, to establish 'willingness-to-pay' for an ocean view or proximity to a beach. However, hedonic models examine the property owners' values but do not provide information on the value to beach visitors and no better market values have been identified to reveal recreational values.

Stated Preference approaches employ contingent valuation or conjoint analysis surveys, in which people are asked in different ways about their willingness to pay for a change in good or service. Stated preference studies determine beach values; however, the results can be very sensitive to the type of survey and the way the questions are asked.

Cost-based approaches rely on replacement cost (the cost of substituting for the lost resource or function) or avoidance costs (costs of avoiding damages). The cost-based approach is compatible with the use of offsets in mitigation. Offsets create or restore a similar type of ecosystem to compensate for loss of habitat, and cost-based methods allow for a way of estimating the monetary value of the offset.

Lastly, benefit transfer is a valuation approach that takes valuation results developed from the various survey methods for specific beach locations and 'transfers' the value to locations that have not been surveyed. The transfer can be a direct, or point transfer, or it can be a function transfer in which the consumer surplus is adjusted through a comparison of attributes at the surveyed site to the attributes at the site to which the values are being applied. The benefit transfer method can avoid the high cost of surveys and site-specific analysis, yet this method is limited by the quality of the original studies.

The academics propose that the Commission use a Benefit Transfer approach to value beach recreation and a Replacement Cost-based (Restoration Cost/Offset) approach to value beach ecology. The following two sections explain the rationale behind these approaches and propose methods for valuing beach recreation, access, and ecology. The literature reviews in Appendix A (Sections 2 and 4) present the rationale behind the recommendations as well as more detail on all of the potential economic valuation methods.

4. ECOSYSTEM VALUATION (Task 3)

Characteristics of Beach Ecosystems

The intrinsic biota and ecological services and functions of sandy beach ecosystems are not found in or provided by any other coastal ecosystem. Sandy beaches are comprised of three different biological zones: the supra-littoral zone, the mid-littoral zone, and the surf zone, each of which provides critical habitat, food and/or breeding grounds for many species. These zones provide functions that include buffering and absorption of wave energy by stored sand, filtration of large volumes of seawater, extensive detrital and wrack processing and nutrient recycling, and the provision of critical habitat and resources for declining and endangered wildlife, such as shorebirds and pinnipeds. Please refer to sections 4.1.1 and 4.1.2 of the Appendix A, *Characterizing Beach Ecosystems* and *Beach Zonation*, respectively, (pages A-65 to A-69), for complete coverage of these topics.

Effects of Coastal Armoring

While quantitative information on the environmental effects of coastal armoring is limited, impacts of coastal armoring are increasingly recognized. On open sandy coasts, seawalls, revetments, geotextile tubes and other engineered shore parallel structures, occupy habitat, alter the wave regime and modify processes that deposit and retain mobile sediments on exposed sandy beaches.[54] Alongshore structures (seawalls and revetments) placed on beaches reflect wave energy and restrict natural landward migration of the shoreline, generally leading to a loss of beach area and width and flanking erosion of adjacent shorelines. The narrowing of the beach and the upper habitat zones results in the loss of adaptive capacity of beaches to respond to ongoing coastal processes and adjust to changing swell, tide and beach conditions.

Overall, the academics' review suggests that loss of coastal habitat caused by alongshore armoring structures disproportionately impacts the upper shore and high intertidal zones of beaches with the greatest relative loss or elimination of habitats evident higher on the shoreline. Critically, this includes the loss of key ecotonal and transitional habitats between land and sea, such as coastal strand, dune, and other vegetated zones, upper beach and intertidal zones on armored beaches. Loss of these key habitats will cause significant changes in biodiversity and community composition, alter vital ecosystem functions, processes and services, and reduce the connectivity between terrestrial and aquatic habitats of these important coastal ecosystems. Please refer to sections 4.1.3, 4.1.4, 4.1.5, and 4.1.6, of the Appendix A, *Coastal Armoring, Impacts of Shore Parallel Armoring, Alteration of Ecological Function and Integrity*, and *Coastal Armoring as Substrate*, respectively, for a complete discussion of these topics.

[54] Dugan, J. E., Hubbard, D. M., Rodil, I. F., Revell, D. L., & Schroeter, S. (2008). Ecological effects of coastal armoring on sandy beaches. Marine Ecology,29(s1), 160-170.

An adult Western Snowy Plover and its chick nest on the beach at Coal Oil Point in Santa Barbara County. Western Snowy Plovers are threatened due to loss of habitat. Photo Credit: Chuck Graham

Academics' Recommended Ecosystem Valuation Method for Beaches

Sandy beach ecosystems are highly valued as key economic and cultural assets for society providing a wealth of ecosystem functions (or ecosystem services) including storm protection, nutrient cycling, carbon sequestration, water filtration, detrital processing, fisheries, food web support, biodiversity and wildlife habitat (See Appendix A). The ecosystem services of sandy beaches link to either direct or indirect use values. Direct use values are uses that directly benefit human consumers such as beach visitation, bait and food organisms, and nursery areas for juvenile fishes. Indirect use values are more difficult to measure but still apparent such as beaches providing protection from flooding and storms, nutrient mineralization and recycling, and maintenance of biodiversity.

At present, the literature identifying and quantifying ecosystem service values for sandy beaches is scarce. Some research has been conducted on ecosystem services for New Jersey beaches, valuing them annually at $42,147 per acre (in 2004 dollars).[55] This ecosystem services value includes an aesthetic and recreational component ($14,847 per acre per year) and a shoreline protection (disturbance control) component ($27,276 per acre per year), but does not include values for other ecosystem services. Aesthetic and recreational consumer surplus values for California beaches are well researched and can be applied more specifically than the generic

[55] Costanza, R., Wilson, M. A., Troy, A., Voinov, A., Liu, S., & D'Agostino, J. 2006. The Value of New Jersey's Ecosystem Services and Natural Capital. Environmental Protection. Gund Institute for Ecological Economics. 177 pp.

model provided for New Jersey beaches.[56] Disturbance control is generally less relevant for beaches where shoreline protective devices are being constructed because these structures are designed to eliminate any future shoreline disturbance so those benefits have already been lost at the time of permitting and are unlikely to be realized after the shoreline armoring is installed. The total economic value of ecosystem services outside of recreational opportunities and disturbance control is clearly greater than zero, indicating that valuation efforts that do not include ecosystem services are undervaluing the resource.

Economists and ecologists have developed a number of techniques to value ecosystem services. There are two main methods: 1) assigning a dollar value directly to each ecosystem service and 2) calculating the relative value of an ecosystem by estimating the cost of restoring such an ecosystem (the replacement cost/offset approach). In practice, assigning a dollar value to an ecosystem service is difficult due to a lack of scientific understanding of many functions, goods and services of beach ecosystems. The highly dynamic nature of the ecological components and functions of sandy beaches (beaches change on daily, weekly, seasonal, yearly, and decadal time periods) also make quantitatively evaluating sandy beach ecosystem services expensive, time-consuming, and difficult. The replacement cost/offset approach is much more widely used in mitigation in the United States and throughout the world. The replacement cost/offset approach can also be used to emphasize that the natural capital of beach ecosystem services should be preserved through restoration. See section 4.3, *Mitigation for Beach Ecosystem Impacts* of the consultant's report for a description of a variety of direct dollar value and replacement cost/offset approaches used for natural ecosystem valuation.

Rather than quantitatively assessing what ecological components and functions are present and potentially altered or lost on a given stretch of sandy beach, due to armoring, as a valuation approach, the consultant's find that it is simplest, most reasonable and most accurate to use the cost of restoring suitable natural habitat, either at that site or nearby as a valuation method for ecological impacts of coastal armoring. This replacement cost/offset approach that relies on determining proportional and appropriate ecological restoration allows for identifying equitable mitigation. The academics reviewed and considered the current beach ecological and economic valuation knowledge, and found that the replacement cost/offset approach is better than what can be accomplished with attempts to confidently identify, replicate, and monitor lost ecological components of a specific stretch of beach. Assuming that the restored ecosystem function is equivalent to the natural function lost and is the least costly way to regain that natural function is fundamental to the replacement cost method. [57,58]

Concomitant with their recommendation of using the replacement cost/offset approach, the academics recommend that the Commission adopt a no-net-loss policy for sandy beaches in California. They state that "this approach has been applied in other areas, notably wetlands. A

[56] Liu, S., Costanza, R., Farber, S., & Troy, A. (2010). Valuing ecosystem services. *Annals of the New York Academy of Sciences*, *1185*(1), 54-78.
[57] US National Research Council. 2005. *Valuing Ecosystem Services: Toward Better Environmental Decision-Making.* The National Academies Press. Washington, DC. http://www.nap.edu/catalog/11139.html
[58] Bockstael, N.E., A.M. Freeman, R.J. Kopp, *et al.* 2000. On measuring economic values for nature. *Environ. Sci.Technol.* 34: 1384–1389.

no-net-loss policy implies that any reduction in ecological value of beaches due to shoreline development or armoring must be offset by a corresponding enhancement of ecological functioning of beaches elsewhere, preferably in the same littoral cell"(Appendix A, page A-6). In addition, the academics' recommend that the Commission apply a mitigation ratio to the estimated restoration cost. They state that "Since these restored projects will almost certainly have lower ecological value [than a beach unaltered by armoring], we also propose that the Coastal Commission adopt the same approach used for wetland restoration and require a 4:1 ratio-a restoration project must be 4 times larger to provide similar levels of ecological goods, functions and services (EFGS). For some particularly sensitive, scarce or threatened habitat or species, a larger ratio may be necessary…" (Appendix A, page A-7).

The academics provide four examples of beach restoration cases (two completed and two future projects) and the actual or estimated cost broken down per linear foot and per acre (Table 2) as the basis for their recommended approach. The four projects are the recent Pacifica State Beach (San Mateo County) and Surfer's Point (Ventura County) restorations and the proposed restorations for Ocean Beach (San Francisco) and Goleta Beach (Santa Barbara County). To proportionally and appropriately account for lost beach ecosystem value, the full restoration cost should include costs for planning, permitting, acquisition of property and easements, legal agreements, restoration implementation including infrastructure removal or relocation, construction, planting, monitoring, and adaptive management. Comprehensive restoration would include all these costs; the proposed values presented in Table 2 below are not necessarily comprehensive (do not include monitoring costs) and may need to be adjusted in order to realistically estimate full restoration costs.

Table 2. Examples of costs for restoration of beach ecosystems in California

Beach	Linear Feet	Area (acres)	Cost (Million) ($2015)	Cost/ Linear Foot	Cost/ Sq. Foot	Project Elements
Pacifica State Beach	2000	4	$6.96 M	$3480	$40	Two homes removed; Parking lot removal; Revetment removed; Sand replacement; Dune restoration
Surfer's Point	1100	2.1	$4.67 M	$4245	$50	Removal of paving and fill; Beach & cobble restoration; Dune restoration; New road & parking lot; New storm drains
Ocean Beach	4000	13.5	$200 M	$50,000	$340	Removal of fill; Removal of rock revetment; Removal of roadway, parking and park elements; Armoring of sewer tunnel; Grading with native and imported sediments; Planting; Construction of public facilities farther inland
Goleta Beach	700	1	$3.65 M	$5214	$84	Protection of sewer outfall pipe; Removal of parking area; Removal of rock revetment; Relocation of utilities; Relocation of bike path; Relocation and protection of utility corridor and highway
Average	**1950**	**4.03**	**$53.82 M**	**$15,735**	**$129**	
Average w/o Ocean Beach	**1267**	**2.37**	**$5.093 M**	**$4,313**	**$58**	

Source: Memo from Bob Battalio from ESA/PWA on Beach Restoration costs, April 23, 2015

The academics present an approach that uses the length of shoreline armoring and the linear foot cost of sandy beach restoration to value the sandy beach ecosystem that would then be used to obtain an in-lieu fee for beach ecology mitigation. They present a hypothetical example for a 50 foot seawall using the average linear foot cost (excluding the Ocean Beach project) to calculate the total cost of restoration; 50 feet * $4,313/ft = $215,640. Applying a mitigation ratio of 4:1 increases the in-lieu fee to $862,600 for the ecological impacts of this seawall.

The academics suggest that the Commission consider developing a surcharge for projects wider than 6 feet, in addition to the length based fee, because of the significance of placement loss from the footprint of such armoring structures.

The proposed approach employs restoration cost to inform in-lieu mitigation offsite. The academics recommend the ecological value be assessed as the cost of restoring the beach, bluff, dune, or back beach land equivalent to the lost area in a similar area of the coast. This restoration cost/offset approach is based on the idea that lost habitat in one area is mitigated by appropriate restoration of habitat in another area that can continue to undergo natural processes and dynamics. The proposed approach does not rely on typical beach nourishment or beach filling practices as a restoration method due to their ecological impacts combined with typically short-lived effects on beach area. The proposed approach focuses on projects/activities that are less ecologically damaging, longer lasting and more sustainable than beach filling. These include beach and dune restoration (creating space for and allowing coastal retreat), enhancing coastal processes, such as transport and delivery of sediment from natural sources (e.g. dam removal, obsolete shoreline armoring removal), and improving current beach management practices (e.g. ceasing beach grooming, seasonal, rotational, and/or hand grooming, ceasing berm creation, etc.).

Summary of Academics’ Recommendations for Beach Ecosystem Valuation

- Use a restoration cost/offset approach for valuing beach ecosystems.
- Require mitigation in the form of an in-lieu fee based on the linear foot distance of the proposed armoring times the average cost/linear foot of restoration, based on four completed California beach restoration projects.
- Use relevant linear foot costs of beach restoration projects as the basis for calculating the in-lieu mitigation fee.
- Add a scaler (USD) for proposed armoring with a six foot or wider footprint to account for the impact of placement loss.
- Apply a 4:1 mitigation ratio to the in-lieu fee in recognition that restored beaches, like restored wetlands, never fully restore the services, functions, and biodiversity found in natural habitats.
- Use in-lieu mitigation fee to 1) restore proximal beach ecosystem that is not constrained by development, 2) contribute to existing beach restoration projects, 3) acquire land with

beach ecosystem restoration potential, 4) removal of infrastructure, 5) enhance sediment supply and/or 6) implement improvements in beach management.

- Avoid using beach nourishment, as currently practiced, as mitigation for beach loss.
- Adopt a no-net loss approach for beaches as the state has done for wetlands.

Commission Staff Beach Ecosystem Valuation Conclusions

The academics make a strong case for employing the restoration cost/offset approach for valuing beach ecosystems. Their method of using the cost of restoring a similar beach provides a direct nexus to the lost beach ecosystem resulting from placement of a seawall. They state that;

> *Placing a dollar value on the ecological functions and services of beach ecosystems, such as nutrient cycling or storm protection, is challenging since we still do not understand these processes well, dynamic of these exposed ecosystems drive very high inherent variability and the economics of valuing ecological services is still in its infancy. Offsets are commonly used both in the United States and elsewhere for mitigation of environmental losses. Offsets have the advantage that they seek to restore ecological services and functions. Using the costs of restoring beaches as ecosystems as a basis for calculating the loss of ecological value of beach ecosystems caused by armoring provides a way forward for developing a viable approach to ecological valuation that can be applied to sandy beaches. Offsets are a common approach to mitigating for the loss of ecosystem services provided by wetlands and other ecosystems which have been lost or damaged by human intervention. Briefly, offsets create or restore a similar type of ecosystem to compensate for the loss of habitat*.

It has not been Commission practice to assign a value to the lost beach ecosystem services or biological resources due to armoring in current armoring mitigation methods. As such, concerns might be raised by future project applicants and/or other key stakeholders when the value of the beach ecosystem is included as part of the mitigation for armoring if it significantly increases the mitigation fee. However, in doing so, the Commission would be acknowledging more explicitly, the estimated value of the loss of the beach ecosystem due to armoring. The Commission mitigates for terrestrial and aquatic habitats, including but not limited to dunes, wetlands, mudflats, and salt marsh; therefore work on mitigation for sandy beach ecosystems is in keeping with Commission practice. This is also in line with mitigation practices applied by other agencies, as the ecological values of marine ecosystems in habitats such as surfgrass and rocky intertidal reefs are explicitly mitigated for by the U.S. Army Corps of Engineers, Environmental Protection Agency, and the Department of the Army.[59]

The academics' recommendation to use a mitigation ratio is consistent with Commission practice for mitigating impacts upon other habitat types. They state that "The literature on offsets, particularly with respect to wetlands, provides us with a number of caution signs. First, offsets,

[59] USACE. 2008. Compensatory Mitigation for Losses of Aquatic Resources. Available at: (http://water.epa.gov/lawsregs/guidance/wetlands/upload/2008_04_10_wetlands_wetlands_mitigation_final_rule_4_10_08.pdf) [Accessed September 19, 2015].

typically in the form of newly created wetlands, often do not fully compensate for the true loss in ecological services and functions. Indeed, there will likely be some beach ecosystems that are irreplaceable" (Appendix A, page A-109).

The academics have provided a framework upon which to launch a beach ecosystem valuation method, however, more work needs to be done. The costs of the four completed and future managed retreat beach restoration cases that form the basis of the estimated beach ecosystem in-lieu mitigation fee must be thoroughly reviewed/vetted and potentially adjusted. Research into regional projects that could be used to develop in-lieu fees tailored to northern, central, and southern California beaches should also be undertaken. The academics' suggestion to use a scalar for armoring that is six feet wide or wider must be further examined and discussed by Commission staff. Also, applying a 4:1 or greater mitigation ratio to the beach ecosystem in-lieu fee needs to be reviewed.

The academics conclude, that adding a beach ecosystem in-lieu mitigation fee for armoring, to the recreation and access in-lieu mitigation fee for armoring, is not double counting. They state;

> *One potential issue with an approach that values recreational services and other ecological services is the problem of double counting. Fu et al. (2010) address this issue specifically and make a number of suggestions to minimize the issue of double counting. In particular, they call for establishing consistent classification systems for EFGS. In our opinion, this paper has established a consistent classification system for recreation and for other distinct EFGS and our discussion above indicates that these are indeed separate types of services. Beach-goers looking to recreate typically look for access, wide sandy beaches (which may have been groomed to eliminate wrack), restrooms, lifeguards services, snack-bars, etc. These amenities are generally not correlated with other EFGS and indeed many of these amenities (e.g., lifeguards who often patrol the beach on trucks or ATVs, snack bars, grooming, etc.) actually reduce other EFGS besides recreation. Hence, we believe that there is no reason to believe that double counting is an issue in this case. Consequently, it is reasonable to charge separate fees for the loss of recreation and the loss of other EFGS.*

However, Commission staff must further examine and consider the double counting concern as well as the other concerns just raised. Furthermore, the beach ecosystem valuation method recommended by the academics must be sent out for examination by an outside peer-review committee before the Commission considers implementing this approach when requiring mitigation for permitted armoring projects.

The academics suggest the Commission adopt a no-net-loss approach for California beaches as some agencies of the state have done for wetlands.[60] This is a smart and timely approach as beaches only occur in the sliver of space between the ocean and coast and face growing and myriad threats (e.g. SLR, sediment loss, development). It is also a strong position from which to

[60] California would not be the only state to adopt a no-net-loss type of approach related to shoreline armoring. Connecticut Department of Energy and Environmental Protection (DEEP) is currently promoting a goal of no-net-increase in coastal armoring for the Connecticut shoreline (Personal Communication, Ian Yue, September 2015).

roll-out an updated beach recreation and access valuation method and introduce a beach ecosystem valuation method to mitigate for the adverse impacts of armoring.

5. RECREATION AND ACCESS VALUATION (Task 4)

Recreational value of a beach area can be determined in many different ways. At their basic levels, all methods can be reduced to two separate factors – the average value that individual beach users place on their recreational experience (consumer surplus) and the number of people recreating on a specific beach (attendance). Consumer surplus is an economic concept, developed from the difference between the actual costs of a beach visit and what individuals (consumers) would be willing to pay for the experience (Figure 2: Recreation Demand Curve with Consumer Surplus from Appendix A). Attendance is a concept that most people can understand although it is often difficult to quantify.

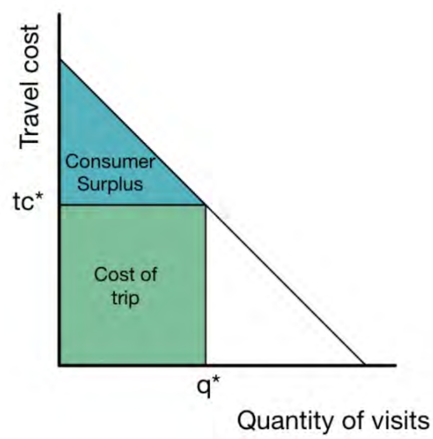


Figure 2. Recreational demand curve with consumer surplus

Consumer Surplus/Day-Use Value and the Academics' Recommendations

The academics provided background literature on the ways to value beach recreation and an overview of what has been done to date. Several studies have been undertaken to determine a beach day-use value (consumer surplus values) for California beaches. Most of the studies have focused on highly used beaches in southern and central California; however, even for these beaches there is little agreement on consumer surplus between different studies. The consumer surplus values (day use values) vary greatly, ranging from $14.77 to $110.06 (all in 2015 dollars) (See Appendix A, Table 5, for the individual study results), not because of flaws in any of the studies, but because it is difficult to control for all the variability that can influece each consumer surplus study. Due to this range of values and the sparseness of beach specific data for areas outside of southern and central California, the academics recommend that the beach recreation valuation not be based on studies for an individual beach, but rather that a single consumer surplus value should be used for the entire state. The consumer surplus value that the academics recommend is $39.49 per attendee per day (2015 dollars). The state-wide value was developed from a state-wide range proposed by Pendleton and Kildow (referred to in Appendix A, Table 5 as Kildow & Pendleton (2006)) for representing the high ($50) and low ($15) state-wide values for a day at the beach. The recommended value of $37.50 has been adjusted for inflation and is currently $39.49 per attendee per day (2015 dollars). The main adjustment or modification that the academics recommend for the state-wide consumer surplus value is to account for future inflation. They also recommend reducing the consumer surplus values for beaches that are less than 250 feet in width, due to the reduced consumer value that they associate with narrower beaches.

The academics provide some information on the CSBAT Model that they have used to model the loss of beach recreation value due to erosion. The CSBAT Model uses 6 separate criteria or amenities to assess the recreational value of California Beaches. They are:

- Weather
- Water Quality/Surf
- Beach Width and Quality
- Overcrowding
- Beach Facilities and Services
- Availability of Substitutes

Each of these criteria or amenities are provided with both a value and a weighting and in the CSBAT model, the academics can alter both of these to develop recreational values for individual beaches. In the report provided to the Commission, the academics have provided a modified CSBAT Model that assigns a value of 50% for each amenity and a weighting of 100% for all the amenities except beach width. The model includes an adjustment to the beach width amenity to reflect the reduction in consumer value for widths narrower than 250 feet. The academics have not provided any direction or guidance for adjusting any of the other criteria or amenities to tailor the general valuation to individual beaches and instead recommend that the $39.49 value be used for all beaches throughout the state, with adjustments only for beach width and inflation.

Academics' Recommendations about Beach Attendance

Beach attendance or visitation can be estimated many ways. Some beaches can use parking receipts and an estimate of the occupancy rate. Other beach areas rely upon visitor counts by life guards, counts from aerial photographs, or from the use of counters at controlled ingress and egress points. Counters at all access points might provide the most reliable information on visitation, but few California beaches have isolated access points and none of these have permanent counters. When other beach count methods are used, the challenges range from the accuracy of the individual counts, to extrapolation of individual counts to daily, weekly, monthly or annual attendance. Beach counts can identify the number of people at the beach at the time of the count, but they provide no information on beach turn-over. Even if counts are taken throughout the day, knowledge that 25 people were on the beach at 10 AM, 2 PM and 4 PM, for example could represent 25 people who stayed on the beach most of the day, 75 visitors in three separate groups of 25 people who visited for only a short time, or some combination of the two. As a result, daily beach attendance is often based upon a single count that is adjusted by a turnover factor. King and McGregor (2012) have reported that most of the official California attendance numbers used for public policy tend to overestimate actual beach user intensity.[61]

[61] King, Philip, and Aaron McGregor. (2012). "Who's counting: An analysis of beach attendance estimates and methodologies in southern California." *Ocean & Coastal Management* 58: 17-25.

Beach attendance often requires estimates and approximations, since good site-specific studies are rarely available.

The academics have provided attendance numbers and attendance densities for many popular beaches in Orange, Ventura and Santa Barbara Counties, and for beaches within San Francisco Bay. The recommended valuation method using attendance density (people per square foot of beach) as an input allows total attendance to change with changes in beach area. Due to the difference in beaches between southern and northern California, the academics have recommended different attendance densities for beaches north of San Luis Obispo and those in San Luis Obispo and south. The academics have undertaken attendance density surveys for beaches throughout parts of the state and they recommend using averages from these studies to develop broadly applicable attendance density numbers. For attendance density, the academics recommend using 3.3 people per square foot per year for central and southern California (i.e. San Luis Obispo County and south) and 1.26 people per square foot per year for northern California beaches (Monterey County and north).

The public takes advantage of open space on the beach for the Morro Bay Kite Festival. Photo Credit: Danna Dykstra-Coy

Academics' Recommendations about Recreational Value Method for Beaches

Annual Recreational Value

The academics recommend that the recreational value of a beach be distilled into two components: the consumer surplus value (or day use value) that quantifies the average, per person value of beach recreation and the number of people who use the beach. Through their study of beach recreation and beach use, they have provided both a state-wide consumer surplus value and regional attendance densities that can be used in these calculations. The equations that summarize their recommended approach for estimating annual recreational value of a beach are:

(1a) Annual Recreational Value ($/yr) = Day use value ($/person) * attendance (people/year)

(1b) Attendance (People/yr) = Attendance density (people/sq.ft/yr) * length (ft) * width (ft)

Or

(2) Annual Recreational Value = Day use value * attendance density * length * width

Where, Day use value (consumer surplus) will change as a function of beach width,
Attendance will change as a function of beach area,
Length (the length of the shoreline protection) will be constant, and
Width (beach width at location of shore protection) will change due to erosion

Values for day use value and attendance density are shown in Table 3. Measurements will be needed for both project length and beach width and the academics also provide some instruction on these factors.

Table 3. Consultant Recommendations for Day Use and Attendance Density (See Appendix A)

Recreational Value Component	San Luis Obispo County and South	Monterey County and North
Day-Use value/Consumer Surplus ($)	**39.49**	**39.49**
Attendance Density (people per square foot per year)	**3.30**	**1.26**

Quantifying Recreational Value Losses due to Shoreline Armoring

The academics have recommended that the recreational losses due to armoring be based upon the differences between the beach without armoring and the beach with armoring. The key parameters for determining the recreational value of the beach without armoring are the inputs for Equation 2, where beach length would be the length of the proposed armoring project. The beach width is the distance from some back beach feature seaward to either the wetted bound or to the wet intertidal beach if the dry beach zone is especially narrow and this parameter would be based upon the conditions of the project site. The academics recommend that beach width (ideally dry beach width, but beach width that includes the wet intertidal beach if necessary) be based on average measurements for the summer months because beach recreational use is highest in the summer.

Beach width is the key parameter for changes in the recreational value of a beach, both over time or due to shoreline armoring. As the beach narrows, the consumer surplus and the bach attendance will change. The consumer surplus will change through amenity values embedded into the recreation value method. Changes in attendance will change due to the direct connection attendance and beach area through the attendance density parameter.

Shoreline armoring will alter beach width in two ways. The first, and most immediate loss is through encroachment or placement when the protective structure is constructed on the beach. The footprint of the protective structure will replace beach area and beach width will be lost along the section of coast where the structure has been placed. Shoreline armoring can also cause longer-term losses of beach width. For an unarmored beach, it can often be assumed that the beach can adjust its location inland, and through this adjustment, there will be no actual loss of beach width. Erosion of the seaward portion of the beach face will be balanced by inland migration of the back beach. When armoring is installed on a beach, it will limit this inland migration. Erosion of the seaward portion of the beach will continue, but there will not be balanced by the inland migration of the back beach and a loss of beach width will occur over time.

Both of these changes in beach width will change the recreational value of the beach. The day-use value (consumer surplus) will decrease as the beach narrows. Likewise, attendance density (people per square foot of beach) will also change as the beach area decreases. These changes in day-use value and attendance can be used to quantify the annual recreational value of a beach with a seawall. Thus, the changes in annual recreational value from construction of a seawall can be based on the annual recreational value with no seawall minus the annual recreational value with a seawall.

The academics have provided a worksheet to allow Commission staff to calculate both of these recreational values. The worksheet calculates recreational values on a yearly basis. For projects that will be in place for more than one year, the method calculates values for future years, based on changes in future beach width resulting from expected erosion and the discount rate (1% is recommended for beach recreation values, based on the academics' best professional judgment). Each annual value is summed to quantify the recreational losses for a multi-year period.

Commission staff must provide information on:

- Armor length
- Armor width
- Dry summer beach width, without armoring
- Dry summer beach width, with armoring
- Annual Average Long-term Erosion rate
- Number of years that recreational value will be calculated

Default values are provided for day-use value (consumer surplus) and attendance density; however, Commission staff can insert more site-specific values for attendance density if such values are available and a more site-specific analysis seems appropriate. As noted previously, the academics recommend that there be no changes to the state-wide consumer surplus value.

Summary of Academics' Recommendations for Recreational Valuation

In summary, the academics provided the following guidance and recommendations:

- Use a recognized method of aggregate user values of a non-market good to determine the monetary value for recreation without and with shoreline armoring.
- Use the parameters of consumer surplus (day use value), attendance density and beach area for beach recreation valuation.
- Use a single state-wide value or $39.49 (2015 dollars) for consumer surplus, modifying this for changes in beach width and inflation.
- Use two regional values, 3.3 people/sq.ft./yr and 1.26 people/sq.ft./yr for attendance density south and north of the San Luis Obispo/Monterey county boundary, respectively.
- Use average summer-time measurements of the distance between the backshore and the wetted bound for beach width. On narrow beaches include the intertidal beach in the measurements.
- Use project length and width to calculate the immediate reduction in beach area and recreational value resulting from encroachment (placement) loss.
- Use annual average long-term erosion of the back shore to account for beach narrowing and to calculate the long-term reduction in beach width as a result of fixing the back beach position; use a rate of zero beach erosion for the without project condition in which the beach could migrate inland without armoring constraints.
- Modify the attendance density value for more geographically-specific values if a government agency or applicant so desires, only with technically sound attendance density surveys that follow the provided guidance in the necessary quality and quantity of surveys.

The academics did not provide guidance or recommendations on the following:

- Mitigation, either in-kind mitigation that could be comparable to the recreational losses, or possible uses for the in-lieu fees.
- Guidance on how local governments can incorporate their own studies of beach value into the state-wide consumer surplus (day use) value to develop a more geographically-specific value.
- Criteria or tipping points, such as new economic studies of beach recreation in California, or documented changes in beach use, consumer surplus, etc., that would signal the need to reassess the basic method used for recreation valuation or the recommended consumer surplus or attendance density values.

Hypothetical Case Studies Prepared by the Academics (Task 5)

San Elijo and Del Monte

To examine the recreational valuation method, the academics developed hypothetical case studies for San Elijo Beach in San Diego County and Del Monte Beach in Monterey County.

They made assumptions about the dimensions of the shoreline armoring project, beach width and erosion rates. In a real situation, the applicant and analyst would use project-specific information; however, these case studies offer some insight into how the proposed recreational valuation will vary for different beach locations and how the resulting valuation compares with current mitigation values. Table 4 provides a summary of these two hypothetical case studies, with the input assumptions and resulting recreational valuations as provided by the academics.

San Elijo Beach is located in Encinitas (north San Diego County) just west of San Elijo Lagoon. The beach provides swimming, surfing, boogie-boarding, skim-boarding, showers, picnicking, and camping. Campsites are located on a bluff just behind the beach. The beach is relatively narrow and continued bluff erosion would likely threaten the existing bluff top campsites. The beach width varies with season and storm patterns. According to a recent survey conducted for SANDAG,[62] the "dry beach" (Mean high tide to bluff back) average width is 212 feet in high season (summer). As shown in Table 4, the hypothetical seawall at San Elijo would be 12 feet wide and 2,000 feet long, protection campsites and parking above the bluff. The assumed erosion rates are 0.5 feet/year without a project and 1 ft/year with a project.[63]

[62] See San Diego Association of Governments. (2014) SANDAG Regional Beach Monitoring Program, prepared by Coastal Frontiers Corporation.

[63] As part of the hypothetical example, the academics assumed there would be some beach erosion even without the seawall as a way to show the flexibility of the model; however, most studies of this area show that for this section of the coast, beach width can remain fairly constant if the backshore is allowed to retreat inland and sediment supplies are not interrupted..

Two girls sit by a fire on Samoa Beach in Eureka just after sunset. While the beach holds recreational value for the two, they aren't considering consumer surplus; they're thinking about consuming their roasted marshmallows. Photo Credit: Carissa Ranario

Del Monte Beach is located in the City of Monterey, just east of the wharf. The beach is popular with locals and visitors to the City. Dog-walking off-leash is popular, as are the fire pits at night. Restrooms are not available on the beach but are available nearby. The beach is backed by a City park closer to the wharf; as one moves north/east there are several condos and a hotel. As shown in Table 4, the hypothetical seawall at Del Monte beach would be a narrow profile wall that is 500 feet long. The dry beach is about 150 feet wide and the assumed beach erosion with the seawall would be 1 foot/year. Without the seawall, the back beach is assumed to retreat to adjust to shoreline change, and beach erosion is assumed to be zero.

Table 4 provides a summary of the two consultant-provided case studies, with the input assumptions and resulting recreational valuations. The following section, Recreation Valuation Commission Staff Conclusions provided comments on both the recommended valuation method and the outputs from these two hypothetical examples.

Table 4. Recreational value case study parameters and results
(All Recreational Values are presented as Present Value (PV), using a 1% Discount Rate)

PARAMETERS/INPUT	San Elijo Beach	Del Monte Beach (1)
PROJECT INFORMATION AND BEACH CONDITIONS		
Project Length	1,000 ft	500 ft
Beach Width without Project	212 ft	150 ft
Beach Width with Project (taking into account placement loss due to project footprint)	200 ft	150 ft
Rate of Beach Narrowing without Project(2) (Called erosion rate by academics)	0 ft/yr	0 ft/yr
Rate of Beach Narrowing with Project(2) (Called erosion rate by academics)	0.5 ft/yr	1 ft/yr
INTERIM OUTPUTS FROM THE METHOD		
Initial Annual Attendance without Project (based on attendance density and beach area)	700,514	94,784
Initial Attendance with Project	660,862	94,784
Initial Recreation Value without Project	$37.89	$35.97
Initial Recreation Value with Project	$37.56	$35.97
OUTPUTS (Rounded to nearest $100)		
20-yr Recreational Value (PV) without Project	$483,700	$62,140,100
20-yr Recreational Value (PV) with Project	$428,600	$57,800,400
20-yr Recreational Value Losses (PV)	$55,084,900	$4,399,600
20-yr Recreational Losses (PV)/ft of project (3)	$55,100 /ft	$8,800/ft
Recreation losses (PV) for a 40 foot long seawall (3)	**$2,203,400 /40-feet**	**$352,000 – 40-feet**

(1) In the presentation of the Del Monte case study in Appendix A, the academics accidentally located Del Monte Beach in southern California and used the South of San Luis Obispo attendance density of 3.3 rather than 1.26. The recreational values for Del Monte Beach that are reported in Appendix A are based upon this erroneous attendance density. In this table, Del Monte Beach has been correctly located in Monterey County and the attendance numbers are based upon the 1.26 attendance density recommended for this location.
(2)The academics provide an option to change erosion rates that result from the shoreline armoring. If there are no constraints on the inland migration of the beach, it is assumed that the back shore bluff or dunes will experience erosion, but that the without project beach erosion will be zero.
(3) Developed for comparison purposes. These loss values are not included in the method output)

Commission Staff Recreation Valuation Conclusions

The California Coastal Act recognizes coastal access and recreation as important coastal resources. Shore protection through hard armoring has well-documented impacts to beach access and recreation and the Commission regularly analyzes these impacts when reviewing armoring projects for consistency with the Coastal Act. For the most part, the impacts and the applied mitigation have focused on the physical changes to the beach that will alter access and recreation. The method proposed by the academics provides an opportunity to value the recreational losses that can be attributed to the beach changes. Such an approach has been used for two large shoreline armoring projects; however, for various reasons of staffing, expertise, and normal project information, the Commission has not used a recreation valuation approach for the review of all recent shoreline protection.

The proposed method uses estimates of consumer surplus and attendance density that could allow a recreation valuation method to be applied to most shoreline armoring projects. The input data would use information that is normally part of the permit application process or that could fairly easily be obtained. Thus, it would not result in undue review time or excessively greater permit application requirements. The provided values for consumer surplus and attendance density are reasonable, and they are supported by peer-reviewed research and/or professional judgment.

If an applicant or community questions the applicability of the attendance density, the academics have provided guidance on an acceptable way to update attendance. The academics provided no alternatives to the consumer surplus values if an applicant or community questions whether the state-wide value is applicability to their location. Some type of peer-review or outside examination of the state-wide consumer surplus might be appropriate before a single consumer surplus value approach is used to determine recreational valuation losses.

Sea level rise **e**ncroaches upon property in Santa Cruz and reduces public access. Photo Credit: Lesley Ewing

Both the consumer surplus and the attendance density will decrease as beach width decreases. Since beach width is only one aspect of the consumer surplus value, beaches continue to have value until the beach disappears. For example, even when there is only 1 foot of dry beach, the consumer surplus will be over $16.50 per attendee. The use of attendance density directly links beach attendance with beach area. As beach width decreases, beach attendance is assumed to decrease proportionally. When the beach is only 1 foot wide, the attendance will drop to only 632 people per year for beaches north of San Luis Obispo and 1,655 people per year for San Luis Obispo land south. The only adjustment for attendance is through changes in beach area. The valuation method has a factor to adjust the consumer surplus for overcrowding; but as presented, the method assumes that the only response to a smaller beach will be fewer people coming to the beach. Increased crowding or changes to the future attendance densities are not included in the method. A large amount of the recreational valuation loss comes from this assumption about attendance changes with beach loss. Due to the major influence of beach change on attendance, and those on overall recreational valuation losses, some type of peer-review or outside examination of this assumption about attendance and beach width seems very important.

Comparison of Academics' Recreational Valuation with Commission's Current Mitigation
Based upon the Commission's current mitigation methods for the loss of recreational beach area, the average San Diego seawall mitigation is about $1,000 to $3000 per linear foot, or $40,000 to $120,000 per single family home with a typical armoring length of 40 feet. The academics southern California example (San Elijo) identifies over $2.2 million for the hypothetical armoring case study. However, the academics made an assumption that the armoring might be 12 feet wide. Changing the extent of the seawall in the San Elijo case study to be a more typical 40-foot long, 2-foot wide seawall, the recreation valuation losses would be about $1.17 million (PV) or $29,250/ft. Thus, in this case the consultant's recommended formula results in a mitigation fee of at least 10 times that of the Commission's current practices.

Del Monte Beach represents a northern California beach. When this example is compared with the Land's End project in Pacifica, a similar disparity between current mitigation and recreational value losses is apparent. The mitigation for Land's End, based on land value, was $1,620,011 or $2,492/ft. Recreational losses for a similar length wall based on the Del Monte example would be $5,641,503 (PV) or $8,420/ft. Thus, in this case the consultant's recommended formula results in a mitigation fee of approximately 3.5 times that of the Commission's current practices.

The identified recreational valuation losses greatly exceed what the Commission has been using as mitigation for the loss of recreational beach area. Based on the case examples, the fees from the recreational value method are 3.5 to over 10 times more than the in-lieu fees that have been applied by the Commission for similar projects. While these recreational losses likely provide a more realistic valuation of the actual impacts from shoreline armoring, staff recommends additional examination or peer-review of some of the underlying assumptions used in this method. As noted earlier, staff recommends that peer review of the consumer surplus value of $39.49 be considered. In addition, further examination of the assumptions about attendance densities will also be important.

6. MITIGATION (Task 6)

Shoreline armoring can result in large ecological and recreational losses. The Commission carefully reviews armoring projects to ensure that there is a need for the project (as determined by the Coastal Act) and that all possible efforts have been taken to avoid or minimize project impacts. For impacts that cannot be avoided, the Commission has required mitigation, either in the form of in-kind project or in-lieu fee. As discussed in the previous sections, there are clear, identifiable connections between the action of armoring and the identified losses or impacts to beach ecology and recreation. The academics have provided methods for valuing the losses that can be reasonably expected to result from shoreline armoring. Mitigation is a way to compensate the public for some or all of the losses identified through the valuation efforts.

Both the beach ecology valuation method and the recreation valuation method provide dollar values (fees) for losses to these resources. In practice, there could be repositories for these fees to support the mitigation projects that are determined to be the most appropriate and proximal to the respective shoreline armoring project. Mitigation may relate directly to the valuation, but in many situations, mitigation will be different from the valuation.

For example, while the recreational losses are associated with a loss in value experienced by beach users, mitigation for recreational losses might provide improved access or expanded beach area in a location close to the impact area The mitigation would not directly reimburse each user for their reduced beach experience. Likewise, ecological mitigation would seek to improve beach ecology in locations close to the ecological losses, through changes in management practices, or ecological enhancements, rather than undertake a one-for-one replacement. The remaining discussion addresses potential options and approaches to mitigation that may be used to address identified recreational and ecological values for armoring project impact costs.

Guiding Principles for Mitigation

Although the Coastal Act does not contain a specific definition for mitigation, California Environmental Quality Act (CEQA) and the associated CEQA guidelines provides several alternative forms of mitigation. Those forms of mitigation that are most relevant to Commission actions include the following:

1) Rectifying the impact by repairing, rehabilitating, or restoring the impacted environment
2) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action
3) Compensating for the impact by replacing or providing substitute resources or environments

The Commission always seeks to first avoid any need for mitigation through project design because this is the best way to prevent direct adverse impacts to public access and sand supply in association with a shoreline protective device.[64] However, if the Commission is required to approve shoreline armoring to protect an existing structure, minimizing or reducing project impacts by design modification is one way to diminish the severity of the armoring related impacts. Although this form of mitigation can result in alterations to the project design, the overall integrity of the project can be preserved.

In the past the Commission has also relied on compensatory mitigation of unavoidable impacts by replacing public access or sand which is lost or adversely impacted, with access or beach area of equivalent value or size. This is considered in-kind mitigation. Instead of direct substitution of resources, another form of compensatory mitigation the Commission has employed is a mitigation fee ("in-lieu fee"), instead of direct action on a beach to compensate for the impacts of armoring on natural shoreline processes and sand supply. A third option for compensatory mitigation is mitigation banking, an approach where there might be economic efficiencies as well as better environmental results if compensatory mitigation actions are carried out in well designed and on-going in-kind and proximal restoration, in advance of foreseeable future projects, or if a single large mitigation action could compensate for the impacts of multiple future development projects[65]. This approach allows for single user banks where credits are intended to be used to offset projects carried out by the bank creator, or multi-user banks in which earned credits can be sold to third parties whose projects require compensatory mitigation. Regardless of the form of compensatory mitigation, it is important to ensure that the mitigation measures required actually offset the impacts of the project.

The best mitigation provides immediate and lasting benefits to the coastal region affected, so in-kind mitigation is normally encouraged first. When in-kind improvements are not possible, the Commission has accepted some off-site improvements, and as a final option has accepted the use of in-lieu mitigation. The approaches used by the Commission in the past connected in-lieu mitigation to the land area, land value or to the user value.

Current Commission Mitigation Approach

In previous studies and permit findings, the Commission has identified three quantifiable impacts to the beach resulting from shoreline armoring – denial of sand to the littoral cell, encroachment or placement losses resulting from the footprint of the shoreline armoring structure, and preventing the creation of new beach by fixing the location of the back beach. The latter two impacts are the impacts addressed in the academics' valuation study and the focus of this report.

Loss of Sand Supply: For full coverage of mitigation, it is assumed that the loss of sediment will continue to be quantified, valued and mitigated by the method that the Commission has used from about 1997 to the present. The sand loss amount is equal to the volume of sand-sized sediment that would have reached the littoral cell if backshore erosion had not stopped. The valuation of this volume of sand has been taken as the market cost of sand, based on the average

[64] California Coastal Commission, Report on In-Lieu Fee Beach Sand Mitigation Program: San Diego County, 1997
[65] Clement, J.P. et al. 2014. A strategy for improving the mitigation policies and practices of the Department of the Interior. A report to the Secretary of the Interior from the Energy and Climate Change Task Force, Washington, D.C., 25 p. Access on 5/8/15 at http://www.doi.gov/news/upload/Mitigation-Report-to-the-Secretary_FINAL_04_08_14.pdf

of three bids from sand suppliers. The sand value mitigation has been provided as an in-lieu fee required as a condition of the coastal development permit for the project. The money from in-lieu fees is often used to augment local sand supplies, by partial or complete funding of beach nourishment projects.

Physical Encroachment and Loss of Beach: In addition to the reducing sand supply to the littoral cell, shoreline armoring can cause loss of the beach through both the placement loss and fixing the back beach. As discussed earlier in this report, the key parameters for these two impacts are the altered length of beach in the case of ecological losses and the altered beach area in the case of recreational losses.[66]

Development along Pacifica is battered by the surf during a King High Tide; the beach is non-existent. Photo Credit: Jack Sutton

The discussion of the Commission's current process of quantifying values for armoring impacts was intended to clarify some of the major impacts and to support development of mitigation strategies. However, armoring impacts are not limited to those that can be easily quantified – there are also temporary but recurring impacts due to scour, longer term impacts due to end effects, and visual impacts, which can result in permanent changes to the character of the coast. In addition, if a seasonal eroded beach condition occurs with greater frequency due to the placement of shoreline armoring, then the subject beach would also accrete at a slower rate. Moreover, if a structure is subject to wave action on a frequent basis, then beach scour during the winter season will be accelerated because there is less beach area to dissipate the wave's energy. Even if these beach changes are reversible or short-lived, the beach disturbances may result in changes to the ecosystem's function that last long after recovery of the recreational values.

[66] For armoring structures wider than 6 feet, beach width may also be a concern due to the immediate changes to the ecological function from the significant loss of beach area.

Implications for Mitigation Based on Academics' Recommendations

The proposed valuation methods for recreation and ecology rely on empirical data to form the basis of consumer surplus, attendance, and restoration costs. The foundation of the recreational valuation method has been extensively published and is considered the best available method for assessing the loss of recreational value on beaches with shoreline armoring (See Appendix A). Even so, the academics cite a lack of studies deriving consumer surplus and attendance density (especially at northern California beaches) as hindering application of their method. There are additional limitations to the ecosystem valuation approach because of the small number of examples of beach restoration and managed retreat projects that can be used for estimating beach restoration and creation costs. Land valuation may be a preliminary approach to placing a dollar value on potential restoration projects because future restoration projects that could be used for mitigation might require land purchase in order to implement the restoration; however, this overlooks the cost of restoration activities. The land valuation proxy may be the best way to estimate these restoration costs by littoral cell in the short term until more restoration project cost values are developed. Consequently, Commission staff believe that the academics' proposed valuation methods could be improved over time as additional data can better inform them.

Grunions spawn on the shores of beaches and their nests are vulnerable to being buried by sand nourishment during spawning seasons.

Challenges of relying on restoration projects as the value for impacts to ecological function are varied and multifaceted. Because many beaches are considered irreplaceable, it will be difficult to fully compensate for or replace lost beach function with in-lieu fees or offsets. In fact, the suggested 4:1 ratio for assessing ecological mitigation is based on the knowledge that restoring beach habitat of equivalent value to an impact site will be imperfect.

Relying on a 4:1 mitigation ratio to compensate for beach ecological loss intends to account for the recovery time and diminished ecological functioning that result from armoring, but monitoring the effects of armoring and restoration is pivotal in providing information to justify and to refine these targets in the future. Offset mitigation that requires a beach ecological restoration project be in the same littoral cell attempts to allow for appropriate mitigation given the location of the armoring impact. At the least, placing individual armoring projects in a regional context can shed light on the cumulative impacts communities can expect for their beaches in the future.

The valuation methods clearly distinguish between the valuation of recreational losses and ecological losses. The costing methods for recreational and ecological losses are distinctly independent, as the recreational method is a use-based metric and ecological value is a land value-based (restoration cost/offset) metric. However, there may be mitigation options that would provide both recreational benefits and ecological benefits. Such synergies and complementary benefits would be fortuitous but they should not be considered as double counting. Furthermore, the academics stated that most beaches heavily used for recreation do not have a high ecological habitat value, and vice versa. Cases where beaches improved by mitigation projects have significant value for both impact areas are expected to be rare.

Ideally, the recommendations contained in the academics' report ultimately will be useful to the application of a common methodology for reviewing shoreline armoring permit applications on a case-by-case basis, including identification of appropriate mitigation based on the specific impacts of each case. The implications for mitigation based on the academics' valuation methods point to additional next steps as well as recommendations on how to better mitigate the impacts of shoreline armoring. The following section details those findings and recommendations.

7. DEVELOPMENT OF GUIDELINES (Task 7)

While the proposed recreational valuation method and ecosystem valuation method provide good conceptual frameworks for improving the Commission's existing approach for assessing impacts to recreation, access and beach ecology from shoreline armoring and developing appropriate mitigation strategies, the data required to feed into these methods and the lack of a State-wide approach to in-lieu fee application, present challenges for their immediate application. Specifically, key information gaps still exist, existing data need refinement, some aspects of the methods need further development and specificity, and appropriate mitigation projects and mechanisms for applying in-lieu fees need to be developed.

Addressing Major Data Gaps and Procedural Limitations

Ecosystem Valuation Method
The ecosystem valuation method proposes that the cost associated with the impacts to beach ecology from shoreline armoring be estimated using the cost of existing and future beach ecosystem restoration projects. A shortcoming of the examples provided by the academics to estimate the average per square foot restoration cost is that they do not represent the diversity of California beaches and do not comprehensively include the full complement of costs associated with each project (e.g. land acquisition, management, monitoring, etc.). Thus, further research on restoration costs at various beaches with different ecological values (ex. sensitive species and habitats) may provide a more accurate cost of restoration.

The academics outline a hierarchy of mitigation approaches to improve beach ecological functions with the in-lieu fees, ranging from full restoration of a beach area and removal of obsolete shoreline armoring to modification of beach management techniques. The realized benefits to beach ecology can vary significantly depending on the type of restoration projects chosen. The Commission should determine appropriate criteria for restoration projects for which mitigation fees can be applied. Regardless of the type of project chosen, the Commission should develop success criteria for various beach restoration efforts, similar to the Commission's current practice for other habitat types, such as wetlands.

The science supporting beach ecology valuation is still in its infancy and will continue to evolve. Therefore, the Commission should continue to follow new studies and adapt the recommended approaches utilizing any future scientific research that will better assess impacts and appropriate mitigation. For example, the proposed approach does not consider beach nourishment, as currently practiced, to be an ecologically sound restoration project for which mitigation fees should be applied due to its ecological impacts combined with its short lived effects. It is possible that in the future beach nourishment projects could be added to the suite of restoration projects if criteria can be developed for undertaking nourishment in a more ecologically sound manner.

Sea wall debris in San Mateo County negatively impacts the surrounding beach ecology. Restoration projects would serve to improve beach environments. Photo Credit: Lesley Ewing

Similar to the recreation valuation method, some local jurisdictions identify restoration or conservation priorities in their LCPs. The Commission should develop appropriate criteria for restoration projects that mitigation fees can be applied to assist local jurisdictions in identifying which types of priority projects outlined in LCPs could be implemented using these fees. In addition, LCP jurisdictions that have not yet cataloged priority restoration and conservation projects will need to undertake this initial effort. Finally, the Commission and many local jurisdictions do not have a centralized, streamlined mechanism in place to capture in-lieu fees and apply them. As such, the best mechanism or variety of mechanisms, still need to be identified and developed.

Recreational Valuation Method

The method that the academics have recommended for determining recreational value of a beach is based upon well-recognized economic models and there is no reason to question its use for quantifying recreational beach values for purposes of determining impacts from shoreline armoring. However, the consumer surplus and attendance densities that are recommended for specific use to California rely primarily upon research focused on heavily used southern California beaches. The academics were hired to assist staff in this beach valuation effort due to their recognized expertise in quantifying the recreational value of California beaches. Nevertheless, it would be appropriate to seek some further peer review of their recommended state-wide day use values, and suggestions for ways to update this value as new, peer-reviewed research becomes available. Further peer-reviewed studies on consumer surplus and attendance conducted on a more regional or site specific level could help to refine these averages for central, north central and northern California or for less heavily used beach areas.

The recommended recreation valuation method includes various criteria or amenities for a beach visit (such as weather, water quality, etc.) that can be used to differentiate the day use value for different beaches. The academics have recommended one consumer surplus value for state-wide use; however, in the future it could be possible and useful to establish more regionally-appropriate criteria or amenities to develop regionally-specific or locally-specific day-use values. It may be possible to further refine the model for individual beaches by setting more representative amenity point values for the various amenities associated with different beaches. However, pursuing this option would first require development of a consistent approach for weighting beach amenities to ensure an objective process. Peer review of the recommendations could help identify the appropriate changes and modifications that might be most useful and most appropriate to development in the future.

It is also important to recognize that estimates of beach width and beach erosion rates before and after shoreline armoring occurs are based on current scientific understanding of these topics and application of the best available methods to estimate these values. If further research reveals a way to better estimate these values and other impacts such as scour at the base of the seawall and edge effects, these too may be folded into the recreation valuation method.

It is clear from the case studies provided that the recreation valuation method will produce a large recreational loss value. If the mitigation fee corresponds directly to this recreation loss value, then a large amount of funds could be available for beneficial mitigation projects either at the site, locally or regionally to improve public access and recreation. Some local jurisdictions already identify public access and recreation improvement priorities in their Local Coastal Programs (LCPs). However, not all of these projects would create an appropriate benefit to mitigate for shoreline armoring impacts. The Commission should develop criteria or priorities for mitigation projects to assist local jurisdictions in identifying which types of priority projects outlined in LCPs could be implemented using these fees. LCP jurisdictions that have not yet cataloged priority recreation and access improvements will need to undertake this initial effort. Finally, the Commission and many local jurisdictions do not have a centralized, streamlined mechanism in place to capture in-lieu fees and apply them. As such, the best mechanism or variety of mechanisms, still need to be identified and developed.

Recommendations

The results of this project highlight the importance of public access, recreation, and ecological services provided by beaches and the value lost to these coastal resources resulting from shoreline armoring projects. While the information gaps and procedural limitations identified above limit the immediate application of the methods, there are potential ways in which the results can be applied to the current LCP Program and coastal development permits, as well as future work Commission staff can undertake to strengthen the valuation methods and their potential application in the future.

Local Coastal Program Recommendations

LCPs provide a mechanism to better refine data and identify opportunities for mitigation to improve application at the local level. Future recommendations for the LCP program which would build upon the frameworks derived from these methods include:

Recommendation 1. Identify potential mitigation projects[67]: The Commission should direct LCP jurisdictions to develop a program that will identify and prioritize mitigation projects as described below.

Ecological mitigation projects: Identify and prioritize potential areas for beach restoration that meet a set of criteria including: locating the restoration site at the impacted beach or a nearby beach, ideally within the same littoral cell; ensuring the restoration has the potential for resiliency (allows for natural or managed retreat due to erosion or climate change); and ensuring it provides an ecological benefit to sandy beaches. A project could include, but is not be limited to any of the following: enhancing existing beach resources (restoration and revegetation of dunes or coastal strands and/or removal of invasive species), acquiring land and/or removing or relocating infrastructure to allow beach ecosystem recovery inland, or enhancing sediment supply through the removal of dams or other infrastructure. Potential restoration sites should include various types of beaches, habitats and ecological zones, as well as areas which support sensitive species. Include detail on the location and extent of the restoration, the type of restoration, the ecological benefits, the type of beach to be restored, any land to be acquired, permits required, and the potential cost (including monitoring for success and land acquisition costs).

Additional mitigation approaches that should be examined include modifying existing beach management practices to be more ecologically sound. This might take the form of cessation of all beach grooming or conducting beach grooming in a more ecologically sound manner – seasonal grooming, interval grooming, grunion sensitive grooming, or hand grooming. Other approaches include cessation of building sand berms and displaying educational signage highlighting the benefits of wrack, etc.

Recreation and public access mitigation projects: Local governments should take into consideration potentially-impacted resources when prioritizing restoration areas in each LCP jurisdiction. Identify and prioritize potential areas for public access and recreation improvements that meet criteria including that the mitigation project provides access and recreation benefits in the immediate project area or within the littoral cell and provides or enhances lateral access along the shoreline or vertical access to the shoreline between the first public road and the sea, or provides or enhances other beach amenities (car or bicycle parking, benches, picnic tables, restrooms, showers, etc.). Include detail on the location and extent of the improvement, the type of improvement, the resulting access and/or recreation benefits, and potential cost of improvements. Consideration should also be given to the identification of potential areas where future land acquisition would allow for managed retreat.

Recommendation 2. Include a mechanism for collection and application of mitigation fees in LCPs: The Commission should direct LCP jurisdictions to identify mechanisms for how applicants/permittees can mitigate for impacts within the context of the LCP process. Potential mitigation strategies should include direct mitigation at the site at an equal or greater level to the

[67] Note: The same area can be identified for a project that would provide both recreation and ecological benefits.

identified value of the impact (ex. install a public access trail or stairway or implement a habitat restoration plan for beach area) or provision of an in-lieu fee to be designated to a separate organization/entity to be used for an appropriate mitigation project. If using the in-lieu fee approach, LCP jurisdictions should (1) identify a responsible entity that will collect and designate mitigation fees to projects and (2) develop a mechanism, such as a Memorandum of Understanding (MOU) to ensure that the entity will allocate the money to appropriate mitigation.

Recommendation 3. Generate local attendance density data and other relevant recreation use data for future use: Further studies on attendance conducted on a more regional or site specific level would help to refine density averages used in the recreational valuation method for central, north central and northern California, as well as provide site specific attendance densities for various beaches throughout the state. The Commission should direct LCP jurisdictions to develop a program to collect beach attendance data concurrently with beach width data to produce more refined estimates of average attendance density and beach width to be used in the recreational valuation method. Beach attendance studies should include multiple counts at representative times of a given day/week/year (or a method for adjusting the numbers for seasonality), a way to account for different recreational activities, and a turnover factor. Beach width studies should estimate the average dry beach width from the mean high tide line to the back of the beach during the high summer season.

Coastal Development Permit Recommendations

Coastal development permits (CDPs) provide a mechanism for presenting the results of this project, the approaches being developed, and the potential implications to new projects when applied to better implement the requirements of the Coastal Act. CDP recommendations include:

Recommendation 4. Develop a mechanism for collection and application of mitigation fees: The Commission often permits shoreline armoring through permits in the Commission's original permit jurisdiction, on appeal, or through consolidated permit applications. As such, similar to the discussion above for LCPs, the Commission should identify mechanisms for how applicants/permittees can mitigate for impacts identified through the recreation and ecosystem valuation methods which would work within the Commission's process. Potential mitigation strategies should include direct mitigation at the site at an equal or greater level to the identified value of the impact or provision of an in-lieu fee to be designated to a separate organization/entity to be used for an appropriate mitigation project. If using the in-lieu fee approach, the Commission should (1) identify a responsible entity that will collect and designate mitigation fees to projects and (2) develop a mechanism for ensuring that, such as a Memorandum of Understanding (MOU) to ensure that the entity will allocate the money to appropriate mitigation projects.

Recommendation 5. Consider and integrate relevant analytical discussions from this report into findings: Commission staff should use the relevant information derived from the beach valuation report in future staff reports for shoreline armoring projects to explain the impacts to recreation, sand supply and ecology that result from shoreline armoring. Background could include description of methods used to calculate impacts, the recommended methods described above and their limitations, how to calculate impacts based on the potential new methods described, an estimate in dollars of the value lost if calculated based on the methods described, and potential mitigation strategies and criteria. Identification of specific impacts and any mitigation requirement will be grounded in Coastal Act or relevant LCP policies and their application to case-specific circumstances supported by case-specific findings. Staff reports may also compare the recommended methods to the Commission's current practices for evaluating impacts and establishing required mitigation including: the current methods for assessing impacts from shoreline armoring to recreation and sand supply, and the types of mitigation fees or in-kind mitigation projects required; and current methods for assessing permanent and temporary impacts to coastal habitats and environmentally sensitive habitats, restoration mitigation ratios applied, success criteria used for restoration, and monitoring and reporting required. Integrating information gathered from the beach valuation project into relevant staff reports will help educate the public and the Commission about the potential developing approach, support the current and future mitigation fees required, and describe a nexus to the application of mitigation fees to either recreation and access projects or ecological restoration projects.

Coastal Commission Program Recommendations

Commission staff should continue to collect new information on beach recreation and ecosystem valuation as the state of the science progresses and modify and evolve/refine the methods and frameworks to reflect the best available information. This will include any data generated at the local level through LCPs, in addition to information gathered at the state-wide level.

Recommendation 6. Peer review of consumer surplus recommendations: Commission staff should attempt to obtain peer review of the academics' recommended value for state-wide consumer surplus and request suggestions for ways to update this value as new, peer-reviewed research becomes available. Staff should continue to keep abreast of research and data on peer reviewed consumer surplus studies for beach valuation as they occur throughout the state or nation. These estimates could potentially be used at a later date to refine the consumer surplus values currently used in the recreation valuation method.

Recommendation 7. Collection of future restoration project data for use in the ecosystem valuation method: Commission staff should continue to research and collect data on beach restoration projects as they occur throughout the state. Data collected should include the cost of the restoration, the size of the area restored, the type of beach, the ecological zones restored, any sensitive species or habitats improved or reintroduced, and the success criteria used to measure the success of the restoration. This data could potentially be used at a later date to update/refine the restoration cost estimates for the **ecosystem valuation method**.

Recommendation 8. Establish a Beach Valuation Task Force within Commission staff: A Beach Valuation Task Force within Commission staff can further the goals of this project by continuing the work necessary to allow the Commission to implement beach valuation methods and mitigation strategies for shoreline armoring. Commission staff can continue to work on the development, refinement, and application of beach valuation methods, including data collection that could support the potential future implementation and evaluation of application of these methods in the context of the Coastal Act.

Summary and Next Steps

The Commission has required armoring projects to mitigate for both the direct losses of beach area and the losses of beach sand. The Commission's mitigation for direct beach losses, however, has not fully addressed the impacts to recreation and does not quantify any of the ecological impacts from shoreline armoring. In order to mitigate, proportionally and appropriately, new methods to determine required mitigation are needed. The valuation effort does not recommend modification to the Commission's method for mitigating the losses of beach sand, but it provides new methods to better assess the true costs of shoreline armoring to the public. This valuation project identifies ways to value the recreational and ecological losses related to the direct beach loss. This report is a first step at developing the framework for accounting for the impacts of shoreline armoring on beach ecosystems and mitigating for these impacts.

To continue making progress on achieving the goal of implementing new beach valuation methods to mitigate for shoreline armoring, **we recommend the creation of a Beach Valuation Task Force within Commission staff**. This group can work on developing protocols for mitigation fee mechanisms (Recommendations 2 and 4); drafting staff report findings (Recommendation 5); and continuing to fill data gaps that prevent use of the new methods (Recommendations 6 and 7). Expertise within Commission staff will also be a valuable resource for local governments collecting data and working to streamline mitigation project implementation (Recommendations 1, 2 and 3). The Task Force could facilitate the next step of reaching out to ecological valuation experts working on Natural Resources Damage Assessment for the May 2015 California Refugio Oil Spill to discuss the beach ecology valuation method and coordinate peer review as well. This valuation project provides a good starting basis for eventually adopting new methods for mitigating proportionally and appropriately for armoring impacts to beach recreation, access, and ecology. In the immediate term, action can be taken to improve current mitigation mechanisms, identify appropriate mitigation projects, and collect data for beach ecology restoration projects.

Appendix A. Deliverable from Academics

Improved Valuation of Impacts to Recreation, Public Access, and Beach Ecology from Shoreline Armoring in California

San Francisco State University

CC-13-22

Task 4 final report

June 30, 2015

This document was prepared for the California Coastal Commission by:

Phil King, PhD, Chad Nelson, PhD, Jenny Dugan, PhD, Dave Hubbard, PhD, and Karen Martin, PhD

Note: The recommendations contained in this report are not endorsed by the Coastal Commission

Table of Contents

Table of Contents 2
Executive Summary 5
1. Introduction 9
2. Recreation Literature and Model Review 11
2.1 Conceptual Background for Beach Loss Valuation 11
2.1.1 Non-market valuation overview 11
2.2 Methods for Valuing Beach/Coastal Recreation 14
2.2.1 Revealed & Stated Preference Approaches 15
2.3 Attendance 22
2.4 Beach Width and Recreational Values 25
2.4.1 Shoreline Armoring Effects Beach Width 25
2.4.2 Beach Width Affects Recreation Value 29
2.5 Conceptual Models for Beach Erosion Loss Valuation 31
2.5.1 Estimating the baseline recreational value of a beach: 31
2.5.2 Valuing lost recreation on an eroding beach 32
2.5.3 Time Period and Discount Rate 33
2.6 Parameters for valuing beach loss 35
2.7 Feasibility of Various Economic Models for use by the California Coastal Commission 37
2.7.1 Estimating a day use value using consumer surplus 38
2.7.2 Review of the Consumer Surplus-based Models: 44
2.7.3 Attendance 45
2.8 Conclusion 45
3. Recreation Method 49
3.1 Value of a Beach Visit (Consumer Surplus) 49
3.2 Impact of Beach Width on Recreational Value 51
3.3 Beach Attendance 52
3.4 Estimating the Recreational Value of a Beach before and after a Proposed Project 56
3.5 Choice of a Discount Rate 56
3.6 Case Study: San Elijo Beach 57

3.7 Case Study: Del Monte Beach 59
3.8 How to Use the Excel Sheets To Estimate Recreational Losses 61
3.9 Suggested Methods for Collecting Additional Attendance Data 62
3.9 Conclusion 63
4. Beach Ecology and Ecosystem Valuation Review 65
4.1 Characterizing and Valuing Beach Ecosystems 65
4.1.1 Characterizing Beach Ecosystems 65
4.1.2 Beach zonation 66
4.1.3 Coastal Armoring 69
4.1.4 Impacts of Shore-Parallel Armoring 70
4.1.5 Alteration of ecological function and integrity 77
4.1.6 Coastal armoring as substrate 84
4.2 The Economics of Beach Ecosystems 84
4.2.1 Total Economic Value 85
4.2.2 Summary 90
4.3 Mitigation for beach ecosystem impacts 91
4.3.1 Assigning a Dollar Value to Ecological Services 91
4.3.2 Offsets 95
4.3.3 Use of HEA or other Offset Mechanism for Beach Ecosystem Services: 105
4.3.4 The Offset Approach and Recreational Value 107
4.3.5 Summary 108
4.4 Conclusion and Discussion 109
5. Ecological Valuation Method 111
5.1 Ecological Valuation 112
5.1.1 Developing Ecologically Sound “Restoration” Projects for Beaches 112
5.1.2 Ecological Costs 114
5.1.3 Economic Costs 115
5.2 The Proposed Valuation Method Explained 116
5.2.1 No Net Loss and Habitat Equivalency 116
5.2.2 Quantifying Ecological Loss 117
5.2.3 Mitigation Ratios 119
5.2.4 Potential Use of Mitigation Funds to Restore Beach Ecosystems 120
5.3 The Valuation Method and its Benefits 122

5.4 Case Studies 125
5.5 Summary and Conclusion 128
6. Conclusion and Recommendations 129
Appendix I: Beach Valuation Studies 133
California Beach Valuation Studies: 133
Market values of California beach recreation 133
Non-market values of California Beach Recreation 133
Non-market values of Beach Recreation outside California 136
Appendix II: The CSBAT Model 137
Appendix III: Restoration Project Data 141
References 172

Executive Summary

- Approximately 110 miles of California's coast is armored, including 33% of southern California. Coastal erosion, exacerbated by sea level rise, threatens vital infrastructure such as property, roads and highways on the coast. Constructing a seawall, revetment or other coastal structure may protect structures, but it also reduces beach width and usually increases the erosion rate of the beach.
- The Coastal Commission has developed mitigation policies to address these losses, but most of this mitigation has focused on the potential loss of recreation and sand supply. Less attention has been paid to loss in ecological functions, even though these losses may well be much more serious. This paper (1) derives a simple and consistent model the Coastal Commission can use to assess recreational losses and (2) creates a framework for mitigating the inevitable loss of ecological function created by coastal armoring structures.
- Economists generally agree on the standard techniques used to estimate the recreation value at sites that are free and open to the public, such as beaches. The main constraint involved is the limited amount of empirical data available on coastal recreation. In this paper, we pulled together the main findings from existing studies and data collection efforts to create a simple method that is feasible for the Coastal Commission to apply in all cases.
- Since beaches in California are typically free and open to the public, economists use a technique called "non-market valuation" to estimate the dollar value of a visit to the beach. Non-market valuation techniques estimate the loss in economic value of this reduction in beach width.
- Estimating the recreational value of a beach requires: (a) a measure of the value of a beach day per visitor (consumer surplus), and (b) an attendance estimate. Both are influenced by the width of the beach. This report discusses standard

techniques used by economists to estimate the value of a beach day as well as attendance.

- We provide a method to estimate the loss of recreational value due to a shoreline armoring which requires the following information: (1) the length of the structure; (2) the beach width and erosion rates of the beach before and after the project; and (3) the location of the structure (northern or southern California). It involves assigning an average value for a typical beach-day along with estimates of visitor densities at northern and southern California beaches
- Beaches and other coastal habitats have tremendous ecological value. Their vital roles and functions include rich invertebrate communities and food webs that are prey for birds and fish, buffering and absorption of wave energy by stored sand, filtration of large volumes of seawater, extensive detrital and wrack processing and nutrient recycling, and the provision of critical habitat and resources for declining and endangered wildlife, such as shorebirds and pinnipeds.
- Beaches are vital transitional zones linking terrestrial and marine realms (Polis & Hurd 1996). Coastal armoring can sever these connections, reducing or eliminating key exchanges and functions including organic and inorganic material transfers (detritus, nutrients, prey, sediments), water filtration and nutrient uptake (Bilkovic & Roggero 2008, Dugan et al. 2012). Shore-parallel armoring disrupts connections between the shoreline and shallow water to terrestrial sources of sediments, such as coastal dunes, which can significantly affect sediment dynamics and supply (Nordstrom 2000).
- California's beaches provide critical natural habitat for many endemic species including threatened and endangered species that do not exist anywhere else. Beach habitat in California is severely constrained and threatened by coastal development.
- Given that beach ecosystems are so critical and irreplaceable, we strongly recommend the Coastal Commission adopt a no-net-loss policy for sandy beaches in California. This approach has been applied in other areas, notably coastal wetlands. A no-net-loss policy implies that any reduction in ecological

value of beaches due to shoreline development or armoring must be offset by a corresponding enhancement of ecological functioning of beaches elsewhere, preferably in the same littoral cell.

- Placing a dollar value on the ecological functions and services of beach ecosystems, such as nutrient cycling or storm protection, is challenging since we still do not understand these processes well, dynamic of these exposed ecosystems drive very high inherent variability and the economics of valuing ecological services is still in its infancy.
- The major principle involved here is that coastal armoring structures seriously impede and inhibit the natural functioning of coastal ecosystems to such an extent that the only way to conserve ecological functioning is by restoring other parts of the coast, preferably within the same littoral cell.
- Using the costs of restoring beaches as ecosystems as a basis for calculating the loss of ecological value of beach ecosystems caused by armoring provides a way forward for developing a viable approach to ecological valuation that can be applied to sandy beaches.
- With this policy, mitigation for coastal armoring can provide sufficient funds for projects that can restore beach ecosystems along California's Coast. This report provides credible estimates of the cost of typical restoration projects on the California coast. We have developed a valuation calculation based on the average cost of several coastal restoration projects. Since these projects involved the use of public land, and thus do not involve acquisition costs, nor monitoring costs, we believe these estimates are conservative and may actually underestimate the true cost of restoring coastal habitat.
- Since these restored projects will almost certainly have lower ecological value, we also propose that the Coastal Commission adopt the same approach used for wetland restoration and require a 4:1 ratio—a restoration project must be 4 times larger to provide similar levels of ecological goods, functions and services (EFGS). For some particularly sensitive, scarce or threatened habitat or species, a larger ratio may be necessary.

- We recommend that the Commission adopt an approach that uses *linear* feet as the primary metric for ecological valuation rather than area alone since: (1) the ecological value of a beach or other coastal systems is not necessarily related to the width of a beach—but rather critically depends upon having all of the zones (surf, intertidal, upper beach zone, coastal strand zone and vegetation) present; (2) characterizing ecological beach zone widths with confidence is problematic since they vary greatly with seasons, tides and other natural processes.
- Ideally we suggest there should be an additional fee assessed for *the area of beach directly covered by the structure* that is added to the linear foot based valuation estimate above. This is due to the need to value the immediate loss of beach habitat, generally upper beach habitat zones, that is caused by the footprint of an armoring structure on the day it is installed. This placement loss depends on the type of armoring structure used by an applicant. For example a seawall will cover considerably less area of the beach than a revetment and the fee would be lower.
- As outlined in this report , creating two separate fees for 1) recreational value and 2) ecological functions, goods and services (EFGS) for beaches does not lead to double counting. The recreational and ecological components are additively separable because they represent the distinct services and functions provided by open coast sandy beaches.

1. **Introduction**

This study report describes a portion of a larger project, funded by the National Ocean and Atmospheric Administration (NOAA), whose objective is to build upon ongoing efforts by the California Coastal Commission to develop approaches for mitigating the impacts to recreation and public access, resulting from changes to beach width due to shoreline armoring in a manner that is proportional and appropriate.

Coastal Act Section 30235 states:

> *"Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fish kills should be phased out or upgraded where feasible."*

Accordingly, Section 30235 only requires the Commission to authorize the construction of shoreline protective structures when the structures are required to serve coastal dependent uses or protect existing structures or public beaches in danger from erosion. The Coastal Act provides these limitations because shoreline armoring can have a variety of impacts on coastal resources, including effects on sand supply, public access and recreation, coastal views, natural landforms, marine resources, and overall shoreline beach dynamics on and off site. While the Coastal Act allows for shoreline armoring as outlined above, it is the Commission's policy to consider all options that will avoid impacts to coastal resources to the maximum extent possible and only to mitigate for any unavoidable impacts.

Two of the main objectives of this project are the following:

1. Develop a method to estimate the value of recreation and public access beach resources that can be used to assess recreation and access losses that may result from shoreline armoring.

2. Develop a new method for estimating the value of ecological services and functions on beaches that can be used to assess ecological losses that may result from shoreline armoring.

3. Apply the recreation and public access valuation method (and the ecological valuation method depending on its state of development) to one or more real world case studies to evaluate its effectiveness for various beach conditions.

Under Objective 1, Section 2 of this report presents the theoretical and conceptual overview of the methods necessary to develop a science-based method to value beach loss due to shoreline armoring. This includes a survey of the literature, both academic and applied, related to economic valuation of beach recreation. The purpose of the survey is to give a general overview of the best current theory and practice related to valuing coastal recreation. Section 3 provides a summary of the main techniques used to value loss of coastal recreation due to beach loss as well as a discussion regarding the feasibility of each technique along with recommendations for moving forward.

Section 4 presents a literature review of beach ecology for characterization and valuation, followed by a discussion of some of the ecological impacts of shoreline armoring. Section 5 develops the rationale for a method that can be used to determine the cost of ecological losses based on a “no net loss” approach and mitigation based in coastal restoration.

2. Recreation Literature and Model Review

2.1 Conceptual Background for Beach Loss Valuation

2.1.1 Non-market valuation overview

General definition:

Economic value is generally defined as a measure of the maximum amount an individual is willing to forego to obtain some good, service, or state of the world (Haab & McConnell, 2002). In a market economy, many goods and services are sold through a market, so the market price is generally considered to be an appropriate measure of value (provided that the consumption of a good or service does not affect others). However, economists also recognize that not all goods and services are provided by markets. These are generally referred to as non-market goods. California's beaches and coastline both represent an example of such non-market goods and services since, beaches (seaward of the mean high tide line at least) are legally open to all and much of the coastline is public property.

There is a large literature on valuing non-market goods. Economists generally agree on a fairly standard taxonomy depicted in Figure 1 below. The key distinction is between use value (non-market goods and services that give immediate and generally quantifiable benefits to users) and non-use value (non-market goods and services that provide potential benefits for future users, possible users or people who simply value the existence of something, e.g., the Alaskan wilderness).

Total Economic Value:

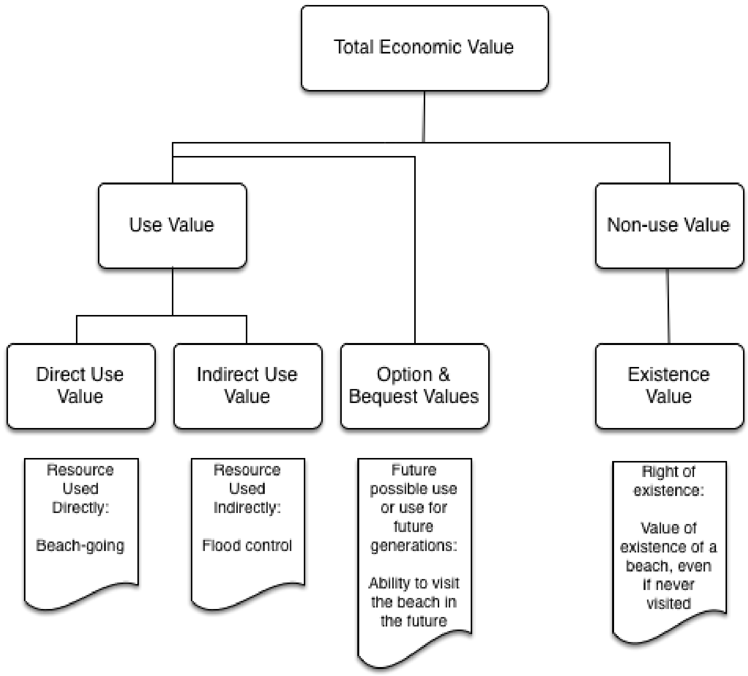


Figure 1: Total Economic Value (TEV) of Goods and Services, with examples of beach use (Nelsen, 2012)

The total economic value (TEV) model provides a framework for valuing the full suite of economic values associated with a resource. The TEV framework is based on the assumption that individuals have multiple values for ecosystems or other non-market goods, and provides a framework to ensure that components of those values are not missed or double counted (NRC, 2004). The TEV framework separates values into direct and indirect use values and considers non-use values (Figure 1). Use value refers to those values associated with current or future (potential) use of an environmental resource by an individual. The use can either be consumptive (e.g. recreational fishing) or non-consumptive (e.g. surfing or beach-going).

Option and bequest values describe the value of preserving the option for use of services in the future either by an individual (option value) or by future generations (bequest values). The primary non-use value is existence value. Existence value is unrelated to the use of the resource and represents the willingness to pay for the resource to exist (e.g. willingness to pay for the protection of a beach you will never visit). Non-use valuation requires contingent valuation methods (NRC, 2004).

The use of economic valuation for natural resources perspective is not without its critics. In contrast to moral, ethical or nature rights-based arguments, the use of economics is highly anthropocentric. That is, values are based on the value to humans. Second, it assumes that humans can meaningfully measure these values. However, the array of standard techniques that economists have developed has been widely accepted in public policy debates and legal proceedings. Furthermore, in practice, providing no economic (dollar) value for non-market goods/services often leads others to assume that the good/service has no value. The study of and literature on non-market valuation has increased in the last few decades, including a more detailed analysis of non-market values provided by ecosystem services rather than relying solely on the market values attributed to these resources through recreation or natural resource extraction (e.g., sand mining, timber).

This report is primarily concerned with the practical application of standard economic methods to estimate the value associated with coastal recreation at beaches and other sites.

Economic Impact and Economic Value

Before going further, it's also important to make a distinction between economic impact and economic value, a distinction that is often confusing for non-economists. Coastal recreation generates two important economic contributions to the economy: economic impacts and non-market consumer surplus. Economic impacts measure the flow of money through an economy and the associated jobs, wages, salaries and taxes associated with these flows. Included in economic impacts are the expenditures by visitors to the coast who spend money locally on food, beverages, parking, and coastal recreation. These expenditures represent money that may have been spent elsewhere in the state (e.g., gas and auto), but are mostly expenditures that would not have been made in the absence of a recreational trip (Pendleton & Kildow, 2005). Expenditures and other market data can be used to estimate values (e.g., cost-reductions or increased value of outputs) but are not, in themselves, true indicators of economic value.

Economic value, in contrast, is the net value that the resource provides to society; value that is often not included in standard measures of economic output such as GDP. Economic value is often measured as willingness to pay. Consumer surplus is defined as the excess of the consumers' willingness to pay over what they actually do pay for use of the resource.

From the perspectives of coastal users and professional economists, economic value should be an important consideration in policy decisions even though many stakeholders (e.g., elected official, city planners, developers) are often more concerned with economic and tax impacts.

2.2 Methods for Valuing Beach/Coastal Recreation

Economists have developed a number of methods for valuing beach/coastal recreation. Although the methods vary, the principle behind the methods is the same: the value of recreation is equal to the amount that a consumer (visitor) would be willing to pay for the good if it was sold through a market. This is commonly called the willingness-to pay. Further, the Law of Demand assumes that when the price of a good increases, an individual will consume less. Economists have developed the concept of consumer surplus to measure the economic benefit of a good or service.

When goods and services such as coastal tourism are traded within a market, the market will determine their values. Conceptually, the same measure of benefits also applies to non-market goods such as a beach, although measures of non-market benefits are concerned exclusively with estimates of consumer demand and consumer surplus since non-market goods are typically not bought and sold.

2.2.1 Revealed & Stated Preference Approaches

Estimating the economic value of goods and services that are bought and sold requires collecting information about the spending by producers and consumers. Once this information is collected, calculating the economic value of these goods and services is straightforward. By contrast, estimating the economic value of non-market goods such as beach and coastal recreation requires accurately measuring the coastal users' willingness to pay without the benefits of data collected in market transactions. Unlike market goods and services, recreational activities at public sites such as beaches often occur without any exchange of money and thus require different methods of measurement.

The methods that are able to measure the non-market values associated with coastal recreation fall into two primary categories: revealed preference and stated preference methods. Revealed preference methods study the activities and expenditures of users to see what that reveals about the value they place on a good or service. For example, a user's willingness to spend time and money driving to a beach to surf reveals a minimum value for that day of surfing. When it's not possible to estimate values based on observed behaviors and expenditures, you can simply ask users what they'd be willing to pay as is done through stated preference methods. Stated preference methods use survey instruments in order to gauge a user's willingness-to-pay based on their response to questions that are designed to elicit a value for a particular resource. Stated preference methods are often used to gauge the value of a hypothetical or proposed change in a resource (Haab & McConnell, 2002).

<u>Stated Preference Methods</u>

- Contingent Valuation

The contingent valuation method (CVM) is a type of stated preference method. CVM is designed to recover information about preferences or willingness-to-pay using direct questions and usually takes the form of a survey questionnaire. CVM can also be used to value a hypothetical future condition. For example, Bhat (2003) used CVM to estimate the non-market recreational benefits from snorkeling and diving that are associated with improved reef health within a proposed marine reserve. In some cases CVM is the only means of estimating willingness-to-pay. CVM is also the only way to measure the value of passive uses that entail no direct involvement with the natural resource (Lipton et al., 1995). For example, CVM were used to obtain the passive use values to assess the settlement for damages from both the Exxon Valdez oil spill as well as the DDT released into the ocean off of Palos Verdes.

CVM is highly sensitive to the survey instrument and the way the questions are asked. While CVM has been controversial because it relies on hypothetical situations and personal preferences, resource economists have accepted CVM as a reliable method for environmental valuation (Haab & McConnell, 2002). To this end, the National Ocean and Atmospheric Administration (NOAA) has established guidelines for best practices to create consistency across CVM studies (Arrow et al., 1993). Even so, Chapman & Hanneman (2001) argue that current studies using contingent valuation to estimate values for California beach visits continue to be unreliable since the surveys are not site specific and fail to account for variation in travel cost to beaches throughout the state.

- Conjoint Analysis

Conjoint Analysis (CJA) represents a related, but somewhat different stated preference technique in which survey respondents are asked to compare different choices rather than simply placing a dollar value on the good or service. While contingent valuation is focused on willingness to pay, conjoint analysis is more focused on the trade-offs between alternatives and attributes. In practice, CJA is often more costly than CVM since it requires more detailed questions about tradeoffs and generally requires the inclusion of a cognitive psychologist. Given that both CVM and CJA are stated preference models, one would think that studies based on these methods would yield similar results. Stevens (2000) found, however, that the two techniques often yield quite different results although the authors found no discernable pattern in these differences.

Revealed Preference Methods

- Hedonic Models

The hedonic pricing method is a revealed preference method for non-market valuation. Hedonic methods use market prices, most often derived from the real estate sales, to estimate the value of nearby environmental attributes (Haab & McConnell, 2002). The method is based on the recognition that real estate values are influenced by at least three types of characteristics: the physical attributes of the property, the attributes of the surrounding neighborhood, and environmental amenities near and at the property (e.g. view of the ocean or proximity to the beach). The method assumes that the total price of the property is a function of these characteristics. Through statistical analysis, it is possible to estimate the separate contribution of these characteristics to the total sales price of the property and estimate the implicit price of each characteristic. For example, if two houses have the same physical attributes and are located in the same area, but one house has easy access to the beach while the other does not, then the difference in price is an indication of the value placed on beach access.

The most typical application of a hedonic model involves comparing housing prices. For example, people will be willing to pay more to live in a neighborhood away from a toxic landfill. By comparing other attributes (e.g., sq. ft. of the house, school quality, etc) hedonic models allows one to estimate the incremental value of some environmental amenities.

Despite that fact that housing prices are typically higher near the coast, hedonic models are rarely used to evaluate specific coastal recreational sites. This is for several reasons. First, a hedonic model only captures the value placed on the site by the property owners rather than by other visitors. Second, a crowded recreational site (e.g., Huntington Beach) may actually be perceived as a negative amenity. In California, much of the residential development near beaches is on a bluff above, complicating the valuation process further because they may value the ocean view regardless of their ability to use the beach below their home.

There are few sound applications of hedonic analysis to beaches or other coastal properties and none that we know of in California. On the East Coast, however, there have been a few applications that have looked at the benefits from wider beaches. None of these studies have looked at the loss of value when beaches get narrower.

Lent (2007) applied a hedonic model to estimate the benefits of beach nourishment (beach widening as opposed to be narrowing) at several beaches in Delaware. The paper concludes that a nourishment project (to widen the beaches) would provide substantial benefits including an increase in property values to homeowners. It should also be noted that beach nourishment provides both storm-damage and recreational benefits to homeowners and that it is not possible with a hedonic model to distinguish between these two effects.

Landry and Hindsley (2011) applied a hedonic model to Tybee Island –a barrier island in Georgia. They also found that additional beach width increases property prices for houses within 300 meters due to enhanced recreational/storm damage benefits, with house values increasing from $39,000 to $75,000 per house. Gopalakrishnan et. al. (2010) applied a hedonic model to ten coastal towns in North Carolina and found that traditional hedonic models underestimate the benefits of increased beach width.

The feasibility of the hedonic price method depends on the quality and availability of data regarding both the real estate prices as well as the attributes used. The way in which the attribute to be valued (such as beach quality) is measured is extremely important to the accuracy of the results.

- Travel Cost Method

The travel cost method (TCM) is another revealed preference method. TCM is based on the premise that visitors reveal their willingness-to-pay to visit a site through travel time and costs. The TCM was first suggested in the late 1940's by Harold Hotelling as a means of valuing public lands. Since that time TCM has become the most popular method for estimating non-market values for recreation, appearing in thousands of academic journal articles (Haab and McConnell 2002).

TCM studies can be divided into single site models and multiple site models. Singe site models focus on visitation to a single location. Multiple site models compare more than one site and model site choice based on the attributes of the site. The single site TCM generates a demand function since visitors who live farther away from a specific recreational site will incur higher travel costs to make a visit and will visit less frequently (Parsons, 2003). Comparison of the number of trips taken by visitors with varying travel costs generates a demand function for the site. This demand function determines the benefit derived for each visitor, known as the consumer surplus (See Figure 2). Consumer surplus is the surplus of value above the cost of visiting the site for the group measured. Multiplying the average consumer surplus value by the annual number of visits shows the total recreational value derived for a site.

Figure 2: Recreational demand curve with consumer surplus.

Single site models are best used to assess the total use value of a site that has few substitutes. Single site methods are less powerful when used to measure how environmental change will affect the value of a site or if a site has many alternatives.

- Random Utility Model

A common multiple site TCM is the Random Utility Model (RUM). RUMs compare visitors' discrete choices of sites from a set of multiple possible sites based on the specific characteristics of the site. The choice of sites reveals how visitors value different site characteristics by examining how they trade-off additional travel cost to gain more or less of an amenity. RUM can be used to value an entire site or to value changes in environmental quality at one or more sites (Parsons, 2003).

These methods model site choice based on beach characteristics and the cost of visiting the beach. A RUM models beach choices by including all beaches that the beach goer might consider as reasonable choices (and sometimes includes non-beach options too). The value of beach visits is revealed through the choice of which beach to visit based on the tradeoffs associated with beaches characteristics and the cost of visiting each beach. RUMs have the advantage to taking into account substitution. Substitution occurs when users choose a substitute site when their primary choice is unavailable or limited. The availability of substitute sites can lower the consumer surplus value of any one beach. However, it should be noted that Pendleton, Mohn, Vaughn, King, & Zoulas, (2011) when measuring the lost value of beach recreation due to sea level rise found the loss value of a trip is stable at just over $100 per trip in their RUM for Orange and Los Angeles County beaches even though their model allowed for more substitution possibilities than previous studies (the model allows beachgoers to change sites, activities, or number of trips).

RUM studies require survey data for multiple beaches and complex economic modeling and are, therefore, time consuming and costly. The Southern California Valuation Beach Project used a RUM to estimate beach recreation values at Los Angeles and Orange County beaches and focused on welfare estimates based on water quality changes.

This project was conducted over several years and cost over $900,000. To date, only one economist in the state can operate the model. With additional investment, it is possible that this model could be rerun to develop consumer surplus values for eroding beaches in Southern California that could be used as a proxy for other beaches in the state, however that is beyond the scope of this project.

Other methods to address substitution include assuming some visitors will not have a substitute. For example, Chapman & Hanneman (2001) estimated that 50% of Huntington Beach surfers would not be able to substitute surfing in Huntington for other locations due to time constraints. King (2006) reduced the consumer surplus value in his benefit transfer to account for substitution effects.

- Benefit Transfer Method

The benefit transfer (BT) approach seeks to apply existing value estimates from previous studies and transfer them to new sites. BT allows decision makers to use the values previously derived elsewhere and modify them in order to estimate the value of local resources (Loomis & Rosenberger, 2006).

Benefit transfer is a common approach used by policy makers who do not have the funding or, more importantly, the time needed to conduct a site-specific study. Conducting original valuation research is time consuming and often prohibitively expensive.

BT allows the “transfer” of benefit estimates from existing studies (study site) to the site being considered (policy site). The transfer of value estimates from the study site to the policy site range from complex analyses that adjust the consumer surplus based on a comparison of the individual attributes of each site (called a function transfer e.g. meta-analysis transfer) to simple applications of a single value from a related study site to the policy site (point transfer). Functional transfer approaches require statistical analysis (e.g. regression modeling) of the data and attributes from prior studies and therefore require a high degrees of economics expertise (Rosenberger & Loomis, 2000).

Moreover a BT model can produce more reliable results than a limited, local study (such as travel cost studies) because the extremely high and low values are bounded by the existing literature. Applying a BT model across a wider area (such as the State of California) also can assure a consistent approach. Consequently, though BT is sometimes called a "second-best" valuation method in comparison to original research at the study site (NRC 2004), this need not be the case if the method is chosen based on sound social science.

All benefit transfer methods are limited by the quality of the original studies and the transferability of the conditions from the study site to the policy site (Desvouges, Johnson et al. 1998). The usefulness of potential benefit transfer values will be determined by the comprehensiveness of the literature. A conservative approach is to provide information on the full range of values for a recreational activity and then estimate a range of values based on end points of that range found within the literature (Pendleton, 2008).

For the reasons stated above, BT is commonly used to value public resources by a number of federal agencies including the Corps of Engineers, the Environmental Protection Agency (EPA) and the National Atmospheric Oceanographic Administration (NOAA). These agencies have produced reports on best practices for the use of BT (Rosenberger and Lewis, 2000, and Lipton et al., 1995). These practices include ensuring that study site estimates are based the following: 1) Adequate data, sound economic methods and correct empirical technique are used and is found in a peer reviewed publication, 2) that the characteristics of the site reasonably match the policy site (e.g. California beaches) and 3) that adequate number of individual studies on a recreational activist have been conducted to enable show the consistency and possible range of values (Rosenberger & Loomis, 2000).

2.3 Attendance

Any economic analysis of beach and coastal recreation requires accurate attendance data since the consumer surplus per visitor (sometimes also referred to as "day use value”) is typically multiplied by attendance in order to arrive at the annual economic value.

Currently, many government agencies in California archive visitation data collected by lifeguards, parking receipts and other available data. Even so, the reliability of these data is an issue. King (2006) conducted two studies for the City of Carlsbad and Encinitas indicating that official estimates of beach attendance needed to be adjusted. In particular the study expressed concern about the very high turnover rates (meaning that for every person counted there will be many more people who use the beach, but who were missed by the attendance count) used in some beach counts—for example some counts assume that beachgoers “turnover” at up to 14 times a day. Since most (non-surfing) beaches experience their prime attendance between 11am and 4-5pm, depending upon the weather, a turnover of fourteen implies that each beach visit would be less than half an hour. Further, when asked about their estimates, lifeguards and other officials essentially state that they are following a procedure that was established decades ago. In the vast majority of cases there is no available social science research or consulting reports for these methodologies. In some cases the actual counts are based on a generally accepted count level given a particular density—though the actual count has not been verified. In other cases, the problem is too high a turnover factor.

While the literature on assessing attendance at beaches is, for the most part, limited, there are a few papers that have been published. The most important early paper is an unpublished working paper, “Estimating Use Levels with Periodic Counts,” by Banzhaf (1996). Banzhaf’s paper provides a comprehensive theoretical treatment on how one should analyze periodic counts—counts done, at one or more times during the day, of people on the beach at such times. These periodic counts are those which are typically conducted by lifeguards or taken from aerial photographs that are sometimes used in these types of analyses.

Apart from getting an accurate periodic count, the key challenge in this methodology is figuring out how to translate a specific count at one particular time (e.g., noon) into an estimate of how many people actually went to the beach on that day. The key element in the paper involves understanding the distribution of visitor arrivals and departures throughout the day—something that can be estimated empirically (by survey data) or by assuming that a particular beach has a similar arrival/departure pattern to another beach. In practice, the most important determinants of the distribution of visitors are weather, access and the type of recreation involved.

In a working paper for NOAA, Wallmo (2003) uses a similar type of analysis as Banzhaf for attendance at Dewey Beach, Delaware. Wallmo uses both periodic counts and "all day counts" which involve using counters at entrances and exits. Wallmo compares three different techniques for estimating beach attendance: all day counts, periodic counts and flyovers by helicopter.[1]

According to Wallmo, nearly all visitors to Dewey Beach access the 1.2 miles of coastline via one of twenty footpaths distributed along the length of the beach. Wallmo concludes that the three techniques produced comparable estimates. In comparing the cost effectiveness of the survey techniques, periodic counts proved the most economical at a cost of $600 per day compared to $2,400 for all day counts and $2,700 for overflights.

More recently King and McGregor (2012) concluded that official beach visitor counts used for public policy in the State of California have a strong tendency to overcount the actual number of people who are on the beach. The main reason for the discrepancy was high turnover factors. They also concluded that attendance data should more accurately reflect the type of recreation (e.g., swimming, lying on sand, walking, surfing) since the recreational values and turnover factors vary significantly among these different types of recreation.

The other reason for a more detailed breakdown by type of activity is that the spending, welfare impacts and substitution possibilities vary significantly depending upon the type of activity. People who frequently walk on a beach may (or may not) have more possibilities for substitution, compared to other users. Similarly the set of beaches that

1 Calculating attendance estimates with flyovers can be done in a similar manner as periodic counts where observations are summed and divided by the probability of being captured in a count.

sand users would consider good substitutes may be completely different from the beaches that surfers would consider good substitutes.

As a practical matter, there are a number of options for estimating attendance at a particular reach of beach. The ideal methodology would involve multiple counts throughout the year as well as a detailed survey that would indicate when people come and go, so that one can extrapolate the total attendance from one specific count. In practice, this method is expensive and time consuming. A second option would be to take a few counts and assume that the distribution of arrivals and departures as well as the distribution of visitors throughout the year is similar to other similar beaches. This method requires far fewer periodic counts. A third option is to estimate the density of people on the beach from studies at similar beaches. This final option is simple, but since beach density varies enormously, even at one particular beach, this method is likely to be less accurate.

2.4 Beach Width and Recreational Values

Sandy beaches are important natural resources that provide ecosystem services that include both ecological functions and human services. Ecological functions include habitat, nesting sites and food sources for numerous aquatic and terrestrial species. Human services include coastal recreation, beach access and protection from storms (Defeo et al., 2009). The focus here is coastal recreation, which is a human use value. Beach visitation to dry beaches and sandy beaches are what drive the majority of beach visits in California. Beach width is controlled by geomorphic and atmospheric processes on multiple temporal and spatial scales. Beach width will narrow over time on beaches that are eroding due to a combination of loss of sand supply and shoreline armoring (Griggs, 2005 a, b). As beach width narrows and the beach eventually disappears, recreational amenities will similarly be reduced.

2.4.1 Shoreline Armoring Effects Beach Width

Approximately ten percent of the California coastline has been armored with seawalls, revetments and bulkhead during the last one hundred years (Griggs 2005). Armoring is more concentrated in Southern California's urban counties. Thirty percent of San Diego, Orange, Los Angeles and Ventura County beaches are armored (Griggs 2005). The extent of coastal armoring in California increased by over four hundred percent during the period from 1971 to 1992 and still continues on to today (Griggs 2005). Shoreline armoring narrows and ultimately eliminates sandy beaches on eroding shorelines through a process called passive erosion (Griggs 2005). In California approximately 86% of the coast is eroding (Griggs, 1998). Accelerating sea level rise will increase the impacts of coastal erosion (Heberger, Cooley, Herrera, Gleick, & Moore, 2009).

Shoreline armoring structures protect coastal development but also prevent naturally occurring beach and bluff erosion (Griggs 2005). Shoreline armoring structures are typically concrete walls or rock revetments designed to prevent wave action from eroding the shoreline (Figure 3). Shoreline armoring has several impacts that limit sand supply and reduce the width of the beach. First, beach area under the footprint of the actual armoring structure is lost. This is known as placement loss (the Coastal Commission calls it encroachment). For example, a 15-foot high riprap revetment could occupy over 30 feet of beach width for its entire length. Second, beach sand that would have eroded from the beach or bluff is impounded behind the structure and is not available to the beach. This is known as impoundment loss. Third, beach is lost due to passive erosion (Figure 4). Passive erosion occurs because the back of the beach, that would otherwise naturally migrate landward, is fixed (Griggs, 1985). As relative sea level rises the beach is submerged and the beach will gradually narrow until the public beach no longer exists.

Figure 3: Shoreline Armoring Structures: a rock revetment in San Clemente, CA and a seawall in Monterey, CA. Source: Surfrider Foundation

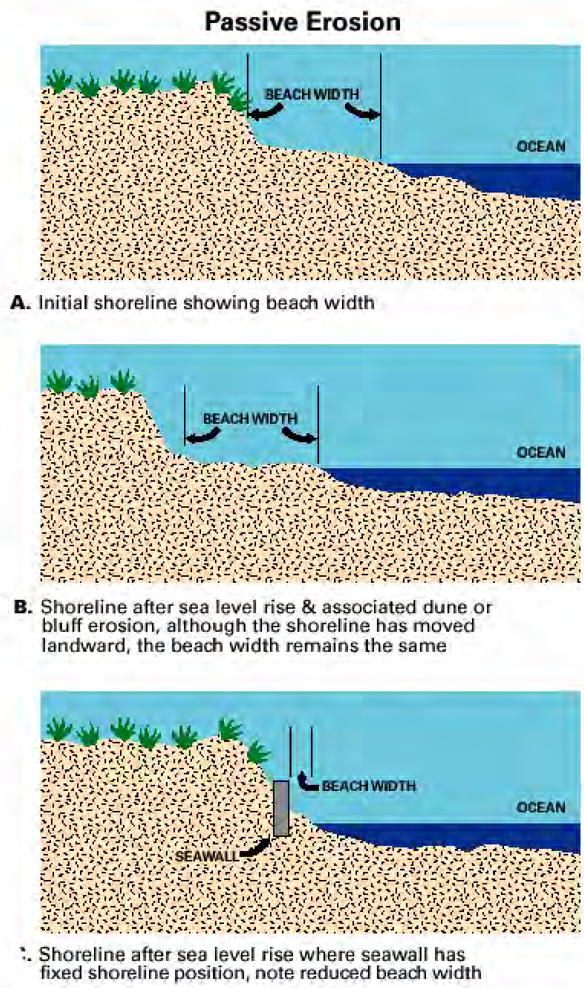


Figure 4: Passive erosion resulting from shoreline armoring narrows. Source: Surfrider Foundation, based on Pilkey and Dixon (1996)

Armoring the beach will ultimately result in the total loss of dry beach seaward of the structure and will thereby limit beach access in addition to denying other forms of coastal recreation in the area influenced by the shoreline armoring (Caldwell & Segall, 2007; Cardiff, 2001). For example, loss of the beach will reduce lateral access along the beach and can limit access to other beach areas or recreational sites. Loss of the beach can also cause wave reflection off the seawall or revetment that can degrade the quality of a surfing area or make it unsafe for swimmers to enter the water.

2.4.2 Beach Width Affects Recreation Value

Determining the value of beach recreation that is lost due to shoreline armoring is complex. It requires determining the recreational value of the beach area seaward of the shoreline armoring structure that is lost as the beach narrows over time. Generally beach width is defined as the distance between a seawall, dune, parking lot, or other back-beach feature and the mean high tide line—often referred to as the "dry beach". However, this definition is a bit simplistic for narrow beaches (e.g., Fletcher Cove at Solana Beach) where the dry beach is so narrow that there is inadequate towel space at anything but low tide. Consequently, it may make sense to include the "wet" intertidal beach in an analysis of recreation at very narrow beaches, though this wet beach should be weighted much lower since the beach is not available during high tide, and wet beach is generally considered less desirable than dry beach.

The value of beach recreation that is lost due to shoreline armoring could also include adjacent beach impacts, down-coast impacts and loss of access to adjacent beaches. The primary characteristic of beach change (caused by seawalls) over time is a loss of beach width. Beach width is an amenity that can affect the consumer surplus of a beach visit directly by changing the area of beach available to recreate. Beach goers generally prefer wider beaches up to 300 feet. More than 300 feet of beach width can become negatively correlated with consumer surplus because it is too far to walk to the ocean (Landry & Hindsley, 2011). Reduction in width can also affect the level of crowding at a beach, which also changes consumer surplus (although this last affect is complicated by the fact that lower per person-visit consumer surplus also lowers attendance at the affected beach).

A portion of the beach width is lost immediately from placement loss when the shoreline protective device is constructed. Over time the change in beach width is controlled by the erosion rate at the beach. Lost beach width can reduce the individual consumer surplus or can result in substitution, if the visitor chooses to visit a different beach (P. King, 2001; Lew & Larson, 2005; Pendleton et al., 2011).

At present, the only empirical model describing changes in consumer surplus and beach attendance on an eroding beach in California is Pendleton, Mohn et al. (2011). Pendleton, Mohn et al. (2011) describe changes in beach attendance and consumers surplus to Orange and San Diego County beaches in response to sea level rise using a RUM model. They show that beach erosion reduces both consumer surplus and beach visits and that those losses can be significant. For example, a 50% decrease in width of San Clemente beaches results in an annual loss of over 8 million dollars in consumer surplus and over 100,000 fewer beach visits. The direct application of Pendleton, Mohn et al. (2011) to individual shoreline armoring projects is limited but could be used as a study site for benefits transfer and to set the bounds for estimates of consumer surplus loss at armored beaches.

There are a few applications of a hedonic model to beach recreation. Lent (2007) applied a hedonic model to estimate the benefits of beach nourishment (beach widening as opposed to be narrowing) at several beaches in Delaware. The paper concludes that a sand placement project to widen the beaches would provide substantial benefits including an increase in property values to home owners. It should also be noted that beach nourishment provides both storm-damage and recreational benefits to home-owners and that it is not possible with a hedonic model to distinguish between these two effects.

Landry and Hindsley (2011) applied a hedonic model to Tybee Island –a barrier island in Georgia. They also found that additional beach width increases property prices for houses within 300 meters due to enhanced recreational/storm damage benefits, with house values increasing from $39,000 to $75,000 per house. Gopalakrishnan et. al. (2010) applied a hedonic model to ten coastal towns in North Carolina and found that traditional hedonic models underestimate the benefits of increased beach width.

To our knowledge, no hedonic study of beach width has been conducted in California. Most of the studies on the east coast involve residences close to the beaches that have low attendance and high vulnerability to storms (generally hurricanes).

To date, the literature on the empirical relationship between beach width and consumer surplus values is limited to the studies sited above. This research does not clearly inform a model for relating beach narrowing over time to reduced consumer surplus or loss of attendance at a specific beach.

2.5 Conceptual Models for Beach Erosion Loss Valuation

Developing a model that estimates the lost value of beach recreation due to shoreline armoring still has challenges. The value of the beach must first be estimated, using both consumer surplus and attendance at the beach. The loss of consumer surplus due to the narrowing of the beach over time can then be estimated. This section develops a conceptual model to show how this lost value is estimated.

2.5.1 Estimating the baseline recreational value of a beach:

The annual recreational value (or total consumer surplus) of a beach is determined by summing all of the individual consumer surplus values of beach visitors. Since each individual consumer surplus value is not known, an average consumer value must be developed. Then, the annual value can be calculated by multiplying the average individual consumer surplus (per person per visit) by the annual attendance at the beach area.

$$CS_{beach} = CS_{ave} * attendance \qquad (1)$$

Where CS_{beach} is the total annual consumer surplus. CS_{ave} is the average individual consumer surplus per visit and *attendance* is the annual individual users of the beach area. The average individual consumer surplus (per visit) can be determined by site-specific original non-market valuation approaches such as Random Utility Models, travel cost methods, and contingent methods or approximations derived from original research conducted elsewhere (i.e. benefit transfer method). Annual attendance is based on counts of beach visitors as discussed above.

2.5.2 Valuing lost recreation on an eroding beach

Determining the value of lost beach recreation that occurs because of shoreline armoring is more complicated than valuing a static area. It requires determining lost recreational value of the beach area seaward of the shoreline armoring structure as the beach narrows over time. It could also include adjacent beach impacts, down-coast impacts and a loss of access to adjacent beaches. The primary characteristic of beach change over time is beach width. Beach width is an amenity that can affect the consumer surplus of a beach visit directly by changing the area of beach available to recreate. Reduction in beach width can also affect the level of crowding at a beach, which also may affect consumer surplus (although this last affect is complicated by the fact that lower per person-visit consumer surplus also lowers attendance at the affected beach). A portion of the beach width is lost immediately from placement loss when the shoreline protective device is constructed. Over time the change in beach width is controlled by the erosion rate at the beach. Lost beach width can reduce the individual consumer surplus or can result in substitution, if the visitor chooses to visit a different beach. (King 2001; Lew and Larson 2005; Pendleton, Mohn et al. 2011). The time over which the lost value is estimated is determined by the lifetime of the project, which is set by the Coastal Commission when permitting the shoreline protective device.

Changes in the recreational value of a beach are determined by summing the lost individual consumer surplus per visit due to lost beach width for each visit over the lifetime of the project adjusted to the net present value.

$$CS_l = \sum_{t=0}^{n} \frac{\left(\Delta CS_i\ (\boldsymbol{bw_t}) * attendance_t\right)}{(1+r)^t} \qquad (2)$$

Where CS_l is the net present value of lost consumer surplus over the lifetime of the project. n is the project lifetime in years. ΔCS_i is the loss of consumer surplus as a function of beach width (bw_t) on year t. bw_t is a function of placement loss at $t=0$ and the erosion rate from $t=1$ to $t=n$. *attendance* is the annual number of beach visits for year t. r is the discount rate.

2.5.3 Time Period and Discount Rate

Any economic evaluation of a public or private project typically involves an evaluation of the costs (e.g., loss in recreational value due to a seawall, ecological damage) and the benefits (e.g., increased recreation from a sand placement project, mitigation fees). In evaluating a seawall project for the California Coastal Commission, the costs of seawall construction are borne by private parties or another State agency (e.g., Caltrans) and would not be part of the Coastal Commission's analysis. But, the costs of beach loss and reduced recreation value would be borne by the public and these costs need to be determined so that these costs can also be transferred to the individual or group that benefits from construction of the seawall.

When considering benefits and costs that are incurred over a number of years, the dollar values must be adjusted to reflect the fact that a dollar received today is considered more valuable than a dollar received in the future. One important reason for this is the fact that a dollar received today could be invested to produce additional wealth. To do this, it is important to identify the period of time that will account for most of the relevant benefits and costs and to select a discount rate that will account for the diminishing value of benefits received in the future.

Consequently the time frame is important and since the costs of a project are cumulative over time, a longer time period will yield higher social costs. However, as a practical matter a timeline should be limited for several reasons. First, seawalls have finite lifetimes, on the order of 20-50 years. Second, as one analyzes costs and benefits forward in time, the degree of uncertainty increases. There is no hard and fast rule on what timeline should be applied in a benefit/ cost analysis other than it typically lasts for the life of the project.

The choice of an appropriate discount rate is generally even more critical in the analysis since a higher discount rate implies that future benefits and costs are weighted lower. For most private projects the choice of a discount rate is relatively simple—whatever the appropriate market rate is. For example, if a private company is considering a $100 million dollar investment in a new factory that would yield a future stream of returns (profit), the firm would use their cost of capital. If they can borrow money at a 5% rate of interest, then 5% would be the discount rate.

For social projects, the discount rate is often tied to something similar—the cost of government bonds over the appropriate time horizon. For example, on a federal project lasting 30 years, one can apply the interest rate on a 30-year treasury bond (3.8% on January 10, 2014). States and municipalities have different (yet similar) interest rate structures, though the analysis is complicated by the fact that municipal bonds generally have lower interest rates since they are generally exempt from both Federal and State income taxes.

A number of economists have argued that using market interest rates when analyzing social costs and benefits is inappropriate for a variety of reasons. First, the social rate of time preference –that is the rate at which society values present consumption over future consumption—is not necessarily given by the market interest rate (Zhuang, Liang, Lin, & Guzman, 2007). A number of economists have conducted empirical studies of the social rate of discount and have found rates ranging from 0.1% to 3% (Liang, Lin, & Guzman, p.6).

Standard discounting practices face another critical problem in that the rates that are typically used discount goods and services to future generations. Applying a discount rate of 3%, for example, implies that benefits or costs born in 100 years are only weighted 5% (1/20) of current costs and benefits; if one uses a 2% rate, the weighting changes to (a still low) 14%. Even applying a rate as low as 1% implies that benefits/costs 100 years from now are only weighted at 37% of today's benefits.

Given the potentially enormous costs of climate change to future generations and the longer time scale, many environmental economists have proposed applying lower discount rates when analyzing the economic impacts of climate change. One of the most widely cited reports, the Stern report (2006), applied a 1.4 % discount rate. Arrow et. al. (2014) point out that climate change modeling presents a unique set of issues given the uncertainty involved and the potential for catastrophic outcomes (even if the probability of such outcomes is low). Consequently, many climate change models use a declining discount rate over time—implying that a longer time horizon should receive a lower discount rate. A number of European countries have already adopted such an approach. For example, Great Britain has adopted a declining rate formula for climate change projects where the discount rate can reach 0.75% after 300 years (Arrow et. al., 2014, p. 11). In a widely cited paper, Weitzman (2001) posits a 1% discount rate for periods exceeding 75 years and 0 for periods exceeding 300 years.

2.6 Parameters for valuing beach loss

Developing a model to estimate lost recreational value from shoreline armoring requires the combination of physical, geological, economic and management parameters. The minimum parameters required to characterize beach recreation and beach values are described in Table 1. Each of these parameters has been discussed in previous sections and is used in a recreational beach loss valuation model.

Table 1: Data required for an erosion loss beach valuation model

Parameter	Type
Length of armoring	Engineering
Beach width	Geologic
Erosion rate	Geologic
Attendance	Economic
Consumer Surplus of a Beach Visit	Economic
Project Lifetime	Policy
Discount rate	Economic

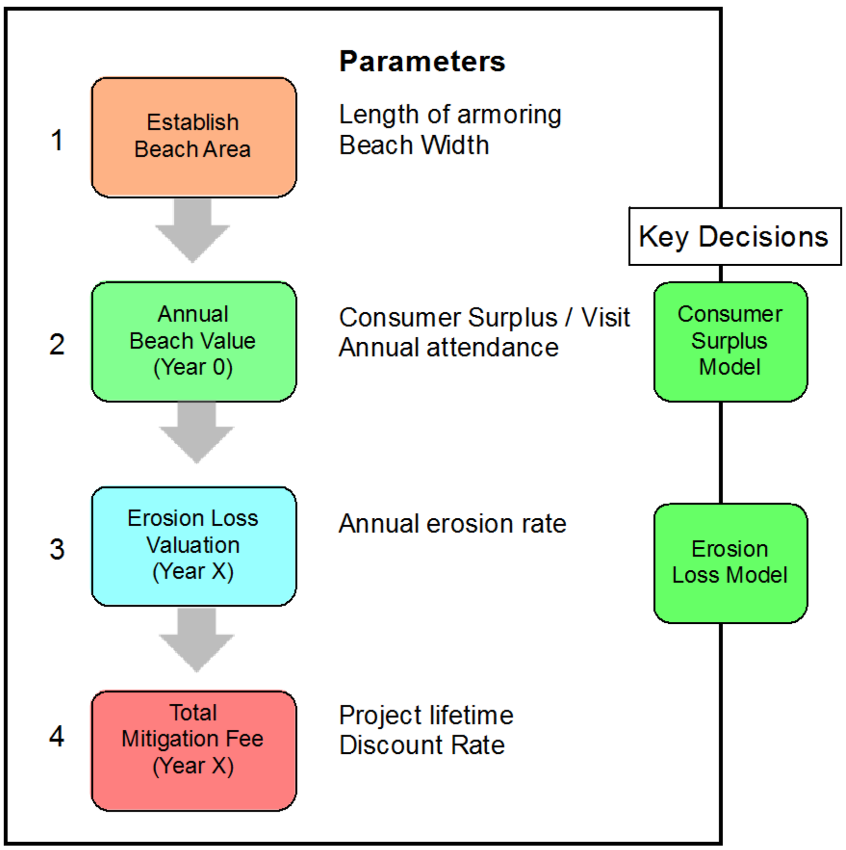


Figure 5: Key parameters necessary to develop a model to value lost recreation on an eroding beach

Table 1 and Figure 5 depict the four key economic parameters (attendance, consumer surplus, discount rate and erosion loss model) necessary to model lost recreational value on a narrowing beach. These parameters are discussed in Section 2.7, below.

Table 2: Steps and parameters required to develop an estimate of beach recreation lost from erosion

Erosion Loss Beach Recreation Valuation Model
Step 1: Determine the area of the beach affected
Step 2: Determine the value of the beach area at time 0 (prior to armoring)
A. Determine consumer surplus (value of a beach day)
a. Select consumer surplus method
b. Determine value of a beach visit
B. Determine the annual attendance at the beach
C. Multiply the CS by attendance to determine the annual value of the beach area
Step 3: Determine the Erosion Loss Model to estimate the annual loss of beach value
A. Determine the annual erosion rate
Step 4: Determine the total in-lieu mitigation fee for the permit lifetime
A. Determine the project lifetime
Determine the appropriate discount rate to account for present value over project lifetime

2.7 Feasibility of Various Economic Models for use by the California Coastal Commission

This section will explore the feasibility of the differing methods discussed in the previous survey of the literature. The California Coastal Commission reviews a large number of coastal development permit applications every year with a relatively small staff that currently includes no professional economists. Although project proponents/ applicants can be asked to provide some information, the Coastal Commission staff needs a method that is consistent with the data and information requirements to conduct the appropriate Coastal Act policy analysis and can be completed within the relevant statutory time frame. In addition, such a method needs to be objective so that it can be applied consistently across all applications and by different staff members. The method must be grounded in reality, applied fairly across projects, and easy to understand by the public. Finally, this method must be based on best available science, be legally defensible and should be acceptable to other government agencies, such as federal agencies like NOAA and the US Army Corps of Engineers.

2.7.1 Estimating a day use value using consumer surplus

Revealed Preference Models

- Travel Cost Method (TC)

The TC method has been widely used for decades in a number of applications that involve estimating recreational value. TC generally requires that a survey of visitors be conducted, which means that a survey instrument needs to be designed, although this instrument can often be re-used from application to application. At minimum, the survey sample needs to be representative of all types of recreational activity through different seasons. The survey instrument needs to be analyzed properly and in order to conduct a TC analysis properly one needs at least a Master's level understanding of economics and econometrics, a doctoral degree and experience being preferable. Consequently, conducting an adequate survey in a short period of time poses challenges and typically does not really represent a true sample of visitors.

- Random Utility Model (RUM)

RUMs take into account substitutions between sites, and are more complicated to undertake than a travel cost model. Survey data must include data from a very large number of sites and it must adequately account for the differences in attributes between these sites so that one can estimate why people make substitutions. The level of econometrics required for a RUM is typically well beyond even a well-trained PhD and requires someone with a very sophisticated knowledge of these particular models and their application. Despite their sophistication, RUMs also have their limitations. For example, the Southern California Beach Model did not adequately factor in congestion and parking/access issues that would be caused by closing a large beach such as Huntington Beach. In practice a RUM would require an external consultant and a budget of at least $200,000 per project.

Stated Preference Models

- Contingent Valuation

As mentioned in the literature review, Stated Preference Models such as the contingent valuation method (CVM) are no longer held in favor by many environmental economists or by many public agencies such as NOAA. In addition, these models require more effort than TC, making them impractical for application with limited resources. The construction and implementation of an appropriate survey instrument is far more critical in stated preference models than in revealed preference models, since respondents are prone to a number of biases. Conjoint Analysis can address some of these biases, but requires an even higher level of effort and someone with a background in cognitive psychology.

- Benefits Transfer (BT)

Benefit transfer relies on applying existing studies to other beaches and recreational sites. Probably the most widely used BT method is the US Army Corps of Engineers technique (USACE, 2004), which the Corps uses for many of its projects, including beach nourishment projects where a specific study is too expensive. The Corps' valuation technique was created for general recreational value at parks and other public facilities and as such is not specific to beaches. One problem with this technique is that there is no explicit way to value changes in beach width, thereby making it difficult to use for nourishment projects that are the most common beach application. It is also challenging to apply a direct benefit transfer to an eroding beach. Given the potential for wide variation in site-specific TC studies and other studies at California's beaches (refer to Appendix I Table 1) it is also likely that BT will provide a more consistent framework. The key difficulty with a BT model is appropriately calibrating each site with previous studies of similar sites and designing a methodology to do so on a consistent basis. Additional challenges in using these valuation studies are that they can be quite expensive and methodologies likely to vary from beach to beach, making direct comparison more difficult.

The typical application of BT would involve the assignment of a “day use value” for a particular type of recreation. For beach going, the rich literature for beach values in California could be used in several ways to establish a day use value. A point transfer would involve choosing a study site that is comparable with the policy site and transferring that value direction. Alternative methods allow for adjustment of the study site value based on the quality of the amenities at the beach (P. King, 2006).

One potential pitfall with BT is that it often requires an economist or analyst to make a subjective evaluation of a particular amenity for a particular site. For example, the US Army Corps of Engineers requires one to make a judgment about the number of recreational opportunities at a specific site (more is better according to the Corps’ criteria). However, since recreational activities can be defined in different ways and estimating the threshold for significance is also a decision, there is inherently an element of judgment and hence subjectivity. However, one can limit the element of subjectivity by making the criteria specific, i.e., number of sunny days, average beach width, etc. It is also useful to provide the user with reference beaches.

<u>Beach Loss Valuation Models</u>

There are several models that provide a direct value for lost beach area. The first is an empirically-based model for the loss of recreational value on an eroding beach by, Pendleton et al. (2011), which used a Random Utility Model to estimate loss of beach value due to sea level rise. As described above, this application of the RUM was limited to gross estimates based on large beach areas (entire cities) over long periods of time (80 years) and is therefore not applicable to the spatial and temporal scales associated with individual permits (Nelsen, 2012).

Two other erosion loss models currently exist. One model is based on valuing the beach equally across the entire area of the policy site and basing the loss of value on the loss of beach area. A second approach adjusts for lost visitation and lost consumer surplus as the beach amenities shift with the narrowing of the beach. Each of these models is explained below.

Area-based model

A simple method, previously used by the Coastal Commission, is the area-based model. The area-based model estimates the annual value of each unit area of beach based on the consumer surplus per visit, the total number of visitors and the total area of this beach. In this method, the individual consumer surplus (CS_{bt}) is determined using a benefits transfer approach.

$$CS_{area} = \frac{CS_{bt} * attendance}{area} \qquad (3)$$

Area-based Consumer surplus

Where CS_{area} is the annual consumer surplus per unit area. CS_{bt} is the individual consumer surplus (per visit) based on the benefits transfer. *Attendance* is the annual attendance at the beach and *area* is the area of the beach that is between the shoreline protective device and the tide line. Lost consumer surplus is then estimated by summing the annual value of lost beach due to erosion over the lifetime of the project and adjusted to the net present value.

$$CS_{total} = \sum_{t=0}^{n} \frac{(CS_{area} * er * t)}{(1+r)^t} \qquad (4)$$

Area-based method to determine consumer surplus lost on an eroding beach

Where CS_{total} is the total consumer surplus lost during the lifetime of the project. *n* is the project lifetime in years. *er* is the annual erosion rate, *t* is time (the number of years since project started) and *r* is the discount rate. In the area-based model individual consumer surplus value does not change as the beach narrows.

Amenity-based model

Developed by King (2005; 2006), the amenity-based model is used not only as a benefit transfer method, but also to adjust the individual consumer surplus (per visit) as the beach narrows. As a benefit transfer method, the amenity-base approach adjusts the consumer surplus of a study site by weighting and rating the amenities at the policy site, compared to some baseline study site. The beach amenities considered are: weather, water quality, beach width and quality, overcrowding, other recreational amenities and availability of substitutes. Based on the Cobb-Douglass functional form, each amenity is given a weight and amenity point value from 0 to 1 as described in Equation 5.

$$IV = W^a * WQ^b * BWQ^c * C^d * A^e * S^f \quad \text{where: } a+b+c+d+e+f=1 \qquad (5)$$

Index Value (*IV*) based on weighted amenities

Where *IV* is the total index value. *W,WQ,BWQ,C, A* and *S* are amenity index point values. *a* through *f* are the relative weightings. See example in Table 3.

Table 3: An example of weighted amenity values for the policy site beach

Amenity	Amenity Point Value	Weight	Weighted Amenity Value
Weather (W)	0.85	0.2	0.968
Water Quality (WQ)	0.75	0.2	0.944
Beach Width and Quality (BWQ	0.2	0.15	0.786
Overcrowding (C)	0.5	0.15	0.901
Other Amenities (A)	0.5	0.15	0.901
Substitutes (S)	0.3	0.15	0.835
Total Index Value	**--**	**1**	**0.487**

The weighted amenity value is then used to adjust the consumer surplus from the study site to the policy site. The amenity values and weights were assigned using general criteria described in King (2006) and build on US Army Corps of Engineers' point values used to estimate the value of a recreational day. In practice, the values and weights have been based on professional judgment and have not been empirically based. Empirical values could best estimated through a multiple site Random Utility Model study designed specifically to estimate the relative value of these parameters. Further research would be required to determine how those values changes with changes beach width.

$$CS_p = CS_s * IV \qquad (6)$$

Using the Index Value (*IV*) to adjust the consumer surplus as the policy site (CS_p)

Where CS_p is the Consumer surplus at the policy site and CS_s is the consumer surplus at the study site and *IV* is the index value from the weighted amenities (Equation 5).

Weighted beach amenities are also used to determine the decrease in consumer surplus value from t=0 and over the project lifetime (t=n) as the beach width decreases. As beach width decreases the amenity point values for beach width (*BWQ*) and overcrowding (*C*) decrease proportional to percentage of total beach width (B_n). The total lost consumer surplus is from lost amenity value to each visitor due to the narrowing beach over the lifetime of the project adjusted to net present value.

$$CS_{SL} = \sum_{t=0}^{n} \frac{CS_P - (CS_p * IV_t) * att}{(1+r)^t} \quad (7)$$

where

$$IV_t = W^a * WQ^b * (B_t * BWQ^c) * (B_t * C^d) * A^e * S^f \quad (8)$$

$$\text{where: } \boldsymbol{a} + \boldsymbol{b} + \boldsymbol{c} + \boldsymbol{d} + \boldsymbol{e} + \boldsymbol{f} = 1 \text{ and } B_t = \frac{bw_t}{bw_{t=0}} \quad (9)$$

Consumer surplus lost over project lifetime due to lost amenity value from beach erosion (King 2006)

Where CS_{SL} is the net present value of the total lost consumer surplus over the project lifetime ($t=n$), CS_P is the consumer surplus at the policy site, IV_n is the amenity value adjusted for a narrowing beach and B_t is the percentage of beach remaining. r is the discount rate. When B_t = 0, the lost consumer surplus of the beach in front of the sea wall (CS_{SL}) is at its maximum for the remaining project lifetime.

2.7.2 Review of the Consumer Surplus-based Models:

The use of a demand-based approach by the Coastal Commission, as described above, requires an individual consumer surplus value per visit using a benefit transfer approach, annual attendance counts, and a model to account for the loss in attendance as well as the loss of consumer surplus from recreation as the beach narrows. The benefit transfer requires an empirically based per-person per-visit consumer surplus value that is based on objective, repeatable criteria for beach recreation at the study site that can then be transferred to the policy site and adjusted for time. It requires an erosion-value loss model that represents a reasonable approximation of the loss of consumer surplus as the beach narrows.

2.7.3 Attendance

Once a per-person per-visit consumer surplus value and erosion-value loss model are assigned, one must also estimate the number of visitors by type of recreation. Many beaches in California have official attendance figures, but in practice these estimates have a number of flaws (King, 2010). Furthermore, most Coastal Commission projects only impact a small segment of any particular reach or beach. King and others provide a detailed discussion of the methods required. If the applicant is required to submit attendance data, there must be well-established protocols, since the applicant cannot be expected to have expertise in beach attendance counts.

<u>Discount rate</u>

Although a wide variety of discount rates can be used, we believe that the analysis should be conducted in real (present) dollars, which implies the use of a real interest rate such as the 30-year treasury inflation protected securities (TIPS). The length of time will depend upon the specific project but generally a 30-50 year time period is appropriate.

<u>Beach Width</u>

Since (recreational) beach width is a key parameter, any engineering analysis should contain data on changes in beach width due to the project as well as any anticipated impacts over the life of the project. This is generally provided by applicants already.

2.8 Conclusion

The discussion above provides an overview of the literature on how economists estimate recreational value, and the recreational value of beaches in particular. Fortunately, there is a rich literature and a general consensus among academic and consulting economists on the appropriate techniques.

Table 4: Summary of beach valuation methodology requirements

Method	Type	Analytical Steps	Parameters	Output	Comment
Contingent Valuation	Stated Preference	Requires original research 1. Survey instrument 2. Survey administration 3. Statistical analysis 4. Results	Survey data on willingness to pay Demographic Information	Willingness to Pay / Value of a Beach Visit	Expensive Not endorsed by some Economists
Contingent Valuation	Contingent Valuation	Requires original research 1. Survey instrument 2. Survey administration 3. Statistical analysis 4. Results	Survey data on willingness to pay Demographic Information	Willingness to Pay / Value of a Beach Visit	Very Expensive
Contingent Valuation	Contingent Valuation	Requires original research 1. Survey instrument 2. Survey administration 3. Statistical analysis 4. Results	Site characteristics of homes and general area Beach characteristics	Consumer Surplus / Value of a Beach Visit	Has not been successfully applied anywhere in California
Travel Cost Method	Contingent Valuation	Requires original research 1. Survey instrument 2. Survey administration 3. Statistical analysis 4. Results	Visitation patterns Transportation mode Travel time Travel distance Demographic Information Experience Primary beach activity Beach Substitutes	Consumer Surplus / Value of a Beach Visit	Less Expensive than other methods than BT but still implies developing survey Results can vary even at similar beaches
Random Utility Method	Revealed Preference	Requires original research 1. Survey instrument 2. Survey administration 3. Highly sophisticated econometric analysis 4. Results	Visitation patterns Transportation mode Travel time Travel distance Demographic Information Experience Primary beach activity Beach Substitutes Beach characteristics Surrounding beach characteristics	Consumer Surplus / Value of a Beach Visit	Expensive Requires advanced econometric techniques
Benefit Transfer	Proxy	Uses existing data 1. Literature review 2. BT method selection 3. BT analysis 4. Result	Literature review Beach characteristics	Consumer Surplus/Value of a (Range)	Inexpensive Easy to use Can be Subjective

Table 4 summarizes the analysis in this section. As one can see, most of the methods discussed above are expensive and would require resources on the order of several hundred thousand dollars per project, at a minimum. Supervising these projects would also require that the Coastal Commission hire staff with a strong background in resource economics. Moreover, there is no guarantee that the results from these projects would be consistent when applied to quite similar beaches since the academic literature does provide a range of values even at very similar beaches.

It may be possible to apply the travel cost method at some sites where funding (on the order of at least $10,000) is available, but the travel cost model can yield significantly different results depending upon how it is applied. Given the resource constraints that the Coastal Commission faces, we believe that a benefits transfer (BT) approach is the most feasible alternative and would also provide the most consistency.

We recommend that the Coastal Commission adopt a benefits transfer (BT) technique and erosion-value loss model similar to the amenity-based model. This model can be developed in a manner that: (a) is consistent with existing studies and across similar beaches; (b) is tractable and applicable by busy Coastal Commission staff; and (c) will hold up under the scrutiny of a legal review. Under this framework, the applicant (or a designated consultant) would be required to submit some of the information necessary for the Commission to make its estimates.

One open question is whether the applicant should submit attendance estimates in conjunction with other data. The engineering report by the applicant should also consider recreational beach width and any changes to recreational amenities caused by the seawall.

Development of a useful BT model requires that the user (most likely Coastal Commission staff or the applicant) be given detailed instructions on how to quantify amenity values. Even a seemingly simple parameter like beach width needs to be measured carefully since beach width almost always varies across a beach/reach and varies by season. In addition, at narrow beaches, visitors often will recreate on the “wet beach” (below tide line).

However, we are confident that a BT method can be developed that: a) a staff member who is not an economist can perform, b) is consistent with existing studies, and c) will be reproducible in a consistent way so that the “subjective” element is reduced. The last element requires detailed instructions so that amenity levels can be scored consistently. Since most beach amenities (e.g., lifeguards, restrooms, and weather) can be measured in a reasonably objective manner, the BT method development needs to provide specific instructions to ensure consistent application.

BT models are widely used by many federal agencies such as the Corps of Engineers, NOAA, the U.S. Forest] (e.g., see Rosenberger, R., & Loomis, J (2000), Lipton, D. W., Wellman, K., & Weifer, S. and R. F. (1995), U.S. Army Corps of Engineers (USACE). (2004) for the reasons discussed above.

3. Recreation Method

As discussed in our review of the literature on recreational methodology, a number of standard techniques have been developed to estimate the recreational value of a beach. Readers interested in a more detailed discussion of the methodological issues involved are referred to this discussion in section 2. To simplify, one generally decomposes the value of beach recreation into two components:

a. The value of a beach day, per visitor (i.e., consumer surplus);
b. The number of people who attend the beach/reach per year (i.e., annual attendance).

Following our review of the literature on methods for assessing recreational value as well as subsequent phone conversations, our understanding is that the Commission would like a methodology that: (a) is simple and does not require the collection of attendance data by staff or the applicant; (b) can be applied by non-economists. The purpose of this paper is to propose a method that can be easily applied by the Coastal Commission with data that is generally available or commonly provided by an applicant (e.g., beach width and erosion over time).

Given these constraints we believe that a simple benefits-transfer methodology makes sense. Benefits transfer is a common technique whereby economists and policy-makers apply results from other studies to the decision at hand. Accompanying this paper is an excel spreadsheet with a model embedded in it.

3.1 Value of a Beach Visit (Consumer Surplus)

The literature on beach visitation values (see Table 5 below) is almost completely focused on high use Southern California beaches. There is limited empirical data that can be used to adjust those values for other beach areas. Given these constraints, the choices include:

a. Use the average value for all beaches in the state
b. Use an average value for all beaches outside of high visitation beaches outside of Southern California and then use a more specific value for Southern California based on characteristics of the Southern California beaches.

We recommend using an average value for all beaches for several reasons. First, although the mix of recreational activities is different between southern and northern California beaches (northern beaches tend to be colder) there is no inherent reason to believe that the valuations should differ. Second, the availability and carrying capacity of recreational beaches in northern California is lower, therefore fewer substitutes are likely available. For California, the average value of studies compiled in Table 5 is $47.29. Pendleton & Kildow (2006) provide a range of $15 to $50 ($2005) for their estimate of the total value of California beach visitation. For their upper range they used the mid point of averages from Leeworthy and Wiley (1993) and Leeworthy (1995) and the average values in the preferred Lew (2002). Our estimates use the midpoint of the range used by Pendleton & Kildow (2006) for the value of a single California beach visit, which is a value of **$39.49** ($2015) per beach visit adjusting for inflation. One could also use the average of $47.29, but we prefer to be conservative.

It is important that the beach value is adjusted for inflation to reflect the current dollar value of the time of the estimate. Here we adjusted all the values to 2015 prices using the Bureau of Labor Statics (BLS) Consumer Price Index (CPI) calculator. The CPI inflation calculator uses the average Consumer Price Index for a given calendar year. This data represents changes in prices of all goods and services purchased for consumption by urban households. This index value has been calculated every year since 1913. For the current year, the latest monthly index value is used. The calculator can be found at: http://www.bls.gov/data/inflation_calculator.htm The CPI calculator provides a simple tool to adjust from date to the current time. The values used to estimate beach value should be adjusted for each individual permit to provide the most current value.

Table 5: Estimates of Day-Use Value (Consumer Surplus) at Various California Beaches

Region	Counties	Usage Level*	Consumer Surplus Studies	CS Values ($2015)
Southern	San Diego Orange Los Angeles Ventura Santa Barbara	High	12	$14.77[1] $21.35[2] $23.95[3] $27.41[2] $30.01[2] $33.24[1] $34.35[4] $37.62[2] $44.63[5] $94.03[1] $103.75[6] $110.06[6]
		Low	0	
Central	San Luis Obispo Monterey Santa Cruz San Mateo San Francisco	High	1	$47.44[6]
		Low	0	
Northern	Marin Sonoma Mendocino Humboldt Del Norte	High	0	
		Low	0	
CA Average		N/A		$47.29
Midpoint Kildow & Pendleton (2006)		N/A		$39.49[7]

[1] Leeworthy & Wiley (1993)
[2] King (2001) – midpoint between two methods
[3] Chapman and Hanemann (2001) – corrected for inflation using CPI
[4] Lew and Larson (2005)
[5] Lew (2002)
[6] Leeworthy (1995)
[7] Midpoint of Kildow & Pendleton (2006) adjusted for inflation ($2015)

3.2 Impact of Beach Width on Recreational Value

As cited in section 2, a number of studies indicate that beach width is a critical component in the value of beach recreation (per person per day). Unfortunately, there is no perfect model of this relationship. The most widely used benefits transfer model for beaches in California is the California Sediment Benefits Analysis Tool (CSBAT). The CSBAT model uses a Cobb-Douglas utility function (see Aappendix II for details) which estimates the value of a beach day based on the “dry” beach width (mean high tide line to back of beach) during high season (summer). The model has been calibrated from survey data collected at beaches in Orange County, San Diego County, Santa Barbara County and Ventura County. Unfortunately, no such data exists for northern California beaches. The model is incorporated into an excel sheet which accompanies this paper.

3.3 Beach Attendance

Although official beach attendance data exists for some beaches in California, the methods used to estimate attendance vary significantly and are often inconsistent. For consistency, we apply data collected by King at various beaches in southern and Northern California. All of these estimates are based on human counts at these beaches; the distribution of visitors is based on survey data. Tables 6-8 below present estimates of attendance, as well as density (# visitors per square foot per year) for beaches in southern California where such information is available.

Table 6: Attendance and Density at Selected Beaches in Santa Barbara and Ventura Counties

Beach	Annual Attendance	Width	Reach Length	Density
Gaviota State Beach	175,000	100	2000	0.88
Refugio State Beach	300,000	90	2000	1.67
El Capitan State Beach	250,000	30	2000	4.17
Isla Vista	20,000	15	7000	0.19
Henry's	200,000	50	600	6.67
Goleta County Beach	500,000	100	2000	2.50
Arroyo Burro County (Hendry's) Beac	200,000	50	2000	2.00
Leadbetter Beach	350,000	175	2000	1.00
West Beach	150,000	275	1500	0.36
East Beach	800,000	190	6000	0.70
Butterfly Beach	100,000	15	2000	3.33
Summerland Beach	150,000	100	4000	0.38
Santa Claus Beach	150,000	90	2000	0.83
Carpinteria City Beach	550,000	110	1500	3.33
Carpinteria State Beach	700,000	60	4000	2.92
Rincon County Beach ("C Street")	140,000	70	2000	1.00
La Conchita Beach	40,000	40	8000	0.13
Oil Piers	10,000	125	2500	0.03
Hobson County Beach	20,000	15	3000	0.44
Rincon Parkway North	100,000	30	3500	0.95
Faria County Beach	25,000	5	1500	3.33
Mandos	200,000	3	6000	11.11
Rincon Parkway South	250,000	5	6000	8.33
Emma Wood State Beach	60,000	5	7000	1.71
Seaside Park/ Surfers Point Park	210,000	3	2000	35.00
San Buenaventura State Beach	300,000	200	3400	0.44
Pierpont Beach	450,000	125	4000	0.90
McGrath State Beach	50,000	300	2000	0.08
Oxnard Shores	50,000	250	2000	0.10
Silver Strand Beach	400,000	300	4000	0.33
Hueneme Pier	50,000	400	2000	0.06
Average				3.06

Table 7: Attendance and Density at Selected Beaches in Orange County[2]

Beach	Annual Attendance	Reach Length	Width	Density
Seal Beach	2,278,774	2440	210	4.45
Surfside/Sunset	2,257,856	10300	350	0.63
Bolsa Chica State	2,764,712	27755	250	0.40
Huntington City	9,931,425	2940	450	7.51
Huntington Harbor Beach	45,000	2220	18	1.13
Huntington State	2,542,332	10695	460	0.52
Newport/Balboa Beach	7,844,108	15000	530	0.99
Corona Del Mar State (inc Little)	369,515	2010	210	0.88
Crystal Cove State	666,820	17265	78	0.50
Laguna City	4,131,516	3850	95	11.30
Aliso	3,298,056	2800	180	6.54
Monarch Beach (inc Dana Strands) 2	220,000	255	94	9.18
Salt Creek	3,967,715	3900	190	5.35
Dana Point	1,214,374	1300	110	8.49
Doheney State	1,827,231	4080	250	1.79
Capistrano 3	516,788	6600	50	1.57
San Clemente City (Main)	2,583,940	9855	110	2.38
San Clemente City S.San Clemente State	519,641	9930	180	0.29
Average				3.55

[2] Data collected by P. King and presented in the Orange County Coastal Regional Sediment Master Plan (CRSMP), April 2012: http://www.dbw.ca.gov/csmw/pdf/OCCRSMP_DraftReport.pdf.

Table 8: Attendance and Density at Selected Beaches in the San Francisco Bay Area[3]

Beach	Est. Yearly Attendance	Width	Reach Length	Density
North Ocean Beach	160000	400	4900	0.082
Middle Ocean Beach	140000	100	10400	0.135
South Ocean Beach	40000	50	2500	0.320
Fort Funston	130000	60	5900	0.367
Beach BLVD	40000	50	2100	0.381
Sharp Park	50000	170	3200	0.092
Rockaway Cove	40000	75	1200	0.444
Linda Mar	80000	150	1900	0.281
Shelter Cove	25000	45	620	0.896
China Camp	29600	22	1145	1.175
McNears Beach	251200	35	1015	7.071
Baker Beach	99200	107	3691	0.251
Albany	24700	9	533	5.149
Pt Pinole	33900	15	1322	1.710
Crown Beach	426000	50	9000	0.947
Crissy Field	461700	95	5280	0.920
Average				**1.264**

The average density for beaches in Orange County is 3.55 people per square foot per year; for Santa Barbara and Ventura Counties its 3.06 people per square foot per year. These estimates are reassuringly close. It also makes sense that Orange County beaches would have higher densities since the weather is typically warmer and sunnier. On the other hand, the densities at Bay Area beaches are significantly lower on average, 1.26 people per square foot per year.[4]

[3] Data collected by P. King for the San Francisco Bay and San Francisco/Daly City/Pacifica Coastal Regional Sediment Master Plans (CRSMP); both are forthcoming.

[4] The median density for Santa Barbara and Ventura Counties is 0.95, lower than the average, the median density for Orange County is 1.68, also somewhat lower and the median for San Francisco Bay beaches is 0.41, also lower. This result reflects the fact that a few beaches have very high attendance densities. Since we are attempting to get a reasonable average mitigation fee, we believe using an average is appropriate.

Given these differences, it makes sense to provide a different estimate for visitor density at northern California, as opposed to southern California, beaches. We propose using an average value for southern California Beach (Pismo Beach and below) of 3.3, which represents the average of the beaches in Table 7 - Table 8. For northern California, the only estimates we have are from the Bay Area, but we believe these estimates are reasonable for northern California, with the possible exception of Santa Cruz.

3.4 Estimating the Recreational Value of a Beach before and after a Proposed Project

Once an estimate of the value of a beach day and an estimate of beach density is provided, it is quite straightforward to estimate the recreational value of a beach before and after a project.

The formula for estimating recreational value is:

Recreational Value (per year) = Day Use Value * Attendance Density*

length of reach * width of reach

The attendance densities are from Table 6 - Table 8. We assume that the density is 3.3 people per square foot per year for southern California (San Luis Obispo County south) and 1.26 for northern California.

3.5 Choice of a Discount Rate

The choice of an appropriate discount rate is currently a subject of debate within the economics profession, particularly for long-term projects, where intergenerational equity is a consideration.[5] However, as discussed in section 2.5.4, there is a growing

[5] See: How should the distant future be discounted when discount rates are uncertain? Christian Gollier, Martin L. Weitzman, Economics Letters 107 (2010) 350–353, and How Should Benefits and Costs Be

consensus that the use of a declining discount rate for longer term horizons is appropriate (e.g., see Arrow, et. al. 2014). Weitzman (2001) and others have suggested a 1% discount rate for longer time horizons. Since seawalls, revetments and other coastal armoring structures are rarely removed, we believe is appropriate to assume a longer time horizon, even if the permit is granted for a shorter time period. Following Weitzman (2001) and Arrow et. al. (2014) we have adopted a 1% discount rate.

3.6 Case Study: San Elijo Beach

San Elijo Beach is located in Encinitas (north San Diego County) just west of San Elijo Lagoon. The beach provides swimming, surfing, boogie-boarding, skim-boarding, showers, picnicking, and camping. Campsites are located on a bluff just behind the beach. The beach is relatively narrow and significant bluff erosion would reduce the number of campsites. The beach width varies with season and storm patterns. According to a recent survey conducted for SANDAG,[6] the "dry beach" (Mean high tide to bluff back) average width is 212 feet in high season.

We do not have specific plans for a seawall or revetment structure and data on erosion rates varies. For the purposes of this exercise, we assume that without the project the bluff will erode back to maintain the beach width at 212 feet. Since there is recreational value on the campsites about the bluff, the loss in this recreational value should also be incorporated into the estimate of losses. This estimate is beyond the scope of this

Discounted in an Intergenerational Context? The Views of an Expert Panel Kenneth J. Arrow, Maureen L. Cropper, Christian Gollier, Ben Groom, Geoffrey M. Heal, Richard G. Newell, William D. Nordhaus, Robert S. Pindyck, William A. Pizer, Paul R. Portney, Thomas Sterner, Richard S. J. Tol, and Martin L. Weitzman, Resources for the Future, 2012.

[6] See San Diego Association of Governments. (2014) SANDAG Regional Beach Monitoring Program, prepared by Coastal Frontiers Corporation.

project; it would involve estimating the loss in camping per lost site and applying a day use value as with loss of beach recreation. The day use value for camping is different than for beach visitation.

For this exercise we assumed that length of the seawall is 1,000 feet, which covers the campsites and parking above the bluff. We assume that the erosion rate with project is one-foot per year. However, this is an arbitrary assumption for the purposes of this exercise.

All of the amenity values have been set at 50% for a typical beach, except for width, which is entered directly in the spreadsheet. It would be possible for the Coastal Commission or applicant to refine the amenities, depending upon the particular beach. We further assume that the seawall will be 12 feet in width (i.e., it will reduce the beach by 12 feet initially).

The model estimates the value of a beach day as a function of beach width (see discussion above) as well as attendance based on the area of the beach (width times length). To be conservative, we assume that the $39.49 day-use value applies to a 250 ft. wide beach; since this beach is narrower, the CSBAT model applies a lower value per beach day. Table 9 below provides a partial picture of the table generated in the Excel Spreadsheet. The Excel sheet estimates values up to 50 years, but Table 10 only displays 4 years due to space limitations. The reader is referred to the sheet itself for more details.

Table 9: Snapshot of Recreational Estimate without Project.

Beach Width without Project								
Year		0		1		2		3
Beach Width without Project (feet)		212		212		212		212
Amenity weighting without width		0.554784736		0.554784736		0.554784736		0.554784736
Amenity Weighting for width		0.975572114		0.975572114		0.975572114		0.975572114
Value of a Beach Day (per visitor per day)	$	37.89	$	37.89	$	37.89	$	37.89
Estimated Attendance		700,514		700,514		700,514		700,514
Recreational Value	$	26,539,875.01	$	26,539,875.01	$	26,539,875.01	$	26,539,875.01
Discounted Present Value	$	26,539,875.01	$	26,277,103.97	$	26,016,934.62	$	25,759,341.21

Table 10 below displays the same information with a seawall—which implies lower initial beach width and a higher erosion rate.

Table 10: Snapshot of Recreational Estimate with Project.

Beach Width with Project				
Year	0	1	2	3
Beach Width with Project (feet)	200	199	198	197
Amenity weighting without width	0.554784736	0.554784736	0.554784736	0.554784736
Amenity Weighting for width	0.967082441	0.966355583	0.965625614	0.964892504
Value of a Beach Day (per visitor per day)	$ 37.56	$ 37.53	$ 37.50	$ 37.47
Estimated Attendance	660,862	657,558	654,254	650,950
Recreational Value	$ 24,819,734.31	$ 24,677,074.43	$ 24,534,522.05	$ 24,392,077.61
Discounted Present Value	$ 24,819,734.31	$ 24,432,746.96	$ 24,051,095.04	$ 23,674,710.22

The bottom row displays the recreational value of beach attendance for a given year, discounted by 1% per year. The row extends for up to 50 years. The final table on this sheet presents the sum of the present values with and without a project, for 20 years and for 50 years. Table 11 presents this information.

Table 11: Estimated Loss in Recreational Value over 20 and 50 Year Period Project.

	50 Year	20 Year
PV Total Recreational Value without Project	$1,050,662,660.78	$ 483,715,987.42
PV Total Recreational Value with Project	$ 857,392,954.91	$ 428,631,078.59
PV Loss in Recreational Value Due to Project	**$ 193,269,705.87**	**$ 55,084,908.83**

As one can see above, over a 20-year period, the seawall will lead to a reduction in recreational value of $55 million; over a 50-year period, the reduction is $193 million.

3.7 Case Study: Del Monte Beach

Del Monte Beach is located in the City of Monterey, just east of the wharf. The beach is popular with locals and visitors to the City. Dog-walking off-leash is popular as are the fire pits at night. Restrooms are not available on the beach but are available nearby. There beach is backed by a City park closer to the wharf; as one moves north/east there are several condos and a hotel.

For the purposes of this exercise, we will examine a 500 ft. seawall. The erosion rate on the beach varies; close to town there is a groin which limits sand movement and the erosion rate is low; as one moves north, the erosion rate increases. This case study will assume that the erosion rate is 0 ft./year with no revetment and 1 ft./year with a (30-ft. wide) revetment. Tables 12 to 14 below are analogous to Tables 9-11 above.

Table 12: Snapshot of Recreational Estimate without Project.

Beach Width without Project								
Year		0		1		2		3
Beach Width without Project (feet)		150		150		150		150
Amenity weighting without width		0.554784736		0.554784736		0.554784736		0.554784736
Amenity Weighting for width		0.926238199		0.926238199		0.926238199		0.926238199
Value of a Beach Day (per visitor per day)	$	35.97	$	35.97	$	35.97	$	35.97
Estimated Attendance		247,823		247,823		247,823		247,823
Recreational Value	$	8,914,306.97	$	8,914,306.97	$	8,914,306.97	$	8,914,306.97
Discounted Present Value	$	8,914,306.97	$	8,826,046.51	$	8,738,659.91	$	8,652,138.52

Table 13: Snapshot of Recreational Estimate with Project.

Beach Width with Project								
Year		0		1		2		3
Beach Width with Project (feet)		150		149		148		147
Amenity weighting without width		0.554784736		0.554784736		0.554784736		0.554784736
Amenity Weighting for width		0.926238199		0.925309325		0.924375138		0.923435569
Value of a Beach Day (per visitor per day)	$	35.97	$	35.93	$	35.90	$	35.86
Estimated Attendance		247,823		246,171		244,519		242,867
Recreational Value	$	8,914,306.97	$	8,845,998.19	$	8,777,758.14	$	8,709,587.22
Discounted Present Value	$	8,914,306.97	$	8,758,414.05	$	8,604,801.63	$	8,453,439.54

Table 14: Snapshot of Recreational Estimate with Project.

		50 Year		20 Year
PV Total Recreational Value without Project	$	352,900,286.09	$	162,472,234.64
PV Total Recreational Value with Project	$	293,231,342.02	$	151,125,809.06
PV Loss in Recreational Value Due to Project	**$**	**59,668,944.07**	**$**	**11,346,425.58**

As indicated in Table 14, the project would reduce recreational value by $11.3 million over a 20-year period and $59.7 million over a 50-year period.

3.8 How to Use the Excel Sheets To Estimate Recreational Losses

In order to estimate the recreational loss from a proposed coastal armoring project, we prepared a spreadsheet that uses the methods described in this section. The first sheet "Inputs for CCC" has several simple inputs that are required in order to estimate recreational losses. These inputs are as follows:

- Length of project Reach (feet)
- Is the location North of San Luis Obispo County (1 if yes; 0 if no)
- Initial Dry Beach width without Project
- Erosion Rate of the beach (feet per year) without Project
- Initial Dry Beach width with Project
- Erosion Rate of the beach with Project
- Day Use Value

Each one of these variables will be discussed (briefly). The length of the project simply refers to the (linear) length of the seawall/revetment or other structure. Since the densities of beach visitors varies, we have divided the Calfiornia Coast into north and south; any beach north of San Luis Obispo County is considered north; any beach in San Luis Obispo County or south is considered south.

The "dry beach" width is measured from the mean high tide to the back of the beach, generally where the armoring structure is planned. Since beach width varies by year and season, measuring the dry beach width can be difficult. Recreational value is highest in the summer for almost all beaches. Consequently, dry beach width should be an average width for high season (summer). Beach erosion rates may also vary, but typically is expressed as an average in feet per year. Without a coastal armoring structure, the beach may be allowed to "retreat" naturally. If this is the case the erosion rate for the dry beach could be zero, even if the coast erodes.

After the project is built the beach width will be reduced by the footprint of the structure, generally greater for a revetment than for a seawall. Consequently the width of the structure should be subtracted from the dry beach width. The erosion rate after the structure is built also needs to be estimated. Often this rate is higher than the erosion rate before the structure is built. The Coastal Commission may also consider requiring applicants to monitor the erosion rate of the beach after in order to determine if the actual rate is consistent with the forecasted rate.

The Day Use Value has been set at $39.49 (Table 5 above) in 2015 dollars. However, in the future, the day-use value needs to be updated to account for inflation using the consumer price index (CPI).

Once these data have been entered, the Excel sheet will generate an answer for lost recreation. The bottom chart on the “Inputs for CCC” sheet generates the Present Value (discounted at 1%) for recreation with and without project and calculates the difference over a 20 and 50 year time period. The estimates of recreational losses should provide a basis for mitigation.

The other sheets provide data and links that are used in the estimates/calculations. However, they do not need to be modified. CCC staff only need to look at the first (“Inputs for CCC”) sheet.

3.9 Suggested Methods for Collecting Additional Attendance Data

One possible refinement to this approach would be to collect attendance data at the site. This method would require that several periodic counts be made at the site (see discussion in section 2.3 for a more detailed discussion). Since attendance is extremely seasonal at most beaches, counts would have to be made throughout the year, or a method of adjusting the numbers for seasonality would be required. One also needs to understand the distribution of people on the beach during a given day in order to estimate the “turnover factor.” One could also use an average turnover factor taken from other studies (e.g., see King and McGregor, 2012). A reasonable method would include the following:

- A sufficient number of counts (at least 20-30) at representative times of the day/week/year.
- An accounting for the different types of recreational activities. In particular, surfing is a higher value activity.
- A turnover factor (which typically varies by the time of day since more people tend to go to the beach midday. King and McGregor (2012) provide turnover factors for various southern California beaches.
- A method for weighing attendance by month of the year. Dwight (2007) provide a reasonable breakdown of attendance by month for many southern California beaches which should be used as a reasonable bases for the distribution of visitors by month. However, care should be take since recreational patterns vary by beach, local weather patterns and type of recreation (e.g., surfers tend to surf all year round).

Counts should be taken for a larger beach/reach than just the area in front of the seawall. If there is a well-defined beach area, then this beach should be used as a reference and the average density for the entire beach/reach should be estimated and then applied proportionately to the area in front of the proposed project. In a few cases it may also be possible to use car counts and adjust accordingly. King and McGregor (2012) discuss this method as well.

If official counts are available for the entire beach, one might also use these counts and apply the attendance estimates proportionately to the area in front of the proposed project.

3.9 Conclusion

This paper has laid out a simple methodology for estimating the loss in recreational value caused by the construction of a seawall, rip rap or other coast armoring structure. An accompanying Excel sheet provides cells for Coastal Commission staff to enter data related to the project. The analysis requires the following information:

- The width of the beach over time before and after the project;
- The length of the project;
- Whether the project is located north of San Luis Obispo Count or south of it.
- Erosion rate with the project.

With this information, which would be supplied by the applicant, one can estimate the loss on recreational value due to an armoring structure.

4. Beach Ecology and Ecosystem Valuation Review

4.1 Characterizing and Valuing Beach Ecosystems

A detailed overview of beach ecosystems and our current understanding of the impacts of coastal armoring open coast sandy shorelines is presented in the first part of this section. An overview of the methods devised by economists to value ecosystems is provided in the second part of the section. Coastal armoring is known to interfere with and reduce beach ecosystem functioning and resiliency. The goal of this section is to provide a background that can be used to support a protocol for the California Coastal Commission to use to value the ecological losses associated with the construction of coastal armoring structures on open coast sandy beaches,

4.1.1 Characterizing Beach Ecosystems

The unique biodiversity and ecological functions and resources supported by sandy beach ecosystems are often under-appreciated compared to their socioeconomic, recreational and cultural values (Schlacher et al. 2007, 2014). However the biodiversity, and the intrinsic ecological roles and functions of sandy beach ecosystems are not provided by any other coastal ecosystem. These vital roles and functions include rich invertebrate communities and food webs that are prey for birds and fish, buffering and absorption of wave energy by stored sand, filtration of large volumes of seawater, extensive detrital and wrack processing and nutrient recycling, and the provision of critical habitat and resources for declining and endangered wildlife, such as shorebirds and pinnipeds.

Importantly, the majority of the intertidal biodiversity found on California beaches lives above MHW (Mean High Water). Approximately 40 to 50% of the invertebrate biodiversity of California beaches is strongly associated with stranded drift macrophytes or wrack. This is in strong contrast to rocky intertidal ecosystems where biodiversity is greatest below MHW and in situ primary production is higher.

4.1.2 Beach zonation

Characterized by unconsolidated sand, a lack of attached intertidal plant life, and highly mobile animals, sandy beaches represent a challenge for biota and ecologists alike. Intertidal zonation can be discerned on sandy beaches, however, its character differs profoundly from rocky or muddy shores (Peterson, 1991). The distinctive mobility of the intertidal animals and of the sand itself mean that concepts of intertidal zonation used for exposed rocky shores cannot be applied to sandy beach ecosystems. On intertidal shores with stable rocky substrates, many biota survive the action of tides and wave by strongly resisting movement with a variety of adaptations and behaviors. On sheltered muddy shores, plants can take root and many animals build and inhabit relatively permanent burrows in the well-consolidated sediments or attach to plants. On sandy beaches it is not possible to attach to the substrate and plants or to occupy permanent burrows. Intertidal animals have to move; swimming, scudding, crawling, running, hopping, or surfing, and then burrowing rapidly, to adjust to ever-changing conditions of tides, waves, storms, and shifting beach profiles. This high mobility of beach animals is the foundation of many of the fundamental differences in the intertidal ecology and zonation of sandy beaches compared to other intertidal ecosystems.

Although far less obvious than observed on rocky or muddy shores, three relatively distinct intertidal ecological zones can be often be identified for a given low tide condition on many of California's sandy beaches and elsewhere (McLachlan and Jaramillo 1995). These zones generally correspond to the relatively dry sand around and above the high tide strand line or drift line, the damp to wet sand of the middle intertidal and the saturated sand of the lower and swash intertidal zone (Figure 6). The low intertidal zone consists of saturated sand that includes the lowest retreat of the tides and the upper and lower bounds of the active swash zone (Figure 6). The mid-intertidal zone extends from below the high tide strand line across the damp sand and to or below the water table outcrop depending on the slope and shape of the beach profile. Highest on the beach profile is an upper beach zone that is located above and around the high tide strand line (HTS) or driftline and extends up to the landward boundary of wave and tide-influenced sandy habitat (e.g. foredune toe, rocky bluff, or man-made coastal infrastructure). The high tide strand line (HTS) or drift line is a highly mobile feature that marks the highest reach of the tides in a 24 hour period. This is where the primary deposition of buoyant material from the ocean and rivers including macrophyte wrack (kelps and red and green macroalgae, and seagrasses), driftwood, carrion, and other marine and terrestrial debris, such as leaf litter and trash, occurs. The upper beach zone varies greatly in width with tide phases, wave events and across accretion and erosion cycles. Although often termed the supralittoral meaning “above the reach of tidal influence”, this terminology is problematic on beaches due to inundation of this zone during spring tides, storms and large swell events and its regular use as habitat by the mobile intertidal biota characteristic of beaches. Upper beach zones are often defined as critical or essential habitat required for wildlife, including nesting shorebirds and sea turtles, many of which are considered threatened or endangered. The landward-most edge of this upper beach zone can support the establishment of coastal strand vegetation**,** at least during periods of accretion when the beach is wide (Barbour et al. 1976,1985, Barbour and Johnson 1988, Feagin et al., 2005; Dugan and Hubbard 2010). This colonizing vegetation, although composed of perennial plant species, may be functionally annual on many beaches due to strong seasonal cycles of erosion and accretion. When present for sufficient time, coastal strand vegetation traps wind-blown sand to form hummocks and embryonic dunes, acting as ecosystem engineers (Dugan and Hubbard 2010). During periods with sufficient sand supplies and relatively low wave energy, these vegetation-generated features may build into primary foredunes (ESHA). On narrow beaches where high tides reach cliffs or manmade structures regularly, coastal strand vegetation and foredunes are usually absent.

Although ecologically distinct intertidal zones can be recognized on beaches, it is important to understand that the locations of these zones and of many of their characteristic biota constantly move up and down (as well as along) the beach in response to tides and water motion, shifting dramatically in just a few hours. As the tide floods after a low tide, animals burrowed in the swash and low zone of a beach, such as sand crabs, emerge from the sand to migrate up the shore with the swash zone. On the ebb tide they move down the shore with the swash zone and reburrow. Zone widths as well as the positions of many beach animals on the profile also respond distinctly to the lunar tide cycle. During spring tides biota occupy wider zones and burrow higher on the beach than during neap tides (Dugan et al. 2013). This means that while overall abundance remains the same, these semilunar movements create major changes in the density of animals burrowed in a particular zone across lunar phases. These animals must move much greater distances up and down the beach profile to adjust to changing conditions and to survive rapid shifts in beach width and volume associated with the seasonal or event-driven erosion and accretion typical of many California beaches (Dugan et al. 2013). In fact, annual shifts in intertidal position defined as the ecological envelopes of beach animals have been shown to extend across >60% of the overall beach width (Dugan et al. 2013). In summary, these ecological envelopes illustrate how the characteristic mobile biota of sandy beaches require large buffers of sandy beach habitat to use as the beach contracts and expands in width with seasonal and event-driven erosion or accretion.

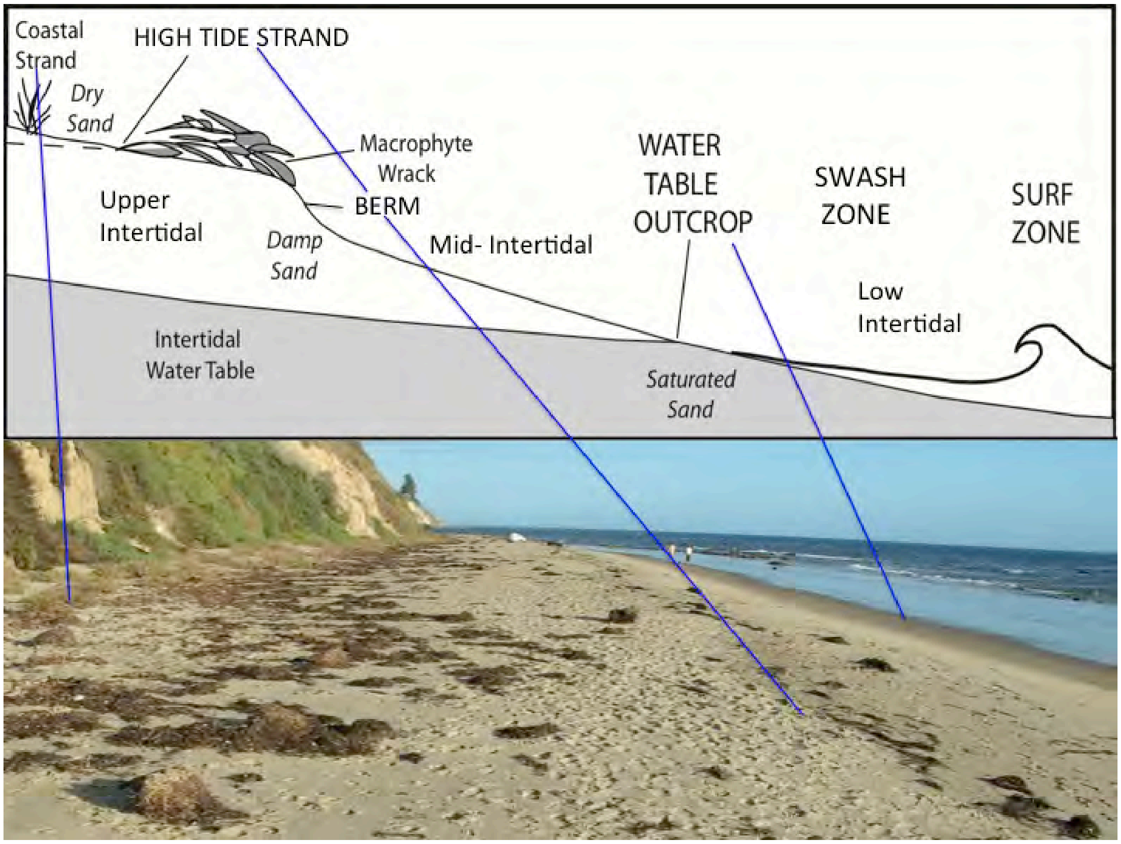


Figure 6: Ecological zones of sandy beaches a) diagram of a California beach at low tide showing zones and features; and b) a photograph of a bluff-backed beach with the features shown in the diagram (Arroyo Burro Beach, Santa Barbara County) (adapted from book chapter in Ecosystems of California in press, Photo: Jenny Dugan).

4.1.3 Coastal Armoring

Rapidly growing populations and expanding development are intensifying pressures on sandy beach ecosystems on the California coastline. Sea-level rise and other predicted effects of climate change are expected to exert even greater pressures on these narrow ecosystems perched at the edge of land and sea, exacerbating erosion, degrading habitat, and accelerating shoreline retreat. Historically, society's responses to threats from erosion and shoreline retreat to coastal development and infrastructure have relied heavily on armoring and other engineered coastal defenses (Charlier et al. 2005).

Despite an increasing prevalence of armored shorelines, particularly on developed coasts (Nordstrom 2000), the understanding of the ecological effects of shoreline armoring is remarkably limited (Chapman and Underwood 2009), particularly quantitative information. Shoreline armoring is currently employed in a broad range of coastal ecosystems with little or no information about its ecological impacts on biodiversity, productivity and critical ecosystem functions (Dugan et al. 2011). During the past century approximately 12% of the mainland coast of California has been armored and the geographic extent of armoring on the coast increased by 400% between 1971 and 1992 (Griggs 1998). In densely populated southern California, armoring covers 30% of the coastline overall (112 km of 371 km of coast). However, 70% or more of the coastline is armored in the cities of Long Beach, Seal Beach, San Clemente and Oceanside, illustrating how armoring varies strongly with region and across littoral cells.

4.1.4 Impacts of Shore-Parallel Armoring

<u>Alteration of coastal processes</u>

Starting from first principles, any engineered structure placed in a coastal setting will alter hydrodynamics and modify the flow of water, wave regime, sediment dynamics, turbidity, grain size and depositional processes (Martin et al. 2005, Fletcher et al., 1997, Runyan & Griggs, 2003, Miles et al. 2001). On open sandy coasts, seawalls, revetments, geotextile tubes and other engineered shore-parallel structures occupy habitat, alter the wave regime and modify processes that deposit and retain mobile sediments on exposed sandy beaches (e.g. Miles et al. 2001). For alongshore structures (seawalls and revetments) placed on beaches, the hardened faces reflect wave energy and restrict natural landward migration of the shoreline, generally leading to loss of beach area and width and flanking erosion of adjacent shorelines (e.g. Hall and Pilkey 1991, Griggs 2005a, b). Armoring fixes shoreline position, constraining the possible responses and evolution of beach ecosystems to adjust to changes in sea level and other dynamic coastal processes. This loss of the scope and ability of beaches to respond to coastal processes results in the reduction of overall width and the elimination of habitat zones and the space needed by biota to adjust to changing swell, tide and beach conditions.

The effects of shore-parallel coastal armoring on the physical features of open coast beaches are relatively well documented (see reviews by Kraus & McDougal 1996, Nordstrom 2000, Wiegel 2002abc, Griggs 2005b). Beach widths are reduced seaward of shore-parallel structures, such as seawalls and revetments, initially in response to placement loss, followed by the ongoing effects of coastal processes, such as passive and active erosion. Placement loss, the loss of original beach area covered by the footprint of the armoring structure, and passive erosion, in which shoreline retreat is inhibited and the beach in front of structure drowns as adjacent shoreline migrates landward are widely recognized effects of seawalls and revetments (Hall and Pilkey 1991, Fletcher et al. 1997, Griggs 2005b) (Figure 7) . The importance of active erosion of the beach caused by the seawall itself is less broadly accepted (Kraus & McDougal 1996, Griggs 2005). Impacts of active erosion include scour of the beach in front of the structure, as well as the effects of flanking erosion associated with stronger physical processes, such as increased wave reflection and the narrowing of the surf zone during storms (e.g. Miles et al. 2001, Griggs 1998, 2005ab, Hall & Pilkey 1991). These effects appear to be related to the hardened faces of seawalls, which reflect rather than dissipate wave energy combined with the constraints of armoring on natural retreat of the shoreline. Importantly, these effects scale with the degree of interaction of the structure with waves and tides. Generally, the lower a structure is located on the beach profile, the greater the physical impacts associated with it (Wiegel 2002abc).

Figure 7: Drowned beach at low tide in front of a seawall in southern California (El Capitan State Beach) illustrates the narrowing of the beach and the attenuation of ecologically important intertidal zones seaward of coastal armoring. Dry sand habitat is lacking and the drift line or high tide strand line is located on the structure rather than on sand. Adapted from Dugan, J.E., Hubbard, D.M., 2006. Ecological responses to coastal armoring on exposed sandy beaches. Shore and Beach 74 (1), 10–16.

Ecological impacts of armoring

Despite the use of coastal armoring on coastlines around the world for thousands of years, numerous studies of the physical effects, costs and efficacy and a very active debate on the geomorphic impacts of armoring on open and sheltered coasts, the ecological effects are little studied and poorly understood. A recent review that focused on sheltered coasts by the Ocean Studies Board of the US National Research Council stated that remarkably little is known about the effects of coastal defense structures on native coastal habitats and their communities and how they can change the ecosystem functions and services provided by natural ecosystems or introduce new ones (NRC

2007). Even less is known concerning the ecological effects of armoring structures on open coast ecosystems, such as sandy beaches. However some evidence on the ecological effects of reduced cross-shore habitat and ecological zones associated with coastal armoring on open coast beaches is available (Dugan et al. 2008, Jaramillo et al 2012).

As a consequence of this lack of knowledge, ecological impacts have generally not been considered in policy decisions regarding coastal armoring. However, as human populations continue to flock to the coast, sea level rises and coastal erosion accelerates, the need to understand the ecological consequences of armoring, in all its forms, on coastal ecosystems is increasingly urgent. We review existing information to synthesize the current understanding of the ecological impacts of coastal armoring. Major themes include ecological effects of 1) the loss of habitat and alteration of processes in soft sediment shores and benthos and 2) the creation of artificial and novel hard substrata in predominately soft sediment ecosystems.

<u>Loss of habitat</u>

When the footprint of a manmade coastal structure covers and directly reduces existing habitat, the magnitude of this 'placement loss' of coastal habitat varies with the type and construction of the structure as well as its location on the shoreline and the characteristics of adjacent habitats. For example, revetments with broad foundations cause more habitat loss per unit of height than do seawalls with more vertical profiles (Griggs 2005).

Although they can change rapidly in width and location, the intertidal or ecological zones described earlier are useful for deciphering the potential impacts of coastal armoring on sandy beaches. A large number of studies have quantified the responses of overall beach widths and profiles to a great variety of forms and applications of coastal armoring, however, they do not account for the relative responses of the different ecological zones of the beach habitat (e.g. McLachlan & Jaramillo 1995, Dugan et al. 2013) further limiting the current understanding of ecological impacts. A conceptual framework developed for open coast beaches states that a number of ecological impacts of armoring may be predicted using changes in the widths of different ecological zones of the beach as proxies for habitat loss (Table 15) (Dugan & Hubbard 2006). As overall beach and intertidal widths narrow from the effects of placement loss and passive erosion in front of armoring structures, habitat area is lost disproportionately from upper shore zones (Figure 7). Thus, effects of armoring are predicted to be greatest and occur most rapidly on the landward-most zones including the upper beach “dry sand” and coastal strand zones (e.g. Feagin et al*.* 2005, Dugan & Hubbard 2010). With the loss of the upper beach zone, the crucial habitat near the high tide driftline, the primary zone for wrack deposition and wrack-associated invertebrates, is also greatly reduced or eliminated. As the driftline habitat shifts from the beach to the armoring structure, the rich three-dimensional beds of mobile invertebrates characteristic of this zone are replaced with steep, reflective, two-dimensional artificial hard substrata (Figure 7). A large proportion of the biodiversity and a number of critical components of the structure and function of beach ecosystems rely on the zones and habitats around and above the driftline, located well above MHW. This strongly contrasts with rocky intertidal ecosystems where important ecological zones are located primarily below MLLW. On California beaches these critical components include upper intertidal zones that support 40-50% of the total intertidal biodiversity (Dugan et al. 2003, 2014), wrack deposition, retention and processing zones; essential spawning habitat for California grunion and other beach-spawning fishes, such as surf smelt and night smelt; nesting habitat for endangered and threatened shorebirds; and the sand-trapping vegetated coastal strand and dune habitats.

Results of the few comparative studies of armored and unarmored beaches to date support these predictions (Table 15). The scale of habitat and ecological effects of armoring observed were strongest for the upper shore zones in studies of seawalls along an undeveloped open coast in Santa Barbara County, California (Table 16) (Dugan & Hubbard 2006, Dugan et al. 2008), in Chile (Jaramillo et al. 2012) and in the sheltered coastline of Puget Sound (Sobocinski et al. 2010). For the open coast study in California, there were no upper beach zones (above the driftline) remaining on the armored segments compared to adjacent unarmored segments where these zones averaged 3.5 m in width (Dugan & Hubbard 2006, Dugan et al. 2008). This means the upper zone was 36 times (3600%) wider on the unarmored segments. This result for upper shore habitat loss was consistent with the scale of placement loss expected for the type of seawalls studied and demonstrates the relative ecological importance of this impact of armoring on narrow beaches. The overall narrowing of the beach by 2.1 times (210%) observed above the water table outcrop (WTO) on armored segments, (averaging 11.4 m), was, however, much greater than that expected from placement loss, suggesting the impacts of passive erosion and/or other mechanisms on beach and zone widths. Similar impacts to upper beach zones were evident on the coast of Chile where no high beach zones were found seaward of seawalls or revetments (Jaramillo et al. 2012).

Table 15: Hypotheses concerning ecological effects of shore-parallel armoring on beaches

As beach width narrows in response to armoring structures:

- Upper intertidal, supralittoral and coastal strand zones are lost disproportionately,
- Loss of sand-trapping coastal vegetation inhibits sand accumulation and retention, reducing the formation of hummocks and dunes that can provide protection during storms and high surf
- Loss of drier upper beach zones decreases number of habitat types available and room for migration of habitats/zones and macroinvertebrates with changing ocean conditions,
- Reduction in habitat types reduces diversity and abundance of macroinvertebrates,
- Loss of upper beach habitat eliminates nesting and resting habitat for sea turtles, fishes, birds, marine mammals etc
- The absence of high tide refugia alters low tide distribution of even highly mobile species
- Lack of dry sand habitat and increased wave reflection associated with structures alters deposition and retention of buoyant materials, (e.g. macrophyte wrack, driftwood) further affecting upper shore biota and processes, including nutrient cycling,
- Intertidal predators, such as shorebirds, decline in response to a combination of habitat loss, decreased accessibility at higher tides, and reduced prey resources

An important consideration with regard to the generality of these predictions is the location of the armoring structure on the beach profile, which affects the amount of interaction with waves and tides and the resulting physical impacts (Wiegel 2002abc). Habitat loss is expected to scale with the intensity of interaction between structures and coastal processes (e.g. wave reflection, tidal action) which is predicted to increase as over time and also as sea levels rise. Thus the ecological impacts of any armoring structure would be expected to respond similarly, whether location on the beach profile is due to initial placement, subsequent erosion of the shore or changes in sea level.

Overall, our review suggests that loss of coastal habitat caused by alongshore armoring structures disproportionately impacts the upper shore and high intertidal zones of beaches with the greatest relative loss or elimination of habitats evident higher on the shoreline. Critically, this includes the loss of key ecotonal and transitional habitats between land and sea, such as coastal strand, dune, and other vegetated zones, upper beach and intertidal zones on armored beaches. Loss of these key habitats will cause significant changes in biodiversity and community composition, alter vital ecosystem functions, processes and services, and reduce the connectivity between terrestrial and aquatic habitats of these important coastal ecosystems.

Table 16. Average scale of ecological effects of armoring (seawalls) detected for open coast beaches in Santa Barbara County expressed as the ratio of mean values for pairs of unarmored and armored beach segments (* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \geq 0.001$, n.d. not detected, values from Dugan & Hubbard 2006, Dugan et al. 2008). Note seawalls in the study were >60 years old and interacted daily with high tides.

Ecological Characteristic	Scale of effect
Intertidal zone widths	
Upper beach limit to driftline	36x***
Upper beach limit to WTO	2.1x***
Macrophyte wrack (standing crop)	374x*
Macroinvertebrates (upper shore)	
Species richness	n.d.
Abundance	10.6x*
Biomass	16.1x***
Mean individual size	1.6x*
Shorebirds	
Species richness	2.0x***
Abundance	3.7x*
Gulls	
Species Richness	2.0x
Abundance	4.8x***
Other birds	
Species richness	3.3x***
Abundance	7.7x***

4.1.5 Alteration of ecological function and integrity

Coastal vegetation

Intact coastal vegetation, including coastal strand and dunes, buffer shores and retain sediments from the effects of erosive processes including tides, waves and storms. These communities provide valuable ecosystem functions including primary production, water filtration, uptake of nutrients, detrital production and degradation and carbon fixation (Constanza et al. 1997). Shoreline vegetation is often lost from coastal habitats as bulkheads and seawalls both directly alter habitat and also prevent the migration of the shoreline in response to changing sea level.

On open coasts, the trapping of sand by coastal strand and dune vegetation is important in the formation of hummocks that can become embryo dunes and foredunes. This pioneering vegetation can be lost from armored beaches as structures directly alter and cover habitat and prevent the migration of the shoreline in response to changes in sea level (Dugan & Hubbard 2006, Jaramillo et al. 2012, Rodil et al. 2015). The effects of human activities such as beach grooming and trampling, coastal erosion and sea level rise on this already restricted habitat (e.g. Feagin et al. 2005, Dugan & Hubbard 2010) combined with the impacts caused by armoring create significant concern for the survival of the coastal strand zone and its functions on coastlines that are either retreating or developed or both.

Connectivity

Shorelines are vital transitional zones linking terrestrial and marine realms (Polis & Hurd 1996). Coastal armoring can sever these connections, reducing or eliminating key exchanges and functions including organic and inorganic material transfers (detritus, nutrients, prey, sediments), water filtration and nutrient uptake (Bilkovic & Roggero 2008, Dugan et al. 2012). Shore-parallel armoring disrupts connections between the shoreline and shallow water to terrestrial sources of sediments, such as coastal dunes, which can significantly affect sediment dynamics and supply (Nordstrom 2000). Although extensive research is needed on this topic, the severing of the connection between seacliff erosion and the beach by coastal armoring may also constitute a significant reduction in sediment supply in some regions of California (e.g. Runyan & Griggs 2003).

Wrack subsidies

Along with habitat loss, the alteration of physical processes that affect the deposition and retention of sediments on armored coasts can also affect the deposition and retention of buoyant material, including macrophyte wrack, driftwood and other natural allochthonous debris, which can be important to biota as food or habitat (e.g. Colombini & Chelazzi 2003, Dugan et al. 2003, Table 15). The significant relationship between wrack abundance and dry beach width found on California beaches (Revell et al. 2011) suggests that when dry upper beach zones are narrow or absent, wrack accumulation and its availability to beach consumers, microbial processing, and remineralization are greatly reduced. This prediction is supported by recent studies of open coast beaches of California (Table 16, Dugan & Hubbard 2006) and protected beaches of Puget Sound (Sobocinski et al. 2010, Heerhartz et al. 2014) that reported significantly lower standing stocks of wrack and driftwood on armored beaches compared to natural beaches. For California, wrack biomass was 374 times lower on armored than on adjacent unarmored segments of beach (Table 16). This impact of armoring on subsidies could significantly impact intertidal biodiversity and the function of open coast beach ecosystems in coastal nutrient cycling and dynamics (Dugan et al. 2011).

Benthic fauna

The loss of ecological zones, structural complexity and habitat types associated with armoring could be expected to directly affect the diversity and abundance of intertidal benthic fauna of sheltered and open coastlines. On open coasts, impacts of shore-parallel armoring are not well studied and only a few community level intertidal analyses have been completed to date for sandy beaches. Importantly, the upper intertidal zone in the vicinity of the driftline (located above MHW) harbors 40-50% of the total intertidal biodiversity in California (Dugan et al. 2003, 2014). Although more research is needed, the prediction of impacts of armoring to upper shore biota of beaches has been generally supported by the results of recent intertidal studies.

For open coast beaches in California, the abundance and biomass of mobile upper shore invertebrates respond significantly to armoring, this included talitrid amphipods, the dominant intertidal consumers of marine wrack, which were more than 10 times greater on unarmored beach segments compared to adjacent armored segments (Dugan et al. 2008, Table 16). Similar responses to armoring were observed for talitrid amphipods on open coast beaches in Chile (Jaramillo et al. 2012). The abundance of talitrid amphipods, and insects was also significantly higher on natural beaches than on armored beaches for protected shores in Puget Sound (Sobocinski et al. 2010). Toft et al. (2007) reported a similar decline in high-shore benthos, which he suggested may have been due to a reduction in food associated with the loss of shoreline vegetation. On beaches in Australia, the densities of burrows of the upper shore scavengers, ghost crabs, were substantially lower on beaches where a seawall replaced dune habitat (Lucrezi et al. 2009) and on urbanized beaches with seawalls than on unarmored reference beaches (Barros 2001), results which are consistent with a response to a loss of upper shore habitat.

On beaches on open coasts, the distribution and survival of mobile invertebrates of the lower shore (e.g. donacid bivalves, whelks, isopods and hippid crabs) may be also reduced by loss of habitat, changes in habitat quality, and by restrictions on tidal migration as well as the reduced availability of alternative sandy habitats (Klapow 1972; McLachlan et al. 1979; Jaramillo et al. 2002b, Dugan et al. 2013) imposed by seawalls. For example, the restriction of tidally-generated landward movement of a cirolanid isopod, *Excirolana chiltoni* imposed by a seawall, was illustrated by Klapow (1972) on the beach in front of the Scripps seawall. This time series shows how a population of these mobile mid intertidal animals "hits the wall" on spring tides increasing their effective density and potential for negative biotic interactions and physical stress. Changes in suspended sediment concentrations and altered littoral current velocities and sediment transport rates in front of seawalls (Miles et al. 2001) could also affect the distribution and condition of benthic animals. Further studies of responses of mid and lower beach biota to shoreline armoring are needed to evaluate if impacts observed for upper intertidal fauna also extend to the mid intertidal and swash zones of open coast beaches but results from recent surveys in Chile and California suggest that they do (Jaramillo et al. 2012, Dugan, Hubbard, Jaramillo, Duarte unpublished). The only BACI (Before After Control Impact) study of responses of intertidal invertebrates to a newly constructed seawall on an open coast beach (Jaramillo et al. 2002a) was a short term effort (< 2years) and did not detect significant effects of armoring on the overall macroinfaunal invertebrate community nor on populations of two abundant mobile crustaceans, a cirolanid isopod, *Excirolana hirsuticauda* and a anomuran decapod, *Emerita analoga*, that inhabit mid to lower intertidal zones. That result suggests that factors, such as the age and the position of the structure on the beach profile, are important in predicting both habitat loss and ecological impacts.

Fishes and nursery habitat

The effects of shore-parallel armoring on surf zone fishes and crustaceans of open coast beaches have not been evaluated to any extent. However shoreline armoring and changes to shading negatively impact the egg survival of beach-spawning surf smelt in Puget Sound (Rice, 2006), and coastal development coupled with erosion have resulted in loss of spawning habitat for California Grunion (Martin, 2015). California Grunion require upper intertidal beach zone habitats of sufficient width during spring high tide nights to successfully spawn and lay their eggs in suitable habitat for incubation and development. It is estimated that only about 0.7 square mile of critical spawning habitat for this endemic species exists in California (Martin 2015).

Barriers to movement of animals and wrack

Mobile scavengers, such as talitrid amphipods and isopods in California and ghost crabs on other coasts, occur in both the vegetated dunes landward of the backshore and the uppermost part of the intertidal and supratidal zone of the unvegetated shore or beach. The animals move between the dunes and the beach, mostly to feed on stranded material. Movement landward from the beach into the dunes is especially important for the intertidal part of the population during extreme weather events, when dunes serve as refuges (Christoffers 1986). Seawalls placed at the back of the shore form a barrier to animal movement, preventing access to dunes for intertidal species and, vice versa, access to the beach for dune inhabitants (Lucrezi et al. 2009). Both effects have negative consequences in terms of higher risk of drowning and displacement during storms, and decreased food availability. Impacts of seawalls on animal movement between the beach and the dunes may also be evident for other taxa, such as small rodents and other terrestrial mammals, accessing beaches to feed on the strandline (Bird 2004, Carlton & Hodder 2003). Armoring can pose a barrier to the chicks of nesting shorebirds (e.g. piping plover and snowy plover) as they attempt to move to the intertidal shoreline for foraging from backdune or marsh habitat (Burger 1994).

Wildlife support

The support of wildlife species, including birds, marine mammals, and on some coasts, sea turtles, is a very important ecological function of coastal ecosystems (e.g. Schlacher et al. 2007, 2013). Beaches provide valuable coastal habitat and prey resources for foraging, roosting and nesting avifauna, including shorebirds or waders, gulls, waterbirds, seabirds and a variety of land birds (Hubbard and Dugan 2003, DeLuca et al. 2008, Neuman et al 2008). Shorebirds require abundant prey resources in order to meet their high metabolic rates and relatively high daily energy requirements (Kersten & Piersma 1987). Loss of habitats used during migration, foraging, and over-wintering has been implicated in the declines of populations of many species of shorebirds and is a major concern for shorebird conservation (Howe et al. 1989, Brown et al. 2001), as are the effects of climate change (e.g. Kendall et al*.* 2004). As an example, declines in horseshoe crab eggs on beaches in heavily armored Delaware Bay have been associated with reduced abundance and body weights of migratory red knots (Niles et al. 2009). Shorebird diversity and abundance are strongly correlated with intertidal prey availability on California beaches, including threatened species such as the Western Snowy Plover (Dugan et al. 2003, 2014). Many species of birds have been observed to feed on the eggs of the California Grunion on California beaches, including shorebirds such as Long-Billed Curlews, Marbled Godwits and Whimbrels (Martin 2015). Changes in habitat area, tidal availability, and quality; and in intertidal prey availability resulting from armoring have the potential to cause significant negative impacts to coastal avifauna.

For open coast beaches, existing evidence, although limited, suggests that coastal avifauna can respond very strongly to armoring. The significant differences found in the diversity and abundance of shorebirds (2-fold and 3.7-fold lower, respectively), as well as the diversity and abundance of seabirds and gulls (3.3 fold and 7.7-fold (seabirds) and 2-fold and 4.8-fold (gulls) lower, respectively), between armored and unarmored segments of narrow exposed beaches in California (Dugan & Hubbard 2006, Dugan et al. 2008) suggests that ecological impacts to coastal avifauna can be substantial (Table 16). Of note, the significant effects of armoring on birds were observed during low tide surveys, when the greatest amount of intertidal habitat was exposed and available for foraging or roosting. During higher tides, all intertidal beach area for birds to use was be eliminated in front of the seawalls. This was in contrast to the adjacent beaches where upper beach habitats remained available to birds over a wider range of tidal conditions. The differences in shorebird abundance associated with coastal armoring (>3-fold) exceeded that predicted by the overall loss of beach habitat area from armoring (2-fold = upper beach to WTO) (Table 16), suggesting that other factors, including prey abundance, availability of high tide feeding habitat and refuges, as well as other landscape factors, may have contributed to the observed responses. Responses of gulls and other birds (both >4-fold, 4.8 and 7.7, respectively) to armoring also greatly exceeded that of the estimated 2-fold loss of habitat (Table 16) suggesting that armoring affects the quality of habitat needed for roosting or loafing by gulls and seabirds, in particular. The avoidance of seawall-backed beaches not only by foraging shorebirds but also by roosting birds, such as gulls, pelicans and other seabirds, indicates that impacts of armoring that extend beyond food web requirements need to be considered for coastal avifauna. Herons that prey on spawning runs of California Grunion were more common and more successful on beaches bordered by upland natural habitat than on beaches bordered by coastal development (Martin & Raim, 2014).

Beaches are critical nesting areas for a number of taxa that require sandy beach habitat that is above the reach of average high tides, typically above the level of the mean high tide, to successfully reproduce and incubate their eggs. Worldwide, these taxa include sea turtles (Wood & Bjorndal 2000) and a number of specialized species of fishes, including capelin *Mallotus villosus* (Nakashima & Taggart 2002), California grunion *Leuresthes tenuis* (Smyder & Martin 2002), surf smelt *Hypomesus pretiosus* (Rice 2006) and sand lance *Ammodytes hexapterus* (Reeves et al. 2003). The loss of upper beach zones resulting from armoring alters or eliminates nesting habitat for these animals (Mosier & Witherington 2002). The effects of armoring on the microclimate (temperature, shading, humidity, light intensity) of these nesting zones can also be important (Wood & Bjorndal 2000, Jackson et al. 2008). For example, mortality of surf smelt embryos was 50% higher on beaches armored with bulkheads in Puget Sound, Washington (Rice 2006). These impacts of armoring on nesting habitats are of particular concern (Jackson et al. 2008) because sea turtles are already threatened by a variety of other human activities, California grunion inhabit a restricted habitat range (Martin 2015), and surf smelt and Pacific sand lance are important prey for juvenile economically important species of salmon (Rice 2006). In California, additional pressures come from recreational and commercial fisheries for beach-nesting surf smelt and California grunion (Martin, 2015).

4.1.6 Coastal armoring as substrate

As armoring structures occupy and alter soft sediment habitats, they also introduce new intertidal or subtidal hard substrata in these predominately sedimentary environments. Superficially coastal armoring may appear to create new habitat for formerly absent marine organisms which rapidly settle and spread on the new hard substrata. However, there is growing evidence that human-made artificial structures do not function as natural rocky or biogenic habitats or support comparable biodiversity of marine fauna and flora to natural habitats (Chapman 2003, Russell 2000, Bacchiocchi & Airoldi 2003; Bulleri & Airoldi 2005; Airoldi et al. 2005a; Bulleri & Chapman 2010, Glasby et al. 2007). At the same time, armoring can create stepping stones or corridors for sessile biota (Glasby & Connell 1999, Dethier et al. 2003, Airoldi et al. 2005a), allowing the spread of species into areas where they would not occur naturally, including invasive taxa (Bulleri & Airoldi 2005).

4.2 The Economics of Beach Ecosystems

This section will discuss how economists approach valuing various ecosystems, including beach ecosystems. The section begins with a discussion of non-market valuation, and continues with a discussion of various techniques currently in use to value these systems.

4.2.1 Total Economic Value

Economists use a standard taxonomy to describe the valuation of environmental functions, goods and services (EFGS). This section provides a brief overview of how economists value EFGS.

Current decision making processes, including the Coastal Commission, approach to mitigating the adverse impacts of shoreline armoring, typically do not include the value of ecosystem services (MA 2005).

> Failure to quantify ecosystem values in commensurate terms with opportunity costs often results in an implicit value of zero being placed on ecosystem services. In most cases, ecosystem services have values larger than zero (Loomis, Paula et al. 2000).

Implementation of an ecosystem services approach could account for the full range of services provided by sandy beaches. These services include recreation and ecological services, such as nutrient cycling, as well as storm damage prevention benefits. Recreational benefits are mentioned in a separate section in this paper. Since seawalls typically are designed to reduce storm damage benefits, valuing these losses is generally not an issue. However, other ecosystem services are often left out or under-represented.

Economists often present a taxonomy for the total economic value (TEV) of ecosystem services. The TEV framework separates ecosystem services into direct and indirect use values and considers non-use values. The ecosystem services of sandy beaches described by Defeo, McLachlan et al. (2009) are all either direct or indirect use values. Direct use values involve uses that directly benefit human consumers, such as timber for a forest or beach visitation. Indirect use values occur when an ecosystem provides benefits which are more difficult to measure but still apparent, such as flood or storm control for a beach, or erosion control for a forest.

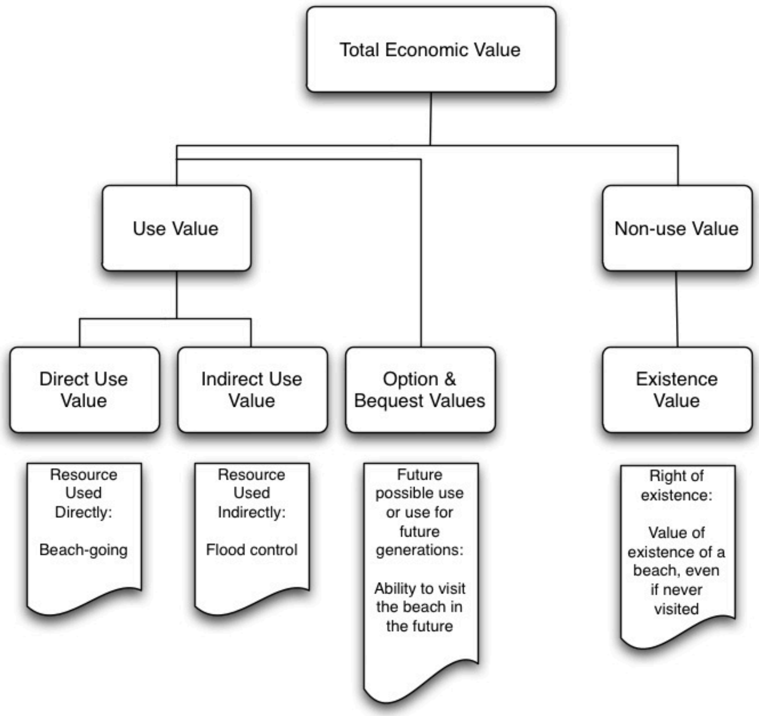


Figure 8: Schemata of Total Economic Value

Direct use values can be measured using revealed preference methods, most commonly the travel cost method, where people indicate their willingness to pay by how far they are willing to travel to a beach or other site and stated preference approaches, such as contingent valuation, where one asks the consumer directly about their valuation (described in detail in the previous section). Indirect uses are more challenging to measure and often require models that link direct use commodities with ecosystem services (NRC 2004). *Production function approaches* seek to determine how changes in ecosystem services affect an economic activity then measure the impact of the change on economic activity (NRC 2004). For example, linking loss of sandy beach prey resources to lower biodiversity of shore birds and then to lost consumer surplus to bird watchers.

The TEV framework also includes option/ bequest value and existence value. Option/ bequest represents the (option) value of leaving a beach or other ecosystem to future generations for benefits as yet unknown. Existence value takes into account the fact that many people are willing to pay for an ecosystem (e.g., Alaska's wilderness habitat) even if they never visit it, or never benefit from it, directly or indirectly. In practice it is very difficult to measure option/bequest value. Existence value can be estimated through stated preference models (see previous section) such as contingent valuation estimates.

Note that beach recreation and storm damage prevention do fall under the rubric of ecological goods and services. However, this section focuses on other EFGS.

Types of Ecosystem Services

This section provides a brief overview of the types of EFGS provided by beaches, wetlands and other similar habitats. The discussion here is not meant to be exhaustive, but rather to provide a general overview of the topic.

Efforts to define and value ecosystem services go back several decades (Liu, Costanza et al. 2010). Ecosystem services are the benefits people obtain from ecosystems. The full definition of ecosystem services provided by the United Nations Millennium Ecosystem Assessment (MA) is:

> Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits (MA 2005).

The ecosystem services model is anthropocentric by definition, but the MA makes clear that sound ecosystem management must include the intrinsic values of ecosystems. Intrinsic values cannot be given a monetary value and instead require a values-based decision making structure (MA 2005).

Although there is a large body of literature on the theoretical underpinnings of the economics of ecological functions, goods, and services (hereafter referred to as EFGS), the field is still in its infancy. Ecological goods (e.g., timber from a forest) and services (water filtration) generate a wide variety of benefits to society both direct (e.g., recreation, mining) and indirect (e.g., biodiversity). As depicted in Table 17 below, valuing EFGS properly requires a sound understanding of ecosystem functions as well as the production of the ecosystem goods and services derived from these functions.

Table 17: Functions, goods and services of natural and semi-natural ecosystems

1	**Gas regulation**	Regulation of atmospheric chemical composition.	CO_2/O_2 balance, O_3 for UVB protection, and SO_x levels.
2	**Climate regulation**	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels.	Green-house gas regulation, DMS production affecting cloud formation.
3	**Disturbance regulation**	Capacitance, damping, and integrity of ecosystem response to environmental fluctuations.	Storm protection, flood control, drought recovery, and other aspects of habitat response to environmental variability mainly controlled by vegetation structure.
4	**Water regulation**	Regulation of hydrological flows.	Provisioning of water for agricultural (e.g., irrigation) or industrial (e.g., milling) processes or transportation.
5	**Water supply**	Storage and retention of water.	Provisioning of water by watersheds, reservoirs, and aquifers.
6	**Erosion control and sediment retention**	Retention of soil within an ecosystem.	Prevention of loss of soil by wind, runoff, or other removal processes, storage of stilt in lakes and wetlands.
7	**Soil formation**	Soil formation processes.	Weathering of rock and the accumulation of organic material.
8	**Nutrient cycling**	Storage, internal cycling, processing, and acquisition of nutrients.	Nitrogen fixation, N, P, and other elemental or nutrient cycles.
9	**Waste treatment**	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.	Waste treatment, pollution control, detoxification.
10	**Pollination**	Movement of floral gametes.	Provisioning of pollinators, for the reproduction of plant population.
11	**Biological control**	Trophic-dynamic regulations of populations.	Keystone predator control of prey species, reduction of herbivory by top predators.
12	**Refugia**	Habitat for resident and transient populations.	Nurseries, habitat for migratory species, or over wintering grounds.
13	**Food production**	That portion of gross primary production extractable as food.	Production of fish, game, crops, nuts, fruits, by hunting, gathering, subsistence farming, or fishing.
14	**Raw materials**	That portion of gross primary production extractable as raw materials.	The production of lumber, fuel, or fodder.
15	**Genetic resources**	Sources of unique biological materials and products.	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticulture varieties of plants).
16	**Recreation**	Providing opportunities for recreational activities.	Eco-tourism, sport fishing, and other outdoor recreational activities.
17	**Cultural**	Providing opportunities for non-commercial uses.	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems.

*We include ecosystem "goods" along with ecosystem services.

Table 17, from Costanza (1987), provides an overview of these ecological functions, goods and services that could be provided by an ecosystem, such as a beach. In addition, beaches (like wetlands) provide water filtration services/functions—effectively the sand acts as a filter for particles and detritus. In the case of beaches, almost all of the attention has been directed at #16 above (recreation) as well as some analysis of # 3 (disturbance regulation) in the form of USACE storm damage prevention analyses of some beach projects as well as some work on the economics of sea level rise (e.g., King 2011). Contingent Valuation studies may also capture some of #17 (cultural value of beaches). Given the importance of California's beaches to many residents and the historical significance of some beaches, especially in southern California, this factor could also be quite significant.

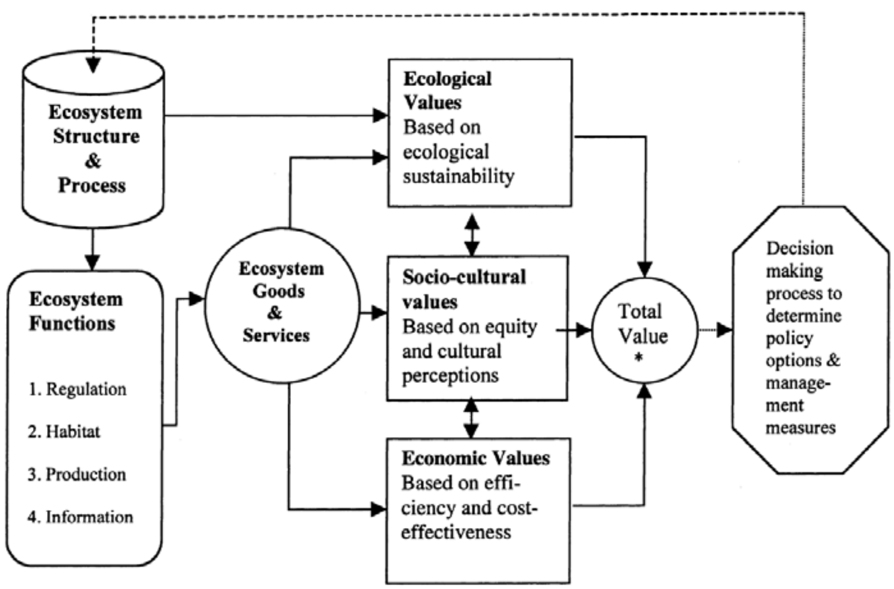


Figure 9: How Ecosystem Services can be incorporated into the Decision Process

Ecosystem Services of a Beach Ecosystem

Coastal ecosystems are amongst the most productive and heavily used ecosystems in the world and provide many services to human society (UNEP 2006). Sandy beaches are one of the largest marine biomes on the planet (Etnoyer, Wood et al. 2010). Sandy beaches are one of the most heavily used but poorly understood coastal ecosystems and our understanding of their ecological functions is limited (Defeo, McLachlan et al. 2009). Defeo, McLachlan et al. (2009) decribe the ecosystem services provided by beaches (Table 18).

Table 18: Sandy Beach Ecosystems services by use value type.

Sandy Beach Ecosystem Services	**Direct Use Value**	**Indirect Use Value**
Sediment storage and transport;		X
Wave dissipation and associated buffering against extreme events (storms, tsunamis);		X
Dynamic response to sea-level rise (within limits);		X
Breakdown of organic materials and pollutants;		X
Water filtration and purification;		X
Nutrient mineralization and recycling;		X
Water storage in dune aquifers and seawater discharge through beaches—beaches with dunes only		X
Maintenance of biodiversity and genetic resources;	X	
Nursery areas for juvenile fishes;	X	
Nesting sites for turtles and shorebirds, and rookeries for pinnipeds;	X	
Prey resources for birds, fishes, and terrestrial wildlife;	X	
Scenic vistas and recreational opportunities;	X	
Bait and food organisms;	X	
Functional links between terrestrial and marine environments in the coastal zone.	X	

4.2.2 Summary

Although best known for recreation (considered a direct use value), beaches provide a wide variety of ecosystem functions, goods, and services (EFGS), which ecologists are only beginning to understand.

4.3 Mitigation for beach ecosystem impacts

At present the Coastal Commission's mitigation approach for coastal armoring emphasizes the value of recreation and the value of sand loss. However, other ecological services and functions are under-represented in this approach. This section will discuss various options to mitigate for ecological services (other than recreation).

4.3.1 Assigning a Dollar Value to Ecological Services

This section examines the issue of assigning a dollar value to EFGS for mitigation purposes. Unfortunately, our knowledge of both the ecology and the economics is still relatively new.

It is now common to assign a dollar value to recreational value (see discussion in previous section) to beaches. However assigning a dollar value to ecological functions, goods, and services is fraught with difficulties. First, it requires quantification and a comprehensive analysis of existing ecological functions. In practice, this requirement is rarely, if ever satisfied. Indeed, it is likely that we still do not fully comprehend the importance or scope of many ecological functions. Even where such knowledge exists, such a study requires a large budget with a team of experts from many disciplines (e.g., see Bockstael, 1995).

Translating ecological functions and goods into a specific, quantifiable inventory of goods and services is also difficult. Perhaps the most difficult and controversial requirement is that one must put a dollar value on the ecological goods and services. While some goods (e.g., timber from a forest) have a market value and some non-market values (e.g., recreation) can be estimated using established techniques, assigning a dollar value to other ecological services is very difficult.

Costanza (1987) estimated the value of the world's ecological services at $16 to $54 trillion a year. Later, the same author (Costanza 2006) used an analysis of 94 peer-reviewed papers and 6 other studies to estimate the economic values of seven types of biomes (including beaches) and the cumulative ecosystem services in New Jersey. He estimated that New Jersey's beaches deliver $42,147 per acre per year in economic/ecological services. He further breaks these benefits down into recreational and aesthetic value ($14,847 per acre per year) and other services ($27,300 per acre per year). However, it should be emphasized that Costanza's estimates only consider two types of EFGS: beach recreation, and storm-damage prevention. As discussed above, there are myriad other types of EFGS not included in Costanza's analysis. Any serious attempt at mitigation/valuation would need to incorporate many other types of EFGS.

While these types of studies are useful in pointing out that beaches and other public areas and preserves do have substantial economic value which should not be overlooked, they do not necessarily provide managers with a framework for preserving key habitat or ecological functions. Further, it is dangerous to apply a "one size fits all" approach to beaches or other habitat since the ecological functions, goods and services vary enormously even at beaches near each other.

<u>Natural Capital</u>

An alternative approach to assigning a dollar value to ecological functions, goods and services is to focus on ecological sustainability. Daly (2005), Costanza (1992) and others have developed the concept of "natural capital" to recognize the important role that EFGS play in economic functions. Their main argument is that economists often fail to account for environmental degradation when measuring economic growth and development. Their sustainability criteria incorporate the concept of natural capital and also incorporate manufactured capital (e.g., factories and other human-made material used to produce goods and services) and human capital (educated labor). Thus the total capital stock, K can be subdivided into the three components:

$$K = K_M + K_H + K_N \quad (1)$$

Where:

K is the total stock of Capital

K_M is human made capital (e.g., schools, factories)

K_N is natural capital (e.g., beaches, forests)

K_H is human capital (e.g., health, education for humans)

Turner (1993) defines two different concepts of sustainability. In "weak sustainability" losses in natural capital can be substituted for by increases in some types of human or physical capital. For example, building more swimming pools might compensate for loss of beach recreation. In contrast, Turner states that one could also adopt a "strong sustainability" approach, which posits that natural capital must be preserved—thus no substitution is possible.

Ekins (2003) and others distinguish between **critical natural capital** (CNC) which must be preserved and other types of natural capital, which can be substituted for with manufactured or human capital. Ekins goes on to develop some general criteria for defining CNC which include:

- Life Support: EFGS that is critical to maintaining human society (e.g., ozone, reduction of greenhouse gases).
- Human Health: EFGS necessary to maintain human health (e.g., clean air and water)
- Other welfare: EFGS with unique aesthetic and cultural importance (e.g., Grand Canyon).

As one can see, the above criteria, while useful, still leaves a great deal of ambiguity in terms of practical application. In policy settings, defining critical EFGS and thus CNC will likely involve many stakeholders as well as policy analysis.

Given the important EFGS that beaches in California play as well as the fact that these beaches are difficult, if not impossible, to replace, the State may consider designating some or all of the coastline as Critical Natural Capital, which would imply, at a minimum, that any detriment to EFGS caused by human intervention (e.g., sand mining, seawalls, climate change) should be offset by mitigation/restoration elsewhere, and this mitigation/restoration should be on the coast. Further, this mitigation/restoration should relate to coastal beaches and seek to provide the same level of EFGS as that lost by human intervention.

Wetlands Ecosystem Valuation

Much of the academic as well as policy oriented approaches to ecosystem valuation have been applied to wetlands. Consequently, this section will begin with a brief overview of this literature followed by a discussion of the relevant lessons learned from wetlands ecosystem valuation. As discussed below, wetland ecosystems provide many of the same benefits and services as beaches and other soft sediment coastal habitats and in turn open coast sandy beach ecosystems fit most of the federal definitions of wetlands and completely fit the California definition. The U.S. Fish and Wildlife Service defines wetlands as:

> "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification, wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports hydrophytes, (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year." (Cowardin, 1979)

Richardson (1994)[7] provides an overview of the literature on valuing wetlands.

The article lays out several "principles" involved in wetlands valuation/restoration:

- Principle One: All wetlands are not equal—the ecological services provided vary greatly.
- Principle Two: A restored or new wetland may not have the same value as the wetland it is replacing.

[7] Ecological Functions and Human Values in Wetlands: A Framework for Assessing Forestry Impacts, Curtis Richardson, Wetlands V. 14 March 1994

- Principle Three: The wetland ecosystem functions are coupled to other systems on the landscape—wetlands do not function on their own.
- Principle Four: Wetlands provide ecosystem functions and values far from adjacent ecosystems.

It is likely that all four principles are relevant for beach ecosystem valuation. Richardson (1994) goes on to state that replacement costs are often very high—higher than avoiding replacement in many cases.

4.3.2 Offsets

Offsets are a common approach to mitigating for the loss of ecosystem services provided by wetlands and other ecosystems which have been lost or damaged by human intervention. Briefly, offsets create or restore a similar type of ecosystem to compensate for the loss of habitat. For example, if an area of wetlands is developed, often the proposed mitigation involves creating a new wetland or restoring/improving another existing wetland. Offsets are generally consistent with the natural capital approach because offsets are designed to maintain and preserve ecosystem function as much as possible. Often, these offsets include ratios to determine a ratio of equivalency (in terms of EFGS). For example, if one were devising an offset for a highly functioning 10-acre wetland, the offset would likely require a much larger newly created wetland. Indeed, its common to use a 3:1 or 4:1 ratio for wetlands restoration, at least in part because a newly formed wetland often has lower EFGS than a well established one. Figure 10 provides a schematic depicting the process involved in determining offsets. This section provides a brief overview of offsets followed by a discussion of specific types of offset methods currently in use for other environmental mitigation.

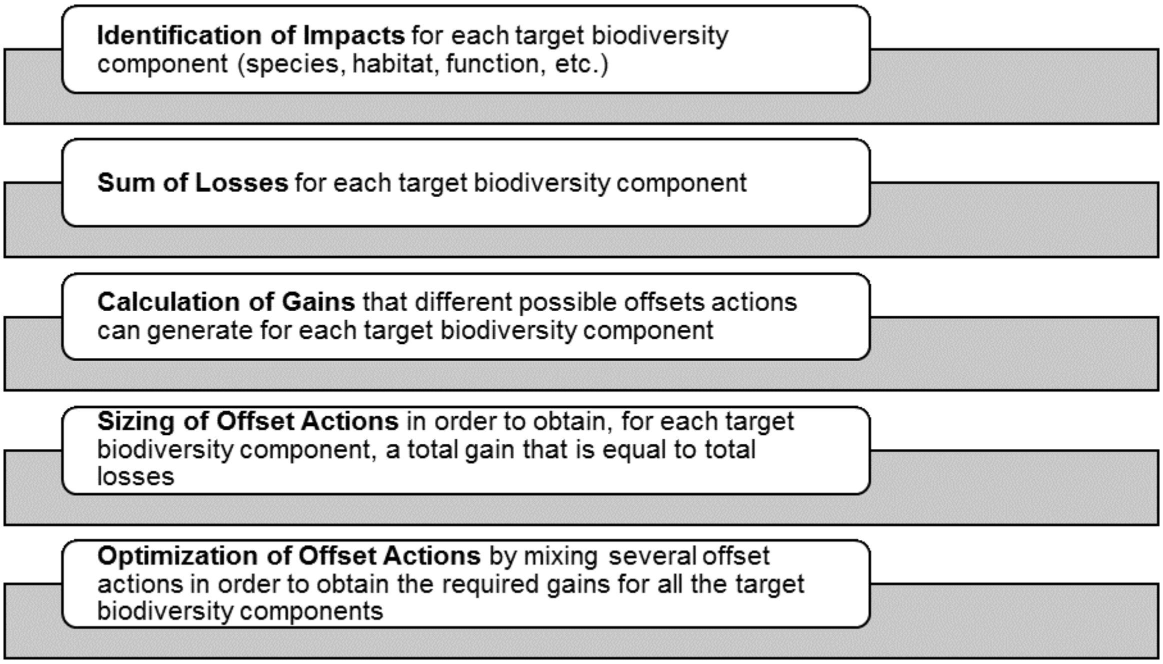


Figure 10: Methodology for Creating Offsets Quetier and Lavorel (2011)

Quetier and Lavorel (2011) provide a comprehensive overview of the use of offsets when mitigating for projects that impair ecosystem function. The main conclusion is that "offsets can offer only poor or incomplete replacement for the loss of biodiversity which is very location-specific or which was generated by long-term ecological dynamics…" They elaborate:

> "some components of biodiversity or ecosystems cannot reasonably be re-created, restored or rehabilitated. Such is the case for old-growth forests, peatlands, slow breeding or very demanding species. In these cases no residual losses should be accepted. (Quetier and Lavorel (2011) "

They also discuss specific mechanisms used to evaluate an ecosystem and ecosystem service losses. For example, species richness or some other measure of biodiversity is often used for offsets but this often does not capture the complexities of biodiversity. Similarly, using the area of a wetland or other ecosystem is an extremely crude approach; the quality of the ecosystem must also be accounted for. Other methods use a standardized scoring system, which applies points to various attributes such as biodiversity.

Table 19 below (from Quetier and Lavorel, 2011) examines a number of specific offset systems used by government agencies from many different countries and jurisdictions. Although all of these techniques vary, there are some general trends that can be identified. First, most of these mechanisms require that an ecosystem be replaced by a (roughly) similar ecosystem, e.g., wetlands should be replaced by other wetlands. Some of these mechanisms are highly defined, in terms of predefined criteria, specific benchmarks, and allowances for time.

Table 19: Offset Mechanism for Ecosystems currently in Place[8]

	A – Target components of biodiversity		B – Indicators				C – Temporal dynamics		D – Uncertainties
	Measure of losses and gains	Out-of-kind offsets possible?	Predefined	One or several	Benchmarks	Landscape component	Baseline	Delays	
Wetland mitigation methods (USA)	Wetlands (area x score)	N	Y	Several	Y	Y	Current	N	N
UMAM (USA)	Wetlands (area x score)	N	Y	Several	Y	Y	Current	Y	Y
HEA/REA (USA)	DSAYs	Y	N	Single	Y	N	Projected	Y	N
Conservation/bio-banking (USA and Australia)	Protected species (credits)	N	N	Single	Y/N	Y/N	Current	N	N
Habitat Hectares (Australia)	Native vegetation (area x score)	N	Y	Several	Y	Y	Current	N	N
Ausgleich (Germany)	Protected species and habitats (area x habitat type)	N	N	Several	N	Y/N	Current	Y	Y
Biotopwertverfahren (Germany)	Undeveloped land (area x score)	Y	Y	Single	Y	N	Current	N	N
Natura 2000 (EU)	Integrity of the Natura 2000 network	N	N	Several	N	Y	Current	N	N
Offset ratios (France)	Protected species and habitats (area x Habitat type)	N	Y	Single	N	N	Current	N	N

Table 20 below summarizes the strengths and weaknesses of various offset approaches in current use (Quetier and Lavorel, 2011). The “Circumstantial Reasoning” approach essentially relies on a case-by-case basis. This allows policy-makers maximum discretion when estimating ecological value.

[8] DSAY is discounted services per acre per year.

Table 20: Analysis of Different Offset Methods

Approach	Opportunities	Constraints	Possible uses
Circumstantial reasoning	– Specificity to the local ecological context (problem-solving approach)	– Harder to process for environmental authorities	– Impacts on nature conservation priorities such as rare or endangered species, priority habitat types, etc
– Freedom to develop or use appropriate indicators and scoring methods	– Heterogeneous data sources can be used	– Less transparent and harder to communicate to stakeholders	– Particular natural or use contexts where standardized methods are not applicable
– The complete reasoning must be presented and justified (e.g. references and benchmarks, model parameters, field data)	– Local expertise can compensate for a lack of quantitative or measurable data	– Requires methodological developments with corresponding time and budget, as well as additional data	– Early stages in the development of standardized methods
	– Makes innovative actions easier	– Not easily comparable between projects	– Examples include German Ausgleich and Natura 2000 procedures in Europe or Habitat banking in the USA
		– Not transferable between projects (hence no accumulation of know-how) and thus less predictability of offset requirements for developers	
Standardized scoring method	– Ease of use and transparency	– Requires consensual references and guidelines that are common across projects (for a given target component of biodiversity)	– Habitat types, species' habitats and ecosystem properties or functions for which suffer from recurring impacts (e.g. wetlands) and for which a scoring system has been agreed upon by environmental authorities
– Indicators and scoring methods are predefined, for impacts on a given target species, habitat type, ecosystem function, etc.	– Comparability between projects, which makes cumulative effects easier to assess	– Limited choice of indicators (off-the-shelf) that may or may not be appropriate to the local ecological context of a project impact	– When applied to broadly defined target component of biodiversity (e.g. ''grasslands''), the approach can be considered as allowing like-for-similar offsetting (see third approach below)
– Validity and reproducibility of indicators and scoring methods must be tested	– Lower legal risks	– Options for modulating offset size according to local context must be anticipated and justified	– Example include several wetland mitigation scoring methods in the USA or the habitat-hectares approach developed in Australia
– It remains essential that offset size can be modulated according to local context (uncertainties, cumulative impacts etc.)	– Depending on the selection of indicators and scoring methods, offset requirements can be easier to predict in early project phases		
Standardized scoring method and like-for-similar correspondence	– Same advantages as the standardized point-based systems above, with also:	– Requires an accepted correspondence scale between target species, habitat types, ecosystem functions, etc. and hence an established hierarchy of nature conservation priorities that does not vary between projects	– Species, habitat types or ecosystem functions that have low priority status but for which offsets are nevertheless required
– Indicators and scoring methods are predefined, for impacts on a given target species, habitat type, ecosystem function, etc.	– Allows like-for-similar offsetting and trading-up, which gives authorities and developers more flexibility in designing offsets	– The local ecological context might only be taken into account superficially	– Species or habitat types for which trading-up is an appropriate source of conservation action (in addition to other means already targeting these Species or habitat types)
– Scores for different targets are made comparable using a common correspondence scale			– Examples include the German Biotopwertverfahren
– It remains essential that offset size can be modulated according to local context (uncertainties, cumulative impacts etc.)			

However this approach generally requires an enormous amount of work and can lead to inconsistent or seemingly inconsistent decisions by public agencies. At the opposite end of the spectrum, the standardized scoring approach provides a relatively simple, straightforward approach to creating offsets. The danger here is that the standard techniques may not fully account for all of the ecosystem services, particularly in the case of unique, irreplaceable systems. The standardized scoring method and like-for similar correspondence technique represents a hybrid between the first two methods, by providing a standardized system, but allowing for adjustments which also requires additional work. The final technique, “Ratios of Acceptable loss or minimum level of conservation,” delineates what ecological losses are acceptable. This technique implicitly allows for some ecosystem destruction to proceed without offsets.

Barbier et. al. (2011) examine a variety of estuarine and coastal ecosystem services (ECEs) including beaches. They point out that our current knowledge of ecosystem services is quite limited. They also point out that many studies value small changes in specific components of ecosystems but one cannot extrapolate from that to a larger scale.

NRDA/HEA Offset Approach

One of the most commonly used offset approaches in the United State is the federal Natural Resource Damage Assessment (NRDA). This process, commonly used for assessing damages and restoring natural resources and services impacted by oil and chemical spills, has a rich peer-reviewed body of literature (Roach and Wade 2006). While the NRDA process is reactive (responding to the injury of natural resources) and the Coastal Commission’s mitigation process is proactive (requiring mitigation for future impacts), the concepts in the NRDA process can provide a model for implementing an ecosystem services approach to mitigating adverse impacts to beaches from shoreline armoring. Unfortunately, the NRDA approach (including Habitat Equivalency Analysis discussed below) requires a comprehensive understanding of EFGS that is simply not available for beaches given the paucity of research on beach ecology. Consequently applying NRDA would almost certainly misestimate and likely underestimate EFGS for beaches. The NRDA approach, even if feasible, would also require significant effort and data collection under the supervision of experts, which may make sense for large ecological disasters like oil spills, but will likely be less feasible for coastal armoring projects, most of which are much smaller.

Habitat Equivalency Analysis

In recent NRDA cases, NOAA has recommended that compensation should be based on restoration projects using Habitat Equivalency Analysis (HEA). HEA is a method for quantifying ecological service losses and calculating the scale of compensatory restoration required to offset those losses (Dunford, Ginn et al. 2004). Compensation is based on the cost to replace the natural resource services that the public has lost (Hampton and Zafonte, 2005). Scaling is used to account for restoration that does not meet the baseline functionality of the lost resource and to discount for the time between the loss and full restoration, known as interim losses (Figure 11).

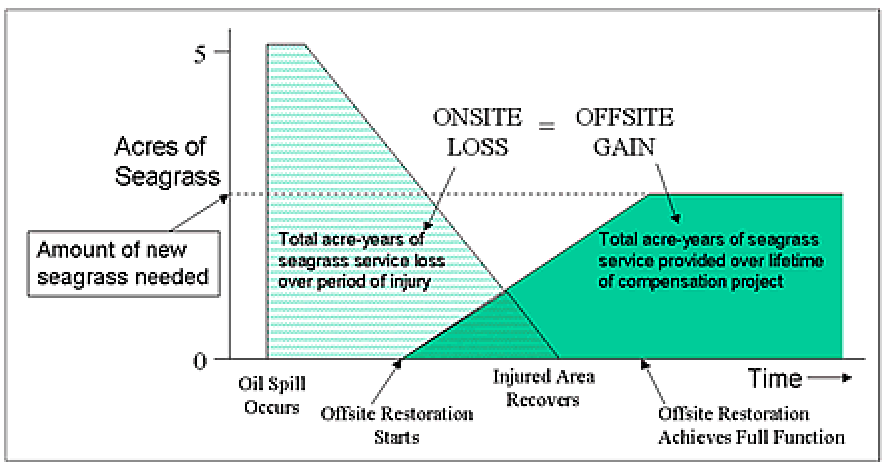


Figure 11: Example of HEA approach to scale offsite mitigation (CSC 2001)

The four basic requirements needed for an HEA are: 1) the primary services lost are biological, as opposed to human use services, 2) there exists a means of quantifying the level of lost services due to the injury and the level of services gained by the compensatory mitigation, 3) an estimate of the recovery rates is available, and 4) a suitable restoration site exists. Further, HEA requires that a single measure of ecological services be used for each type of habitat assessed in the model (NOAA 2000). This metric is the single most important parameter in the HEA model because it is the basis for all assessment of injury and restoration (Dunford, Ginn et al. 2004). The input parameters required for the HEA model are listed in Table 21.

Table 21: Input parameters required in a HEA model (NOAA 2000)

Input parameters	**Units**
Size of injury	Area
Year of injury	Year
Level of services in injury year	Percentage *(relative to baseline services)*
Year recovery starts	Year
Services at maximum recovery	Percentage *(relative to baseline services)*
Year recovery starts	Year
Year net service gains start	Year
Shape of recovery function	Function *(usually assumed to be linear)*

Use of HEA requires a number of assumptions. These include a preference for compensation with the same services, use of a single service metric, a fixed proportion of habitat services to habitat value, a constant real value of injured services and an equal unit value for the injured and compensatory habitat values (Dunford, Ginn et al. 2004).

NOAA's (2000) guidance document provides an overview and examples of HEA application. Dunford, Ginn et al. (2004) discuss the conceptual foundation, key assumptions and sensitivity analysis using a hypothetical example. Milon and Dodge (2001) show the application of HEA to coral reef damage assessment and restoration. Roach and Wade (2006) provide an example of HEA applied proactively for policy analysis.

Standard Assessment Methodology

The Standardized Assessment Methodology (SAM) is a computational modeling and tracking tool developed by Stillwater Sciences that evaluates river bank protection alternatives by taking into account several key factors affecting Threatened and Endangered fish species, originally developed for the Sacramento River. By identifying and then quantifying the response of focal species to changing habitat conditions over time, users can effectively determine the necessary measures to avoid, minimize, or fully compensate for impacts to habitat suitability for various life stages.

The SAM systematically evaluates the response of each life stage to habitat features affected by bank protection projects and compares responses to different project scenarios. Biological simulation relies upon conceptual models that relate measured habitat conditions into life stage specific differences in predation risk, food availability, and growth. The model can then be used to assess species responses as a result of changes to habitat conditions, either by direct quantification of bank stabilization design parameters (e.g., bank slope, substrate) or by separate modelling of long-term habitat evolution due to channel migration at unconstrained sites and/or growth of riparian and aquatic plants.

The SAM was initially developed for application along the Corps of Engineers' Sacramento River Bank Protection Project and has since been applied to several other sites along the Sacramento River, and has been used by Agency staff and other consultants as part of ongoing efforts to strengthen the Central Valley levee system. The SAM is a robust model that can be used to inform the design of any number of bank protection alternatives such as set back levees, installed wood, vertical extent of bank armour, rock sizes, rock clusters, fish groins, launchable riprap, as well as various biotechnical treatments such as soil and plant coverings and planted benches. Source: http://www.stillwatersci.com/tools.php?tid=2

Based on the description above, application of SAM for beaches would be better suited to designing alternatives to minimize impacts to beach ecosystems from shoreline armouring as opposed to using the methodology for valuation of lost services.

The Natural Capital InVest Model

InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) is a suite of ecosystem service models developed by the Natural Capital Project to provide spatial and economic information on ecosystem services on a landscape scale. InVEST is designed to help local, regional and national decision-makers incorporate ecosystem services into a range of policy and planning contexts for terrestrial, freshwater and marine ecosystems, including spatial planning, strategic environmental assessments and environmental impact assessments.

InVEST models are based on production functions that define how an ecosystem's structure and function affect the flows and values of ecosystem services. The models account for both service supply (e.g. living habitats as buffers for storm waves) and the location and activities of people who benefit from services (e.g. location of people and infrastructure potentially affected by coastal storms). Since data are often scarce, the first version of InVEST offers relatively simple models with few input requirements. These models are best suited for identifying patterns in the provision and value of ecosystem services. With validation, these models can also provide useful estimates of the magnitude and value of services provided at varying spatial scales dependent on the quality of the ecological data.

The Natural Capital Project is also developing more complex, data intensive models for informing policies that require more certainty and specificity in results. In terrestrial and freshwater ecosystems, InVEST models habitat quality (terrestrial only) and the benefits of: carbon sequestration; annual water yield for hydropower, water purification (for nutrients); erosion control (for reservoir maintenance), crop pollination; timber production, and non-timber forest product harvest. In coastal and marine systems, InVEST models the benefits of food from fisheries, food from aquaculture, coastal protection, wave energy conversion, the provisioning of aesthetic views and recreation. InVEST is spatially explicit, allowing the production of maps indicating where ecosystem services are provided and where they are consumed. It can provide biophysical results (e.g. meters of shoreline retained) and economic values (e.g. avoided cost of damage to property). A relative index of habitat quality is also provided, but biodiversity is not given an economic value directly.

The InVest and other similar models require detailed knowledge of the ecosystem functions and services provided by a beach as well as a sound understanding of how a seawall would alter these services and functions. In practice, this information is not currently available for most, if any, beaches. At present the InVest approach is not suited to provide valuation for a specific project but could be used to identify cumulative impacts of shoreline armoring or to identify restoration opportunities within a littoral cell.

Source:
http://www.naturalcapitalproject.org/pubs/NatCap_InVEST_and_Case_Study_Summary_TEEB_2010.pdf

<u>Hedonic Analysis</u>

Hedonic methods (also discussed under methods for estimating recreational value) use market prices, most often derived from the real estate sales, to estimate the value of nearby environmental attributes (Haab & McConnell, 2002). The method is based on the recognition that real estate values are influenced by at least three types of characteristics: the physical attributes of the property, the attributes of the surrounding neighborhood, and environmental amenities near and at the property (e.g. view of the ocean or proximity to the beach). The method assumes that the total price of the property is a function of these characteristics. Through statistical analysis, it is possible to estimate the separate contribution of these characteristics to the total sales price of the property and estimate the implicit price of each characteristic. For example, if two houses have the same physical attributes and are located in the same area, but one house has easy access to the beach while the other does not, then the difference in price is an indication of the value placed on beach access.

The most typical application of a hedonic model involves estimating housing prices. For example, people will be willing to pay more to live in a neighborhood near a sandy beach. By comparing other attributes (e.g., sq. ft. of the house, school quality, etc.) HM allows one to estimate the incremental value of some environmental amenities.

Although hedonic models are likely to capture *some* of the benefits of ecological services, they are likely to underestimate these benefits since many ecological services benefit people who do not live in the immediate vicinity. Moreover, hedonic analyses assume that people know the value of these ecological services and then price them into private real estate values. Since many ecosystem services of beaches are poorly understood, even by experts in the field, it is unlikely that all of these services will be properly priced.

There are few sound applications of hedonic analysis to beaches or other coastal properties and none that we know of in California. The few applications that do exist are based on the East Coast. Lent (2007) found that a 1% increase in beach width resulted in a 0.01% increase in housing prices but her results were not statistically significant and hence are not suitable in any legal or regulatory analysis. Landry & Hindsley (2011) also employed a hedonic model to property in North Carolina and found that beach width, quality and dunes positively influence housing prices. It should be noted, that their analysis included the storm damage reduction effects of beaches since hurricanes are quite frequent in North Carolina. Landry & Hindsley's analysis did not specifically value the ecology of the beach.

The feasibility of the hedonic price method depends on the quality and availability of data regarding both the real estate prices as well as the attributes used. The way in which the attribute to be valued (such as beach quality) is measured is extremely important to the accuracy of the results.

4.3.3 Use of HEA or other Offset Mechanism for Beach Ecosystem Services:

The use of HEA or another offset-based approach by the Coastal Commission for compensatory mitigation to adverse impacts to beaches from shoreline armoring would shift their approach from a strictly demand-based model aimed at compensating lost beach recreation to include a supply-based model that is focused on restoration of ecological services of beaches. For beach recreation, the assumption is often that the direct restoration approach would be beach fill (i.e., sand placement projects or beach nourishment) even though beach filling, as typically practiced, significantly degrades ecosystem condition and functioning. This approach could require that sand replenishment projects are focused on returning ecological services of beaches to an established baseline as opposed to the current focus on sediment quality and beach width. However, beach filling has significant deleterious impacts on many EFGS which must also be accounted for.

At present, use of HEA for compensatory mitigation of lost beach services is limited by a lack of understanding of the ecological services of beaches. Table 22 shows that sandy beach ecosystem services do not meet the four basic requirements to conduct HEA: (1) that the primary services are not necessarily biological, (2) that one can quantify in some way the lost EFGS, (3) one can estimate the recovery rate (e.g., post sand replenishment), (4) a suitable restoration site exists.

The primary service considered by the Coastal Commission is recreation, a human use not a biological use. The inherent high variability of many beach ecosystem features and current lack of basic science on the ecological services of beaches precludes selecting or quantifying a single measure of ecological services lost provided or recovery rates from impacts with any confidence. Impacts include loss of habitat from the gradual narrowing of beaches in front of armoring or direct mortality from burial by the dredging and dumping of sand on the eroded beach (Peterson and Bishop 2005; Dugan, Hubbard et al. 2008). Suitable sites for restoration of beach ecosystem services could include the beach that is being adversely affected, or nearby beaches, ideally in the same littoral cell.

Table 22: Assessment of HEA requirements for sandy beach ecosystem services

Requirement	Beach ecosystem services
Primary services are biological	Not at present
Quantification of services lost	No
Estimate of recovery rate is available	No
Suitable site exists	Yes

The HEA approach is further challenged because shoreline protective devices are issued on different temporal and spatial scales than coastal erosion and beach nourishment projects. Shoreline armoring permits are issued at the spatial scale of a single development and are often granted episodically, based on threats from erosion. Renewal may address long term losses. Coastal erosion and beach filling projects are also episodic in occurrence. Beach erosion occurs episodically and is often associated with semi-decadal or longer climatic phases, such as ENSO (Griggs 1998) or the Pacific Decadal Oscillation (PDO) (Griggs et al., 2005). Beach filling projects are are generally based on episodic federal, state and local funding cycles and permit requirements. HEA does provide a mechanism to address these spatial and temporal mismatches but would be challenged by having numerous small compensatory mitigation actions cumulatively support one larger restoration effort. There are also governance challenges. The Coastal Commission is the agency responsible for permitting and seeking mitigation for adverse impacts of shoreline armoring but other states and federal agencies are responsible for beach fill projects. Coordination between these agencies would be required for the HEA model to function effectively.

4.3.4 The Offset Approach and Recreational Value

One potential issue with an approach that values recreational services and other ecological services is the problem of double counting. Fu et. al. (2010) address this issue specifically and make a number of suggestions to minimize the issue of double counting. In particular, they call for establishing consistent classification systems for EFGS. In our opinion, this paper has established a consistent classification system for recreation and for other distinct EFGS and our discussion above indicates that these are indeed separate types of services. Beach-goers looking to recreate typically look for access, wide sandy beaches (which may have been groomed to eliminate wrack), restrooms, lifeguards services, snack-bars, etc. These amenities are generally not correlated with other EFGS and indeed many of these amenities (e.g., lifeguards who often patrol the beach on trucks or ATVs, snack bars, grooming, etc.) actually reduce other EFGS besides recreation. Hence, we believe that there is no reason to believe that double counting is an issue in this case. Consequently, it is reasonable to charge separate fees for the loss of recreation and the loss of other EFGS.

4.3.5 Summary

Economists have developed a number of techniques to value EFGS. There are two main methods: assigning a dollar value directly to each EFGS, and estimating the relative value of an ecosystem in order to facilitate restoration—the offset approach. In practice, assigning a dollar value to EFGS is difficult, since we do not yet have a good understanding of many functions, goods and services of beach ecosystems and assigning a dollar value is also fraught with difficulties. The offset approach is widely used in mitigation throughout the world including in the United States. The offset approach can also be used to emphasize that the natural capital stock of beach EFGS should be preserved and not destroyed, through restoration.

Table 23 below summarizes the techniques discussed above and divides these methods into three distinct approaches. The InVest model is essentially an EFGS production function model, requiring very detailed information about each distinct ecosystem. SAM and HEA are examples of the offset approach (though other examples also exist, not discussed in this paper). These methods have lower data requirements and are much more widely used in practice. Finally, hedonic analysis does not fit into either category, and only values environmental amenities which influence the prices of houses nearby. In practice, hedonic analysis is quite limiting and not recommended.

Table 23: Overview of Methods for Valuing Beach Ecosystems

Method	Data Requirements	Concerns
Ecological Production Function	Need to know Ecological Production Function	Science and Economics of these functions not well enough established
InVest Natural Capital Model	Need very detailed knowldeg of EFGS	Expensive; site specific
Offset Methods	Need to evaluate relative value of ecosystems	Estimates may be based on limited information/science
Standard Assessment Method (SAM)	Requires detailed model of ecological functions	Expensive and probably impractical for Beaches
Habitat Equivalency Analysis (HEA)	Requires basic knowledge of EFGS	Applications only value some EFGS leading to potential undervaluation
Other Techniques		
Hedonic Analysis	Need detailed data on housing prices, econometric skills	Excludes EFGS not valued in housung prices

4.4 Conclusion and Discussion

Sandy beach ecosystems support unique and often under-appreciated biodiversity and provide a irreplaceable suite of ecosystem services and functions. Coastal armoring has been shown to seriously impact the habitat, biodiversity and functioning of beach ecosystems, as well as their resilience. Consequently, the Coastal Commission needs to devise a mechanism for valuing these losses in ecosystem functions and services of sandy beaches due to shore-parallel armoring.

Broadly speaking, there are two main methods that can be used to mitigate for loss of ecosystem services due to shoreline armoring or other coastal development. The first approach involves estimating the ecological services and functions and then placing a dollar value on the loss. This approach has a number of pitfalls: (1) we don't understand the ecological services and functions well, (2) even if we did, placing a dollar value on these services is controversial and the science is not well established, However, if one adopts a natural capital approach, which implies that ecological services and functions should be preserved, mitigation in dollars may not require any direct offsetting of ecological services and functions.

Offsets are commonly used both in the United States and elsewhere for mitigation of environmental losses. Offsets have the advantage that they seek to restore ecological services and functions. Offsets also suffer from the limitation that we poorly understand the ecological services and functions of beaches. However, if the loss of beach is mitigated by restoration of a similar beach in the same area, it is far more likely that the loss of ecological services and functions will be mitigated more fully since the restored beach may also provide these functions.

The literature on offsets, particularly with respect to wetlands, provides us with a number of caution signs. First, offsets, typically in the form of newly created wetlands, often do not fully compensate for the true loss in ecological services and functions. Indeed, there will likely be some beach ecosystems that are irreplaceable. There are a number of established methodologies for estimating appropriate offsets, though none have been specifically developed for beach ecosystems. To fully implement an offset system, the Coastal Commission would need to develop protocols that could be applied to specific sites. As discussed above, these protocols can be in the form of simple checklists or may involve more extensive research (presumably by trained biologists). Given staffing limitations at the Coastal Commission, a simpler procedure probably makes sense, but care must be taken to create a procedure which truly accounts for the ecological services and functions of the site.

5. Ecological Valuation Method

The purpose of this section is to articulate a conceptual rationale for and initiate the development of an ecological valuation method for California beaches. The goal is to develop a method to estimate the value of the ecological components of a beach ecosystem that are impacted or lost due to specific changes to the beach and coastal processes resulting from the installation of shoreline armoring. This effort is an interdisciplinary approach between ecologists and economists, and represents the first steps in establishing a conceptual framework that will allow valuation of the ecological losses to beaches associated with coastal armoring. This framework is intended to provide a starting place for ecological valuation rather than a finished product.

Valuation methods traditionally provide results expressed in quantifiable units, such as currency (e.g. USD), area (e.g. acres), or in biological contexts such as loss of a number or biomass of specific guilds, groups, or individual species. Direct losses of area on an armored beach may include immediate loss of beach under the structure, subsequent loss of beach area due to erosion caused by a fixed back of the beach, loss of new sand deposition by loss of space for that sand deposition, prevention of sand supplied by bluff erosion, and progressive loss of beach area and accommodation space from sea level rise against a fixed back beach. Adverse effects of shoreline armoring on the beach ecosystem (animals, plants, food webs, and habitats) have not been monetarily valued on California beaches to date. However, California's beaches support some of the highest biodiversity, productivity, abundance and biomass in the world. This biodiversity includes numerous endemic species of plants and animals, species of special significance, marine mammals, migratory birds, and endangered species that depend on sandy beaches as habitat (McLachlan and Brown, 2006; Hubbard and Dugan 2003; Schlacher et al. 2012, Harris et al., 2014, Schooler et al. 2014, Dugan and Hubbard in press).

Here we explore an approach that could be used to address the mitigation of adverse ecological effects caused by seawalls on sandy beach ecosystems. As defined by CEQA guidelines Section 15370, “mitigation may take the following forms:

1) Avoid the impact altogether by not taking an action;
2) Minimize the impact by limiting the degree or magnitude of the action or its implementation
3) Rectify the impact by repairing, rehabilitating, or restoring the impacted environment
4) Reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action
5) Compensate for the impact by replacing or providing substitute resources or environments.”

Here we focus on developing a rationale and a framework for building opportunities for the mitigation of impacts of shoreline armoring through the restoration of sandy beach ecosystems either at the project site or within the same littoral cell.

5.1 Ecological Valuation

5.1.1 Developing Ecologically Sound “Restoration” Projects for Beaches

In the past, sand placement and beach filling projects have often been called beach “restoration” projects. However the goals and implementation of these projects have not followed any of the biological, ecological guidance or goals that are required standards in restoration projects for other coastal ecosystems, such as seagrass beds or wetlands (Lawrenz-Miller, 1991; Peterson and Bishop, 2005; Peterson et al., 2006, Viola et al 2014). Beach filling projects are expensive and have also proven to be short-lived in many sections of the California coast (Griggs et al. 2012) and sand supplies are rapidly becoming a limiting factor for these projects (Pilkey and Cooper 2014). In this section we propose the development of a more ecologically sensitive and sustainable approach to the restoration and mitigation of losses of sandy beach ecosystems resulting from placement of coastal armoring.

As with all other types of coastal wetlands, the goal for beach ecosystems needs to be no net loss of habitat area. To date, there has been substantial loss and fragmentation of California beach and dune habitats as a result of coastal development and other human impacts (Dugan et al 2003; Dugan and Hubbard 2010; Griggs et al., 2005; Orme et al., 2011; Pilkey and Cooper, 2014). This has adversely impacted the viability of populations of vulnerable beach-dependent organisms particularly as these impacts accumulate over time in beach ecosystems (e.g. Page et al 1991, Hubbard et al 2014).

Fundamentally, the ecological components (habitats, communities, individual species) and functions of sandy beach ecosystems are unique and irreplaceable (Schlacher et al. 2007, Dugan et al., 2010). These components are not found in or provided by any other coastal ecosystem. The different habitat zones of the beach are used by characteristic mobile organisms, with numerous endemic species adapted to the harsh and dynamic sandy environment, including mole crabs and clams in the wave wash, polychaetes and isopods in the mid-beach and direct-developing invertebrates on the upper dryer beach. Many shorebirds forage along the high tide line, in stranded macrophyte wrack, and in the wave wash along with roosting on the upper beach. Some shorebirds, such as the threatened Western Snowy Plover, nest and raise their chicks on open coast beaches. Beaches are also extensively used as haul out areas and rookeries by marine mammals, and fish and turtles lay their eggs in nests in the warm sands of the upper beach.

Organisms living in the upper beach zones and habitats are most strongly impacted by the effects of armoring and coastal human uses (Feagin et al., 2005; Dugan et al., 2008; Dugan and Hubbard, 2006, 2010b; Jaramillo et al., 2012). As seawalls tend to increase the amount of erosion and the intensity of wave refraction, the dry upper areas of a beach decrease in width and ultimately disappear under waves (Fletcher et al., 1997; Griggs et al., 2005). These zones represent critical habitat for nesting birds, pupping and early life stages of marine mammals, and beach-spawning fishes (Martin, 2015). The upper zones also are the habitat required by numerous endemic species of plants, invertebrates, and reptiles. Upper beach zones have already been severely degraded as habitats, and reduced in size in many areas of the California coast. Additional loss of this key habitat zone caused by coastal armoring will further fragment this habitat and threaten populations of these organisms.

Mobile animals that live on sandy beaches can require large swaths of suitable habitat to adjust to changing beach conditions. Each species may need a much larger potential habitat than is temporarily in use at a given moment (Defeo et al., 2009; Dugan et al., 2013). This is because beaches are naturally variable in size, changing hourly in wave and tidal exposure, and seasonally and on longer scales in width, depth and zone distributions (Bird, 1996; Hubbard and Dugan, 2003; Yates et al., 2009). The scope of changing beach area or width for cross-shore adjustments, or "ecological envelope" that allows animals such as birds, invertebrates, fishes, marine mammals, and birds to adapt to changing beach conditions is integral to survival for these animals. For these reasons, the addition of buffers, such as those used to extend the protection of other sensitive habitats like wetlands, are recommended for beach ecosystems

5.1.2 Ecological Costs

As the climate shifts, organisms currently living on sandy beaches along the coast will need to adjust to increasing ocean temperatures and rising sea levels (Dugan et al., 2008, 2011; Dugan and Hubbard, 2006, 2010). These adjustments can include moving landward as beaches retreat and moving along the coast to follow suitable temperatures. It is predicted that species that live in the narrow interface between ocean and land will be more strongly and rapidly impacted by climate change than fully marine or fully terrestrial organisms (Harley et al. 2006). In places where beaches have room to retreat, intertidal and upper shore organisms can follow the beach and suitable habitats landward. However much of the California coastline has limited scope for retreat, including shorelines that have been armored and those that are backed by resistant natural bluffs or cliffs. In addition, some of these coastal species may require different habitats for different life cycle stages (Martin, 2015). For example, it is possible that sand temperatures will increase faster than ocean temperatures, forcing the beach-spawning California Grunion to move to more northern habitats for spawning even while the ocean temperatures are still acceptable for adult life (Roberts et al., 2007; Johnson et al., 2009; Martin et al., 2013).

5.1.3 Economic Costs

As discussed above, the ecological components and functions of sandy beaches are highly dynamic. Quantitatively evaluating the sandy beach ecosystem, identifying and cataloging all components on a given beach in detail is expensive, time-consuming, and difficult to evaluate quantitatively with sufficient confidence due to high variability in the biota and the form of sandy beaches (Barbier et al., 2011; Borja et al., 2014; Schlacher et al., 2008, 2014). All the key components of sandy beach ecosystems are capable of changing dramatically in the short term in response to wave climate, beach conditions, population dynamics and season (Hubbard and Dugan 2003; Scapini and Ottaviano, 2010; Revell et al. 2011) . In addition, climate change may accelerate erosion and alter the physical and biological dynamics of sandy beaches (Zhang et al., 2004; Griggs et al., 2005; Flick and Ewing, 2009). Quantifying and valuing all the elements of fully functional beach ecosystems with confidence would require prohibitively expensive and time-consuming data collection and analyses beyond the scope of most property owners and coastal residents (Barbier et al., 2011; Borja et al., 2014; Schlacher et al., 2014).

Rather than quantitatively assessing what ecological components and functions may be altered or lost on a given stretch of sandy beach due to shoreline armoring as a valuation approach, we recommend using the cost of restoring a sandy beach ecosystem, either at that site or nearby as a simple and robust valuation approach for mitigating the ecological impacts of coastal armoring. This approach allows greater consistency and accuracy than can be achieved with attempts to confidently identify, replicate, and monitor the lost ecological components of a specific stretch of sandy beach. The latter is particularly problematic for a beach that may have been altered long ago and impacted over a long period of time (Orme et al., 2011). Such a site may retain little of its original character, yet it still represents a coastal ecosystem lost to nature, but one that has with the potential for rehabilitation (Dugan and Hubbard 2010, Dugan et al., 2010, 2012).

5.2 The Proposed Valuation Method Explained

The purpose of ecological valuation is to address impacts of shoreline armoring on natural habitats. With improved and more comprehensive valuation methods the immediate, future, and cumulative impacts of shoreline armoring may be reduced and better mitigated for the California coastline.

5.2.1 No Net Loss and Habitat Equivalency

An approach that embraces “no net loss” of beach habitats or beach zones as a result of future development will be critically important to the ability to maintain and in some areas restore healthy resilient beach ecosystems along the coast. Current methods employed by the California Coastal Commission evaluate loss of sand, erosion impacts, loss of beach area, and loss of recreation. They do not adequately address the loss of ecological value or functioning. For this purpose we strongly suggest defining sandy beaches as tidal wetlands, and applying the concept of “no net loss” to their preservation and restoration. With this approach, we recommend mitigation for armoring projects could be achieved by ecological restoration projects of suitable scope in either the project area or on a nearby coastline, ideally in the same littoral cell and sand-shed. A substantial proportion of the California coastline is armored at this time; therefore areas available for restoration though possible managed retreat already are limited.

The proposed approach fits into third type of mitigation as discussed in the beginning of this chapter (repairing, rehabilitating, or restoring the impacted environment) as well as the fifth type (replacing or providing substitute resources or environments). This approach optimistically assumes that well-designed restoration projects, with attention to local and regional physical and biological processes, biodiversity and metapopulations, seeding, management and monitoring, can potentially provide reasonable habitat equivalency with natural sandy beaches in the same area and littoral cell. We have removed sand replenishment from this primary list due to the high ecological impacts (Manning et al. 2013, 2014; Peterson et al. 2000, 2006, 2014; Viola et al. 2014) and the typically short lifespan of these projects (e.g. Leonard et al. 1990).

5.2.2 Quantifying Ecological Loss

Although the loss of beach area is already used for the calculation of sand mitigation and recreation mitigation, and it could also potentially be used as a component of the calculations of ecological loss valuation, there are concerns with this approach for ecological valuation. The estimations of area lost must consider placement loss due to the area of the structure, the effects of the structure on coastal processes including the loss of the ability of the shoreline to retreat by fixing the back of the beach, and the loss of sand storage and beach area to erosion during the lifetime of the permit. The increased erosion of the beach and the loss of ability to store sand that can be caused by an armoring structure are not necessarily accounted for in the average erosion rates currently used by the CCC. The loss of ecological zones over time, in particular the disproportionate loss of vegetated and upper beach zones and biodiversity relative to lower beach zones needs to be addressed in loss calculations. Loss of area currently or potentially used for feeding, roosting, or reproduction of wildlife, particularly species of special concern, must be recognized (Schlacher et al. 2014).

Importantly, the highly dynamic nature of the beach and biota are problematic for an approach that relies on simple estimates of beach area and/or the use of a variety of biotic measures to calculate value. If only a few metrics and estimates of erosion rates and beach ecology are available for use in valuation, then it is critical to capture the coastal processes and especially the potential for shoreline retreat in the 20-year lifespan of a project.

The state of the science on beach ecosystems is not sufficient for making accurate quantitative predictions of erosion and habitat loss rates in front of newly installed armoring structures. Quantifying every crab, clam, worm, fish, or bird on a beach with sufficient confidence is not only difficult and expensive, it often requires destructive sampling of the biota. The dynamics of the beach and its mobile biota mean that what you measure today on a beach, be it zone width, numbers of sand crabs or numbers of shorebirds, will most certainly be different tomorrow. Width and sediment characteristics of beaches will vary with lunar tidal cycles, seasons, swell events, interannual cycles and with ENSO and PDO phases. Erosion and accretion rates will fluctuate with precipitation, wave energy and other factors. With every shift of the tide and swell the mobile and often cryptic animals of beaches will shift in location and their estimated densities per unit area of habitat will change dramatically (Dugan et al. 2013). For these reasons, the use of projections from long-term average rates of erosion or shoreline retreat may not be very useful or constructive for determining the actual ecological conditions or components on any given beach. Therefore, determining the specific conditions of a beach will not be sufficiently accurate or precise for valuation purposes. These concepts provide the foundation for the restoration approach to valuation that we propose here.

Using the costs of restoring beaches as functional ecosystems as the basis for calculating the loss of ecological value of beach ecosystems caused by armoring provides a way forward for developing a viable approach to ecological valuation that can be applied to sandy beaches.

Understanding that pouring concrete or placing rocks on the beach fixes a line on the shore and eliminates the potential for future adaptation or even recovery from low sand levels is crucial. The real impacts to the coast will accumulate over time as any armoring structure interacts with coastal processes. These impacts will not be adequately captured in per square foot metrics. An appropriate way to mitigate for beach ecosystem losses would be to free another stretch of coast to interact freely with coastal processes and evolve naturally over time. For this reason we suggest that shoreline length may be the most reliable and defensible way to measure overall beach ecosystem loss over the life of an armoring structure. The loss of habitat area due to placement loss from the structure needs to be an additional component that is added to the shoreline length. For example a rock revetment will have a substantially greater footprint and consequent habitat loss than a soil nail wall of a few inches in depth.

Although the loss of beach habitat area over time can be challenging to estimate for use in mitigation, the area of beach directly covered by the installation of a shore-parallel armoring structure, such as a seawall or a revetment, also known as placement loss, is a straightforward calculation that is likely to be part of the engineering study for any new armoring structure application. The placement loss caused by a new structure has an immediate impact on habitat and disproportionately affects the upper shore habitats with negative impacts on overall biodiversity, birds, fish and ecosystem function. This initial impact of the footprint of the structure is strongly influenced by the structure type. As an example, a revetment built to currently accepted design standards will need to have a width to height ratio of at least 1.5 to 1 or 2.1 to 1 to be able to maintain structural integrity during strong storms (Griggs and Fulton-Bennett 1988). Thus a revetment that needs to be 15 feet high will initially cover up to 30 feet of cross shore beach habitat. A seawall at the same location will cover less cross shore habitat, approximately 6 feet. A comparison of the placement loss of these two types of armoring structures for a 50-foot stretch of coastline would yield a footprint of 300 square feet for the seawall vs. 1500 square feet for the revetment, a 5-fold difference in the immediate loss of beach habitat after construction. Over time, both types of structures will continue to cause more significant habitat loss by fixing the shoreline and generating erosion. .

Although placement loss is significant and should be accounted for by the Coastal Commission, we believe using a linear foot approach is the best approach since any coastal armoring structure prevents a natural retreat and limits the beaches' ecological functioning. Since it is also difficult to forecast erosion rates for different ecological zones and beach width varies seasonally and due to other factors, using beach area to estimate ecological functioning is also difficult.

5.2.3 Mitigation Ratios

Resource and regulatory agencies usually require the restoration of additional habitat acreage beyond that lost directly through development. This is because of interim losses in habitat acreage and functional capacity, and because the success and resulting value of compensatory mitigation projects are uncertain. The ratio of habitat acreage created or restored to the habitat acreage lost to development is termed the mitigation ratio. Mitigation ratios should be applied to beach ecosystems as is already done for other coastal ecosystems by the California Coastal Commission. For example, the ratio for coastal sage scrub mitigation is 2 units area restored for every 1 unit of area lost, for coastal wetlands it is 4:1, terrestrial ESHA is 3:1, and seagrass beds are 1.2:1.

We suggest using a 4:1 mitigation ratio for sandy beach ecosystems, to match that used for coastal wetlands. This can be justified because beaches can be considered coastal wetlands by state definitions. The California Coastal Commission is able to use any one of the three Army Corps of Engineers criteria to delineate wetlands in the coastal zone: Wetland Vegetation, Soils, or Hydrology. Although beaches don't support intertidal vegetation and wetland soils take time to develop, the Hydrology criteria clearly fits the regularly wetted part of the sandy beach. The Coastal Act contains language about protecting areas that are inundated by seawater or waves for at least 14 days per year. Incorporating these criteria encompasses considerably more of the beach ecosystem extending more or less up to the storm or driftwood line, or the coastal strand vegetation. Additional considerations for Species of Special Status and wildlife are expected. For example, the southern coastal dune habitat that backs some beaches and persists as remnants on others is designated as Environmentally Sensitive Habitat Area (ESHA) and is subject to special consideration. Other habitats considered ESHA will be regularly encountered on beaches that interface with coastal stream mouths, lagoons and estuaries. The addition of buffers, such as the 100 foot buffers often used around coastal wetlands to extend the protection of these sensitive habitats, would be particularly useful to apply to dynamic systems like beaches and stream/lagoon mouths.

5.2.4 Potential Use of Mitigation Funds to Restore Beach Ecosystems

Funds for mitigation projects associated with individual armoring projects could be used for a variety of restoration purposes. Funds could be managed using various existing models including mitigation banks or in lieu fees. Sand replenishment or beach nourishment projects that simply add sand to the shoreline would not be considered an ecological restoration for mitigation, due to the ecological damage associated with these projects and their relatively short life spans. The area to be restored in mitigation for a given project should be located nearby on the coast, preferably within the same littoral cell or sandshed. The restoration or mitigation site ideally would also have the potential for resiliency through natural or managed retreat to adjust to continued erosion and climate change. Public access is desirable for the restored beach as appropriate but not required for ecological restoration. If the impacted area itself has the potential for restoration and fits all the other criteria above, then local restoration would be encouraged. We suggest that mitigation funds be directed toward one or more of the following restoration purposes:

1. Initiate new beach ecosystem restoration projects, including but not limited to building and revegetating dunes and coastal strand zones;
2. Enhance existing beach ecosystem restoration projects;
3. Acquire land in coastal areas with restoration potential, for example, areas with adjacent upland habitat available that is suitable for managed retreat, or land use conversions in areas pending removal of infrastructure or seawalls;
4. Removal or relocation of infrastructure and other barriers that would allow beach ecosystem recovery by retreat inland. This could involve the removal of obsolete or damaged coastal infrastructure, such as seawalls, revetments, or roads, as well as threatened coastal infrastructure such as sewage lines, septic systems, parking lots, and other buildings, where this removal would provide a route for natural retreat of the beach.; A project within an area that has the potential for retreat, such as moving a park campground, would also be considered appropriate if this provided more area for the beach, provided that such action did not damage currently present sandy beach or dune habitat.
5. Enhance sediment supply to a littoral cell through the removal of obsolete dams, watershed infrastructures, groins, seawalls and debris basins;
6. Implement changes in management methods to effect beach ecosystem restoration, for example changes in mechanized maintenance practices that impact beach ecosystems, such as beach grooming, or beach contouring &

berm building; Ideally this would occur in combination with an easement or long-term agreement to allow natural processes time to develop, as a form of passive restoration. See Llewellyn and Shackley (1997), Dugan et al. (2003), Dugan and Hubbard (2010) and Martin et al. (2006) for some of the biological impacts of beach grooming. Alternatively or in addition, this could include restoration of habitat by removal of invasive or non-native species e.g iceplant or European beach grass.

Restoration would necessarily take an ecological approach including, as needed, plant and animal re-introductions and ecosystem monitoring over appropriate time scales. While some of these examples would not replace lost beach areas, the changes would help to improve the ecological function and resilience of these beaches (Bird, 2000). Mitigation must consider the appropriate recovery times for ecological restoration and natural recolonization of areas.

5.3 The Valuation Method and its Benefits

The proposed valuation method is In-lieu mitigation offset, the value of restoring the beach, bluff, dune, or back beach land equivalent at a 4:1 ratio to the lost area in a similar area of the coast. The proposed approach addresses the issue by a policy of no net loss; lost habitat in one area can be mitigated by appropriately scaled restoration of habitat in another area that can continue to undergo natural processes and dynamics. The proposed approach does not rely on beach nourishment or beach filling as a restoration method due to its ecological impacts combined with the typically short-lived effects on beach areas and profiles. A survey of beach filling projects along the west coast of the US determined that a small fraction, only 27%, of the projects survived more than five years and 18% of the projects lasted less than 1 year (Leonard et al. 1990). The proposed approach focuses on mitigation methods that are less ecologically damaging, longer lasting and more sustainable than beach filling. These include creating space for and allowing coastal retreat, ceasing beach grooming, restoring dunes, enhancing coastal processes, such as transport and delivery of sediment from natural sources, and creating suitable beach habitats for conservation.

Our approach is specifically aimed at fulfilling the following conceptual goals of the Coastal Act as detailed in the scope of work ?:

- "**Marine resources shall be maintained, enhanced, and where feasible, restored.** Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes." - From Scope of Work, Section 30230
- "The **biological productivity and the quality of coastal waters**, streams, wetlands, estuaries, and lakes **appropriate to maintain optimum populations of marine organisms and for the protection of human health** shall be maintained, **and where feasible, restored** through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of groundwater supplies and substantial interference with surface water flow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of natural streams." (emphasis added) -From Scope of Work, Section 30231

The valuation method we suggest also satisfies several other criteria provided by the scope of work of the project:

"<u>Method must be linked to beach resources that are impacted by shoreline armoring.</u>"

This method directly addresses the loss of ecological habitat and organisms. The method directly addresses the impacts of armoring that are most strongly associated with constraints on shoreline retreat, particularly the loss of upper shore zones and their endemic vegetation and fauna, and the loss of tide refuge habitat. It can be adjusted to account for future improvements in ecological knowledge and restoration techniques.

“Must be applicable to a variety of beaches that vary in size and material for use throughout California.”

Restoration is a way of preserving natural habitat in California of various types of beaches, representative of their occurrence, ideally in the same littoral cell. Restoring the beach zones and habitat types will help preserve ecological functions representative of their occurrence in the same littoral cell as the construction.

“Data required must be readily available in the peer-reviewed scientific literature, government reports, or other easily collected documents.”

The data needed would be collected under current procedures, including loss of beach area and beach zones. Data for costs of restoration projects can be obtained from current projects.

“Method must be relatively straightforward as it will be employed by coastal analysts and managers under tight deadlines.”

The proposed method is both shoreline length- and area-based and requires the classification of the type of beach and the bounding habitats, the length of shoreline and the types and zones of habitat that will likely be impacted by the area of directly impoundment by the new structure and the subsequent effects on the structure on coastal habitats, biota, and processes from construction or armoring.

“Results must be quantifiable currency, i.e. USD, number of acres, amount of larvae, biomass.”

Results are quantifiable in terms of the costs of restoration of specific types and amounts of habitat.

“Method must logically lead to appropriate, site specific mitigation options.”

Each type of beach that was armored would require the improvement and enhancement of appropriate habitats on the same or a similar beach. Mitigation should occur in the same littoral cell.

5.4 Case Studies

We chose four projects as examples of restoration projects that would be appropriate for valuing sandy beach mitigation for loss of habitat. For each of these, cost per acre includes the cost for planning, permitting, acquisition of property and easements, legal agreements, implementation including infrastructure removal or relocation, sandy beach and dune restoration of vegetation. Monitoring of living and physical resources for compliance are not included in these estimates. Restoration planning realistically needs to include all these costs.

The four projects are recent restoration projects at Pacifica State Beach in San Mateo County (aka Taco Bell Beach); Surfer’s Point in Ventura County, and two proposed projects at Ocean Beach in San Francisco, and Goleta Beach in Santa Barbara County (Table 24). Costs per area including all of the components listed above would be appropriate for mitigation of equivalent area in response to ecological damage or loss of a sandy beach habitat following shoreline armoring.

Two of these projects have been conducted and two are proposed. All projects were conducted or planned by Bob Battalio, PE from ESA/PWA. The two complete projects are Pacifica State Beach Managed Retreat and Surfers Point Managed Retreat projects. The two proposed projects are Ocean Beach Master Plan and Goleta Beach Managed Retreat projects. The Pacifica project included private property but the other three projects are on public land. The projects are described in more detail in Appendix III. Using these projects, cost estimates were derived by linear foot and area. Table 24 shows the size of the projects, costs and costs per linear foot and area and includes notes describing the general nature of the work. It should be noted that each beach restoration project requires a site specific approach that will ultimately dictate the total cost of the project. The costs for these projects ranged from $3.65 million to $200 million dollars. The shoreline length of the projects ranged from 700 to 4000 linear feet and the area of the projects ranged from 1 acre to 4.3 acres. Cost per linear foot ranged from $3580 to $50,000 per linear foot and the cost per square foot ranged from $40 to $340 dollars. Cost is based on actual cost of restoration work plus professional services, estimated to be 40% of the construction costs, and then adjusted for inflation for 2015 dollars. Each project included site-specific components that are summarized. At Pacific Beach two private homes were purchased and removed and at Ocean Beach a significant amount of public infrastructure, including removal, reconfiguration and construction of the Great Highway significantly increased the cost of that project.

Average costs were estimated with and without the Ocean Beach project given the notable difference in costs associated with that project. The Ocean Beach project provides a good example for projects that would require major infrastructure adjustment.

Please also note that all of these projects involve public land, so that **the cost of acquiring expensive coastal property is not included in these estimates,** with the exception to two homes purchased as part of the Pacific restoration project. If land acquisition costs were added in the costs of restoration would be significantly higher. Further, any restoration project would also likely be subject to environmental monitoring, and the cost of this monitoring has not been factored in to our estimates.

As Table 24 shows, the linear foot estimate can vary by a large amount based on the area and shoreline length of the project. At Ocean Beach the project includes a larger landward area per length of coast, which significantly increases the cost per linear foot. Excluding Ocean Beach the average cost per linear foot is $4,313 per linear foot. The average cost per square foot is similar without including Ocean Beach and is approximately $58 per square foot.

<u>Hypothetical example:</u>

If a 200 foot long shoreline armoring project was constructed on a beach with a 50 foot width, the area of beach impacts would be 10,000 square feet. Using the linear foot cost (without Ocean Beach), the restoration fee would be $862,600. Using the area-based approach the restoration fee would be $580,000. For the area-based and linear approach to be equivalent the impacted beach area would need to be more than 100 feet wide. This example does not include scaling or adjustments for time. To balance the beach impacts the restoration should occur prior to the end of the permit lifetime.

Table 24: Examples of costs for restoration of beach ecosystems in California- Note that costs for acquisition or permission, easements, permitting , planning, monitoring etc are not included in these estimates.

Beach	Lineal Feet	Area (acres)	Cost ($2015)	Cost/Linear Foot	Cost/Sq. Foot	Project Elements
Pacifica State Beach	2000	4	$6,960,000	$3480	$40	Two homes removed Parking lot removal Revetment removed Sand replacement Dune restoration
Surfer's Point	1100	2.1	$4,670,000	$4245	$50	Removal of paving and fill Beach & cobble restoration Dune restoration New road & parking lot New storm drains
Ocean Beach	4000	13.5	$200,000,000	$50,000	340	Removal of fill Removal of rock revetment Removal of roadway, parking and park elements Armoring of sewer tunnel Grading with native and imported sediments Planting Construction of public facilities farther inland
Goleta Beach	700	1	$3,650,000	$5214	84	Protect of sewer outfall pipe Removal of parking area Removal of rock revetment Relocation of utilities Relocation of bike path Relocation and protection of utility corridor and highway
Average	**1950**	**4.03**	**$53,820,000**	**$15,735**	**129**	
Average w/o Ocean Beach	**1267**	**2.37**	**$5,093,333**	**$4,313**	**58**	

Source: Memo from Bob Battalio from ESA/PWA on Beach Restoration costs, April 23, 2015

5.5 Summary and Conclusion

In this section, we have proposed a method to estimate the loss of ecological value to beach ecosystems due to coastal armoring. Using the costs of restoring beaches as ecosystems as a basis for calculating the loss of ecological value of beach ecosystems caused by armoring provided a way forward for developing a viable approach to ecological valuation that can be applied to sandy beaches. The proposed offset approach relies on valuing the cost of a beach ecosystem restoration project, preferably located near the proposed coastal armoring site or at least in the same littoral cell, designed to provide similar ecological values. The existing scientific literature as well as standard practice for other ecological restoration projects indicates that the offset ratio needs to be higher than 1:1—in other words the restoration project's ecological value is likely to be significantly lower for an equivalent metric, hence a higher offset ratio is required. A 4:1 ratio is common for wetland restoration. For beaches we recommend that a 4:1 ratio also be applied to restoration projects, unless the beach ecosystem contains particularly sensitive, scarce or valuable habitat or species, in which case a larger ratio might be required.

To estimate the loss of the ecological value for a beach ecosystem caused by armoring, we recommend the use of a metric that focuses on the loss in linear feet to generate a cost for restoration and then adds a fee based on the square footage due to the immediate loss in area from the footprint of the armoring structure. Since future erosion rates are difficult to predict, this approach emphasizes the loss of linear feet of shoreline to retreat, the immediate placement loss due to the new structure and the need to restore an equivalent stretch of sandy beach on the local coast.

6. Conclusion and Recommendations

Approximately 110 miles of the California coast is currently armored, considerably more than 10% of the entire coast, and 33% of southern California's coast has already been armored (Griggs 2009). Coastal erosion, exacerbated by sea level rise, threatens property, roads and highways, and other vital infrastructure on the coast. The Coastal Act allows shoreline armoring to be permitted when it is required to serve coastal dependent uses, protect exciting structures, or public beaches in danger of erosion. Unfortunately, armoring the coast also seriously inhibits the ability of beaches and other coastal ecosystems to naturally adapt to maintain habitats and biodiversity by retreating landward as the coast erodes. Armoring structures also create a barrier for many intertidal species, further reducing the ecological richness and diversity of our coast.

The Coastal Commission has developed mitigation policies to address these issues, but most of this mitigation has focused on the potential loss of sand supply and recreation. Far less attention has been paid to the losses of ecological functions, even though these losses may well be much more serious. This report has two main goals: (1) to derive a simple and consistent model the Coastal Commission can use to assess recreational losses without requiring expensive studies (that might cost more than the actual mitigation); (2) to create a framework for mitigating the loss of ecological value and function caused by coastal armoring structures.

Economists generally agree on the standard techniques used to estimate the value of recreation at sites that are free and open to the public, such as beaches. The major constraint involved is the limited amount of empirical data available on coastal recreation. In this paper, we have pulled together the main findings from existing studies and data collection efforts to create a simple feasible method, which the Coastal Commission can apply in all cases. It involves assigning an average value for a typical beach-day along with estimates of visitor densities at northern and southern California beaches. (This technique is generally referred to as "benefits transfer.")

The method for estimating the loss in recreational value developed in this paper is consistent, based on the best available social science, and takes account of the limits in data availability (in particular for attendance at specific reaches). Conducting an individual study for each application would be extremely expensive (either for the applicant or for the Coastal Commission) and could lead to inconsistent results even if a standard method was applied. It would also require that attendance data be collected over a relatively long time horizon (at least a year) which is probably not feasible and would delay the applicant and the Commission.

This method accounts for the fact that limiting beach width at relatively narrow beaches (which is where seawalls are most likely to be placed) restricts recreational value. Although data on the effect of beach width on recreational value is more limited, a number of studies (cited in the main text) clearly show a strong relationship between beach width and recreational value, at least for beaches up to 250 feet.

Sandy beaches and other coastal ecosystems also provide tremendous ecological value. California's beaches provide critical natural habitat for many species that do not exist anywhere else in the world. These include grunion who spawn on California's beaches—the total spawning habitat for these endemic fish is now less than one square mile) as well numerous wildlife, plant, and invertebrate species. Placing a dollar value on the ecological functions and services of sandy beaches is challenging due to the high variability and dynamics of these ecosystems and the lack of a sufficient understanding of many of the key processes. In addition the economics of valuing ecological services is still in its infancy.

Sandy beach ecosystems are so unique, threatened and critical and that they cannot be replaced elsewhere. For this reason we suggest that the best approach for the Coastal Commission to adopt is to accept that the California coast contains critical natural capital that cannot be replaced and thus adopt a no-net loss policy for beach ecosystems and the ecological functions and services they provide. This approach has been applied in other areas, notably wetlands, based on scarcity and ecological functions, services and importance. The approach proposed here implies that mitigation for coastal armoring structures be valued using the costs of existing beach ecosystem restoration projects along California's Coast and then the fees assessed can be used to fund beach ecosystem restoration projects, ideally in the same littoral cell. As a proof of concept for the ecology valuation framework, we developed a valuation based on the average cost of several of the existing beach ecosystem restoration projects in California. Since the costs we used did not involve land acquisition (they use public land) or environmental monitoring costs, we believe our estimates are actually quite conservative, compared to the actual costs of restoration.

This paper recommends that the Commission adopt an approach that uses linear feet as the primary metric for ecological value, rather than area (which we do use for recreational value). Ideally we suggest there should be an additional fee assessed for the area of beach directly covered by the structure that is added to the linear foot estimate. We made this decision after a great deal of reflection for a number of reasons: (1) the ecological value of a beach or other coastal system is not directly related to the width of a beach—but rather critically depends upon having all of the zones (surf, intertidal, dry sand beach, coastal strand vegetation, etc.); (2) characterizing beach zone width accurately is problematic since it varies with seasons and other natural processes; (3) forecasting the erosion rate of a beach after a coastal armoring structure has been placed on the coast is difficult; 4) an immediate loss of beach habitat is caused by the footprint of an armoring structure.

The major principle involved here is that coastal armoring structures seriously impede and inhibit the natural functioning of sandy beach ecosystems such an extent that the only way to conserve ecological functioning and value is through the restoration of beach ecosystems in other parts of the coast, preferably within the same littoral cell. Since these restored projects will almost certainly have lower ecological value (at least initially) we also propose that the Coastal Commission adopt the same approach used for wetland restoration and require a 4:1 ratio—a restoration project must be 4 times larger to provide similar levels of ecological goods, functions and services (EFGS). For some particularly sensitive, scarce or threatened habitat or species, a larger ratio may be necessary.

If our recommendations are implemented, the ecological mitigation fee should be considered separate from the recreation fee. The recreation fee can and should be used to enhance coastal recreation by providing access and amenities to beaches and other coastal recreation. The ecological fee should be applied to projects which can be used to directly enhance and restore beach ecosystems. There are a number of methods that can be used to enhance ecological value, biodiversity and function of beaches even in heavily urbanized regions. These include eliminating mechanical grooming which picks up trash on the beach, but also picks up wrack, which forms a foundation for food webs of beach ecosystems and can help foster the establishment of native coastal strand and dune vegetation.

In the future, if our recommendations are adopted, we recommend that the Commission (or other agency, non-profit, or academic institution) develop a list of priorities for enhancing ecological value of sandy beach ecosystems on the coast that can provide options for restoration for each littoral cell. The aim here should be to maximize the ecological return on scarce dollars going to mitigate and remediate for loss of ecological function and services of beach ecosystems caused by coastal armoring.

Appendix I: Beach Valuation Studies

California Beach Valuation Studies:

The beach recreation papers can be divided into two groups, those reporting on economic impacts (market expenditures) and those reporting on non-market values, with some papers reporting on both.

Market values of California beach recreation

King (1999) estimated the fiscal impact of California beaches and found that beach visits generated $14 billion dollars in direct revenue. Other studies have estimated the average expenditures per person per day trip ($/ trip/ person) for visits to California beaches. In a study of San Clemente beaches, King found that average beach related expenditures (including gas and automobile costs) were $54.79. A survey of beach goers in Southern California (Hanemann, Pendleton et al. 2002) found that per person per trip expenditures on beach related items and services were $23.19 for beach goers that took at least one trip in the summer of 2000. Nelsen, Pendleton, & Vaugh (2007) surveyed surfers visiting Trestles Beach near San Clemente and found an average expenditure per trip to be $40.20 ($2006) and estimated that visits to Trestles Beach produced an economic impact of between $8 and $13 million to the City of San Clemente.

Non-market values of California Beach Recreation

The literature on the non-market value of beaches in California is rich in comparison to other states. Only in Florida are their more valuation studies. Most of the beach valuation research in California uses the travel cost method but random utility method and benefit transfer approaches are used in a few cases (Atiyah, 2009). See Table 25 for a summary of beaches, values, authors and methods.

Leeworthy & Wiley (1993) used the TCM and found that recreational use values for three southern California beaches had annual non-market values of $360 million and found that average values per person per day trip ($1993/trip/person) ranged from $12.19 to $77.61. Leeworthy, Bowker, Hospital, and Stone (2005) estimated values of $85.39 and $90.58 ($2005) for San Onofre State Beach (very popular for surfing) and San Diego beaches, respectively. Chapman and Hanneman (2001) estimated a consumer surplus value of $13 ($1990/ trip/ person) at Huntington Beach. Hanemann, Pendleton et al. (2004) conducted an intensive study of coastal recreation at 53 beaches in Orange and Los Angeles counties. They then used a RUM to estimate the net change in the economic values across all beach sites due to changes in either water quality or beach closures of different durations for different sets of beaches. This study did not, however, estimate per person values for individual beach visits. Lew and Larson (2005) used a random utility model to estimate the value of recreation and specific amenities at 31 San Diego County beaches. They found an average value of $28.27 ($2005/ trip/ person). They also found that the certain beach amenities including presence of lifeguards in towers, activity zones that separate swimmers from surfers, and free parking were important (statistically significant) to beach goers. Interestingly, their study found that water quality conditions are not a statistically significant factor in beach choice. Lew and Larson (2005) did not aggregate their per trip per person value to a total annual value for San Diego County beaches citing a lack of availability and reliability of beach attendance data for the entire County. Pendleton, Mohn, Vaughn, King, & Zoulas, (2011) found the loss value of a trip was just over $100 per trip in their RUM for Orange and Los Angeles County beaches, even though their model allowed for more substitution possibilities than previous studies (the model allows beachgoers to change sites, activities, or number of trips). Pendleton and Kildow (2005) created an aggregated estimate for the non-market value of all beach recreation in California through a two-step process. Using existing literature, they first estimated the total number of annual beach visits and then used a benefits transfer approach to estimate a range for the average per person per trip value. They used a conservative estimate of 150 million annual beach visits and find that the non-market value of

California beach visits ranges from $2.25 to 7.5 billion per year ($2005). These values are adjusted for inflation to 2013 using the Bureau of Labor Statistic Consumer Price Index.

Table 25 shows consumer surplus values for existing site-specific studies for California beaches that could be used as the study site for benefits transfer.

Table 25: The Value of a Beach Day (Consumer Surplus) at Selected California Beaches

Beach	Author	Date	Method	Consumer Surplus ($2013)
Cabrillo-Long Beach	Leeworthy and Wiley	1993	TCM	$14.47
Solana Beach	King [1]	2001	TCM	$20.91
Huntington Beach	Chapman and Hanemann [2]	2001	BT	$23.46
Encinitas	King [1]	2001	TCM	$26.85
Carpenteria	King [1]	2001	TCM	$29.39
Santa Monica	Leeworthy and Wiley	1993	TCM	$32.56
San Diego – 3	Lew and Larson	2005	RUM	$33.64
San Clemente	King [1]	2001	TCM	$36.84
San Diego – 2	Lew[3]	2002	TCM	$43.71
Pismo State Beach	Leeworthy	1995	TCM	$46.46
Leo Carillo State Beach	Leeworthy and Wiley	1993	TCM	$92.09
LA & Orange County Beaches	Pendleton et al. [4]	2011	RUM	$100
San Onofre State Beach	Leeworthy	1995	TCM	$101.61
San Diego	Leeworthy	1995	TCM	$107.79
CA beaches	Kildow & Pendleton	2006	BT	$38.68

1)midpoint between two methods
2)corrected for inflation using CPI
3)cited by authors and preferred value
4)Estimated value for a lost beach day

Table 25 above shows that the consumer surplus of a beach visit from site-specific studies varies from $14 to $108, a range of an order of magnitude. The average value across these studies is $39. Pendleton & Kildow (2006) used a range of $15 to $50 for their overview of the non-market value of beach recreation in California. The consumer surplus of a beach visit is a critical parameter in the valuation of the total value provided by the beach and is the basis for any benefit transfer from a study site to the policy site. It is also the basis for determining the lost recreational value as the beach narrows.

Non-market values of Beach Recreation outside California

The beach values for Florida and California have been examined more often than the rest of the coastal states combined. On the East Coast, most studies have been conducted in Massachusetts and New Jersey. Most other coastal and Great Lakes state have few or no studies on beach use. The earliest studies on beach use were in Hawaii, Rhode Island, and Massachusetts in the late 1970s (Moncur, 1975; McConnell, 1977; Hanemann, 1978). Studies providing estimates of values for Florida beaches were conducted mostly in the 1980s and 1990s (Bell & Leeworthy, 1990; English, Kriesel, Leeworthy, & Wiley, 1996; Leeworthy & Bowker, 1997). In Florida, consumer surplus values for an individual beach visit range from about $2.60 to $128.18.

Appendix II: The CSBAT Model

In modeling losses to recreational value following shoreline erosion, we use a standard model that is reasonably tractable—a benefits transfer (BT) approach, which allows one to apply estimates from previously analyzed sites to similar beaches. In practice, BT is much cheaper than other methods and also has the advantage of consistency.

For BT to work properly, consistent methodology must be used to assess the recreational value of a particular beach. Several federal agencies, most notable the USACE, have developed a scale from 1-100 to assess the value of a recreation day, with distinctive amenities each assigned a subtotal of the total 100 points, see Table 26 (USACE 2004).[9]

Table 26. USACE unit day value method – point values

Criteria	Total Possible Points
Recreation Experience	30
Availability of Opportunity	18
Carrying Capacity	14
Accessibility	18
Environmental	20
Total	**100**

[9] The USACE Unit Day Value (UDV) method is generally used for recreation sites where there are less than 750,000 annual visitors and recreation is not a deciding factor to endorse a project. For detailed feasibility studies, the USACE will generally perform a site-specific contingent valuation or travel cost study to value recreation. Further, the UDV method was not developed specifically for evaluating beach recreation given the limited number of beaches in the USACE project portfolio.

The USACE criteria indicate how to assign point values to each beach (or other recreation site) One serious limitation of the USACE criteria is that beach width is not specifically accounted for, although “carrying capacity” depends in part on beach width. Another problem with the above scheme is that, since it is additive, a site can score a zero on a particular criterion and yet still earn a relatively high day use value. Realistically, however, if the recreational experience is zero or very low, it matters little whether the site is accessible or has an adequate carrying capacity. A further complication with the USACE methodology is that additional recreation points are given if multiple recreational opportunities are available. In practice, some beaches cater only to one type of recreation (e.g., surfing, bathing) but do so extremely well (e.g., Trestles for surfing or Carpinteria for family recreation) and the USACE methodology may undervalue the recreation experience.

The Coastal Sediment Benefits Analysis Tool (CSBAT) approach used in this study avoids some of the above issues by assuming that the value of each amenity is multiplicative—that is, one should rate each amenity on an appropriately defined scale and then multiply each amenity’s point value to derive a final index. The index can then be translated (as the USACE methodology is) to a day use value.

CSBAT uses the following six criteria to assess the recreational value of California beaches:

1. **Weather**: Typically California beaches are overcast early in the morning and clear before noon, though some beaches remain overcast for a significant number of days. In assessing the weather, many sub-criteria are considered: the number of sunny days, average temperature of the air and water, currents, and wind.
2. **Water Quality/ Surf**: Water quality has become a critical issue for southern California, leading to the closure of many beaches. However, this

factor will be revised in future studies and model updates, since surf waves and water quality are quite different attributes.

3. **Beach Width and Quality**: While a wide beach is not crucial to high recreation value, all else equal, people generally prefer wider beaches. Beaches at our study sites all have good sand quality (and little cobble except near shore), so distinguishing sand quality was not a priority issue in this study.
4. **Overcrowding**: Previous surveys of beachgoers indicate that overcrowded beaches are considered less desirable (King 2001c). Crowding can be measured in a number of ways. Typically, it is measured by the amount of sand available per person, though crowding can also occur in the water, in parking lots, at snack bars, and elsewhere.
5. **Beach Facilities and Services**: Beachgoers generally prefer access to restrooms, trashcans, and lifeguards. Most (but not all) also prefer some food facilities and other shops.
6. **Availability of Substitutes**: Scarcity also affects the relative value of a beach. If similar beaches are available within a short distance, a beach is considered less valuable than if it were the only choice. From a planner's perspective, it may not make sense to nourish a beach if another similar beach is available nearby. However, in making an assessment of substitutes, one must keep in mind the differing preferences of beach users. For example, some prefer a city beach with an urban or tourist ambiance while other prefer a more "natural" beach. A critical issue often overlooked in studies of California beaches is congestion and availability of parking.

The functional form used in the CSBAT analysis is a Cobb-Douglas utility function—a standard practice in the economic field. The equation is of the general form:

$$\text{Value of a Beach Day} = M^* \; A^a * A_2^b * A_3^c * A_4^d * A_5^e * A_6^f$$

Where:

M is the maximum value for a beach day

$A_1 \ldots A_n$ represent each beach amenity (rated on a scale of 0 to 1)

a…f are the weighting of each amenity value

$a + b + c + d + e + f = 1$.

The CSBAT model has been calibrated with data from existing studies. The Cobb-Douglas function exhibits diminishing marginal utility with respect to beach width (e.g., adding 50 ft of sand to a narrow beach has a larger welfare benefit, *ceteris paribus*, than adding 50 ft to a wider beach). This model behavior is consistent with empirical studies and anecdotal evidence. In addition, the CSBAT model employed in this study caps beach width benefits at 250 ft. This is consistent with a number of studies indicating that beaches can, in fact, be too wide. However, wider beaches also diminish crowding, the benefits of which are taken into account in the model.

Appendix III: Restoration Project Data

550 Kearny Street
Suite 900
San Francisco, CA 94108
415.896.5900 phone
415.896.0332 fax
www.esassoc.com

memorandum

date April 23, 2015

to Chad Nelson, Surfrider; Phil King, PhD UCSF

from Bob Battalio, PE

subject Beach Valuation

Chad and Phil

Per our discussions, I understand that you all are working on valuation of beaches to inform evaluation of coastal erosion mitigation measures. You requested information on the cost of shore enhancement projects to serve as surrogate (reference) valuations. I offered to provide information on a couple of projects that I've been involved in:

- Pacifica State Beach Managed Retreat
- Surfers Point Managed Retreat
- Ocean Beach Master Plan
- Goleta Beach Managed Retreat.

This memorandum provides a description of each in terms of pertinent dimensions and parameters for your use in assessing values.

Pacifica State Beach Managed Retreat

Location: Pacifica, CA

Owners / Sponsors: City of Pacifica; California State Parks; California State Coastal Conservancy

Status: Constructed between 2002 and 2004.

Summary: Restoration of 2,000 feet of shore by removing development (including purchase and removal of two homes), grading with native and imported sediments to establish stable geomorphology, planting of dunes, and construction of public facilities about 60 feet farther landward to result in restoration of about 4 acres of dry beach (about 2,000 feet by 87 feet) while improving public access amenities. Costs about $4 Million (2004). Other elements (multi-objective creek and lagoon restoration, creation of storm water treatment wetlands, 2 miles of coastal trail, utilities relocation) resulted in additional costs of $6M and total costs of about $10M (2004). These costs do not include professional services and municipal staff time(design, environmental and regulatory approvals, project management, construction period services): These additional costs are estimated to be on the order of 40% of the construction costs.

References:

(1) http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_retreat.html#1

(2) City of Pacifica, 2004: Pacifica State Beach Restoration. Project description for application to ASBPA Best Restored Beaches Award.

(3) Philip Williams & Associates, Ltd. (PWA) PACIFICA STATE BEACH RESTORATION PHASE 1 Prepared for RRM Design Group and City of Pacifica, January 16, 2002, Amended May 22, 2002, PWA Ref. # 1547.

Description:

Pacific State Beach is within the embayment referred to as Linda Mar Cove, and includes over 70% of the shoreline within the cove. The total length of shoreline is about 3,900 feet (Figure 1). The beach restoration that is the focus of this document is approximately 2,000 feet from the San Pedro Creek mouth to the Highway One - Crespi Drive intersection (Figure 2). The northern part consisted primarily of minor earth fill removal, sand placement and restoration of sand dunes where vegetation had been lost and the wind had cut through the dunes to Highway One. Most of the expenditure was in the southern 1,200 feet from the creek mouth to the north pump station – restroom structure: In this area, private property was purchased, two homes demolished, parking lots, rock revetment and fill were removed, the back beach grades and materials were restored based on geomorphology / engineering design, and new public access and water quality facilities were constructed at a location set back from the ocean (Figures 3 and 4). A large pump station serving sanitary sewer and ground water management was left in place, with a public restroom added along with architectural upgrade and a seawall for protection. A private restaurant on piles was also left in place. Sand was placed along the entire 2,000 feet: 30,000 cubic yards were attained opportunistically from construction of a parking structure in Golden Gate Park, San Francisco. The entire site is shown in Figure 5. Restoration of the lower portion of San Pedro Creek was accomplished simultaneously and integrated into the beach project. These costs are not addressed here.

The following features were included in the beach restoration described in this document:

- The managed retreat of a parking lot (removed and reconstructed 60 feet farther inland);
- The purchase and removal of two old homes on the beach;

- Restoration of over 4 acres of beach area;
- Beach nourishment over a half mile stretch of beach with about 30,000 cubic yards of sand;
- Expansion of Parking and new restroom and changing facilities; and,
- Construction of a portion (2,000 feet) of the 2 miles of new State Beach Coastal Trail.

The total project cost, which included 2 miles of new beach trail, storm water treatment wetlands, and restoration of lower San Pedro Creek exceeded $10,000,000. The cost of the beach restoration and public access facilities was not separately accounted for, but is estimated to have been about $3.5 to $4.0 Million (2004 dollars). This amounts to about $2,000 / linear foot of shore (based on 2,000 feet of shore) and about $1 Million / acre (based on 4 acres of beach restored, or about 87 feet of restored width over the 2,000 foot length of shore).

Figure 1: Pacifica State Beach location and vicinity. Source: Philip Williams & Associates, Ltd. (PWA) PACIFICA STATE BEACH RESTORATION PHASE 1 Prepared for RRM Design Group and City of Pacifica, January 16, 2002, Amended May 22, 2002PWA Ref. # 1547.

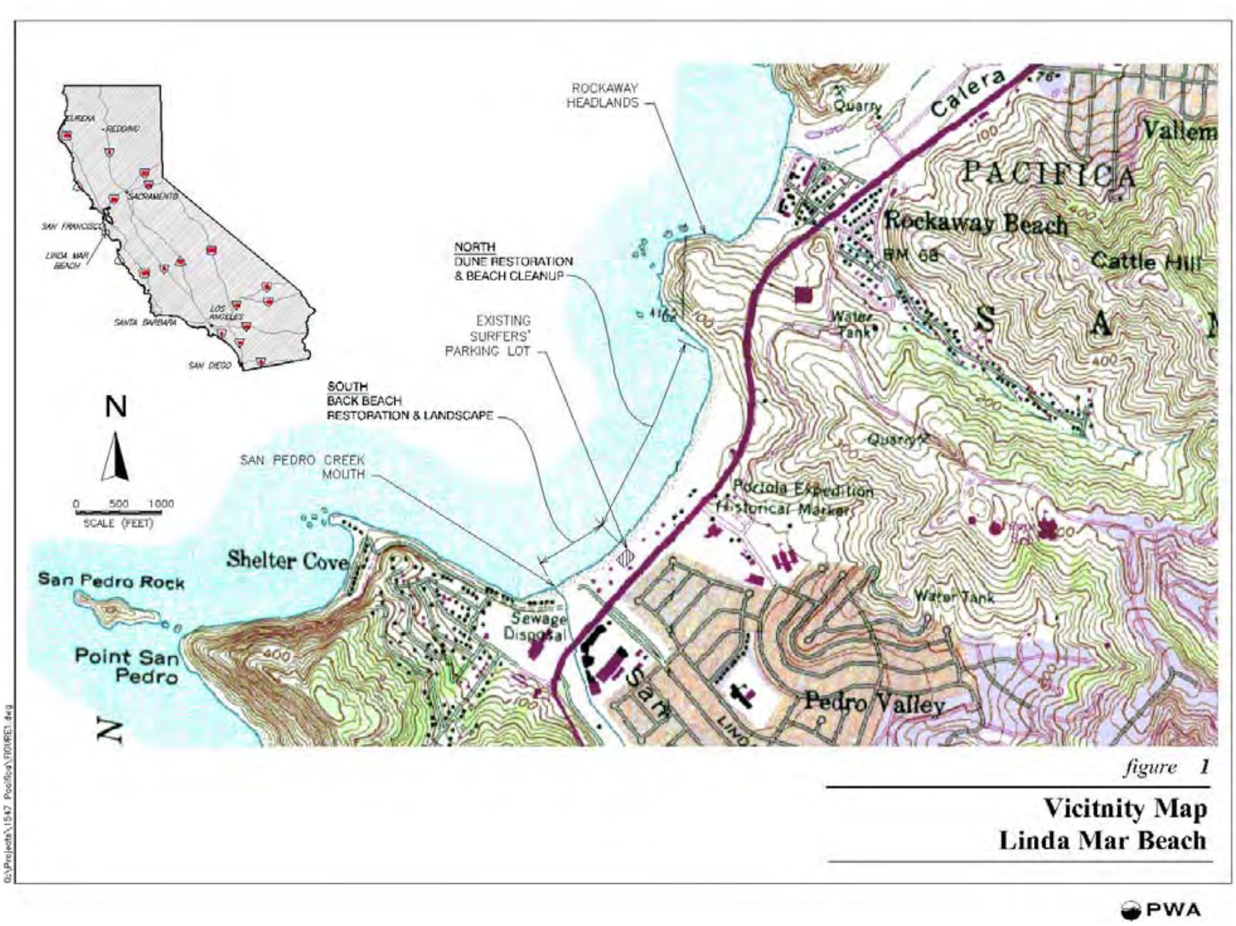


Figure 2: Plan view of coastal restoration elements and development setbacks, with preliminary grading plan. Source: Philip Williams & Associates, Ltd. (PWA) PACIFICA STATE BEACH RESTORATION PHASE 1 Prepared for RRM Design Group and City of Pacifica, January 16, 2002, Amended May 22, 2002PWA Ref. # 1547.

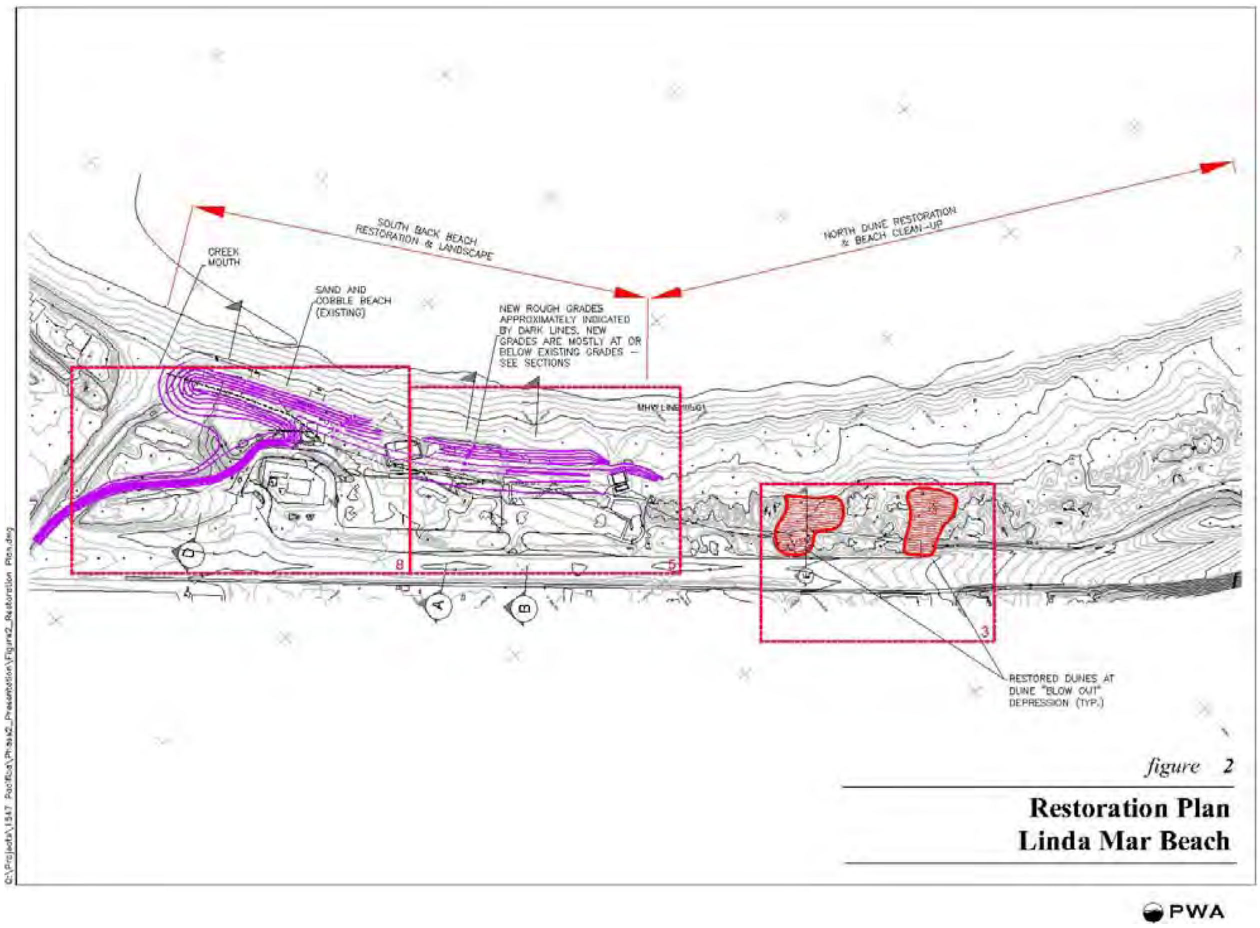


Figure 2A: entire project area.

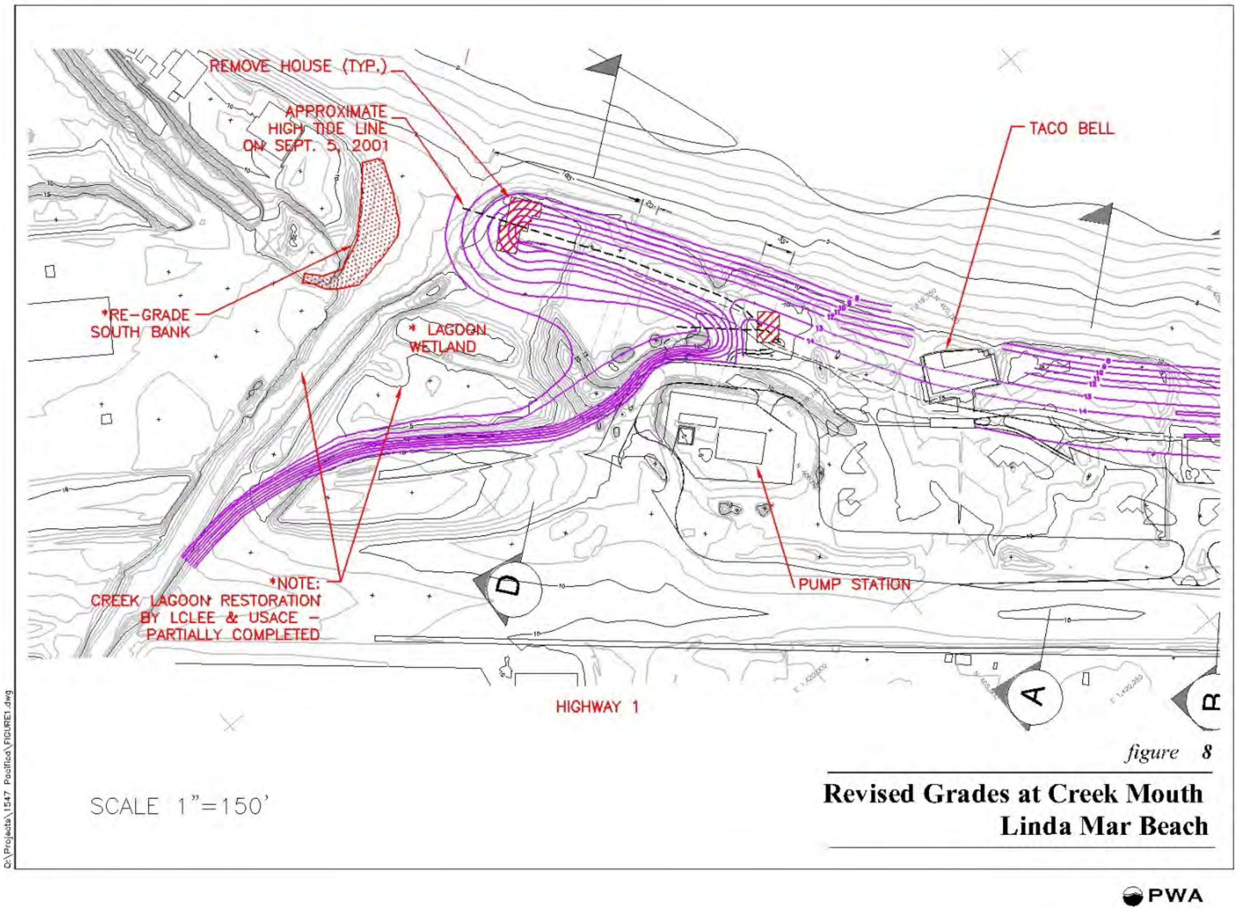


Figure 2B: southern area showing San Pedro Creek

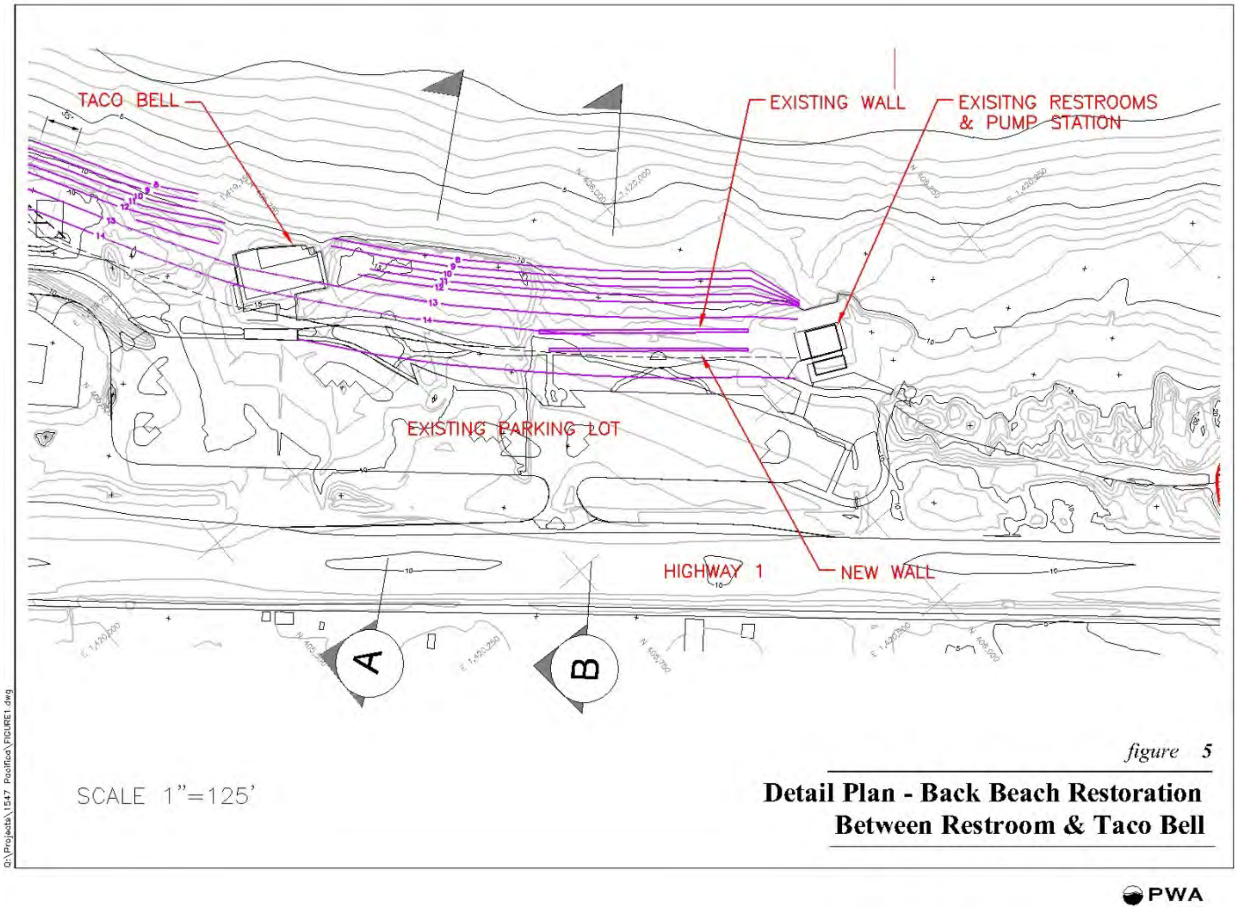
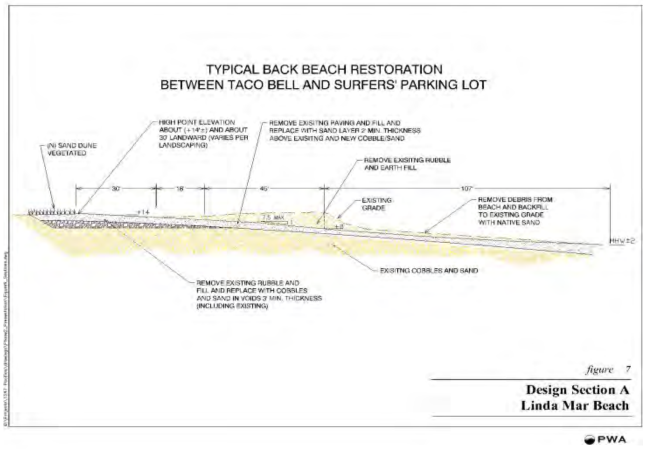
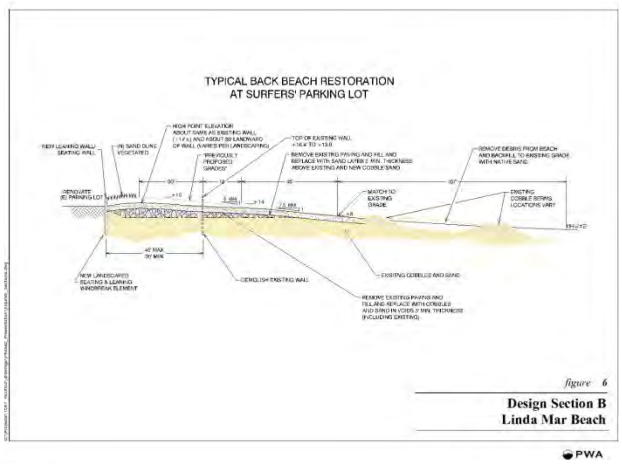


Figure 2C: Southern area showing restaurant and Pump Station – Restroom.

Figure 3: Typical sections. NOTE: cobbles not installed. Source: Philip Williams & Associates, Ltd. (PWA) PACIFICA STATE BEACH RESTORATION PHASE 1 Prepared for RRM Design Group and City of Pacifica, January 16, 2002, Amended May 22, 2002PWA Ref. # 1547.





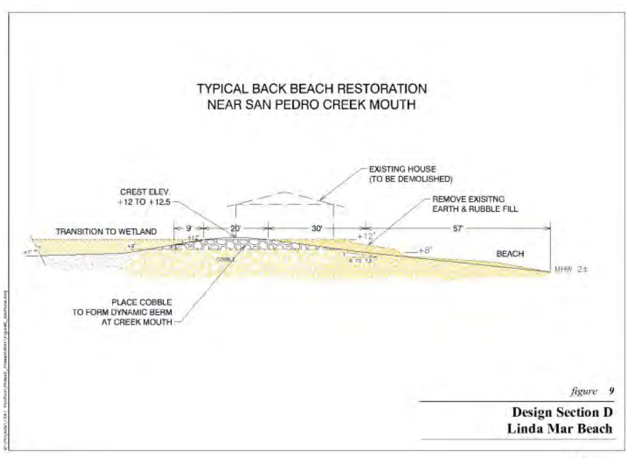


Figure 4: Pictures before and after construction of a part of the restored shore. The building left close to the beach is a private restaurant on piles and elevated above the FEMA flood level. Source: ESA. Photographs, Photograph Source: Copyright © 2004-2010 Kenneth & Gabrielle Adelman, California Coastal Records Project, www.californiacoastline.org

2004 - Before

2009 – After Constructed 2005

Figure 5: Pacifica State Beach managed retreat project in the southern Pacifica district called Linda Mar. The project entailed restoration of the backshore including removal of public and private development and placement of sand. New public amenities including a parking lot, trail and storm water treatment wetlands were constructed farther landward and integrated into the natural restored shore. A sewer pump station and private restaurant were left "bold" on the beach: The restaurant is on piles and the pump station was renovated with restrooms and showers, and armored. A restored creek mouth discharges in the background adjacent to remaining private residents. The coast road State Highway One is on the left. The project was award 2005 America's Best Restored Beaches by ASBPA. Photograph courtesy of the City of Pacifica.

Surfers Point Managed Retreat

Location: Ventura, CA

Owners / Sponsors: City of San Buenaventura (Ventura); California State Fairgrounds; California State Coastal Conservancy, Federal Transportation Funds

Status: Phase 1 constructed 2010-2011. Dunes constructed 2013.

Summary: Restoration of 1,100 feet of shore by removing paving and fill, grading with native and imported sediments to establish stable geomorphology, planting of dunes, and construction of public facilities about 70 to 100 feet farther landward to result in restoration of about _ acres of dry beach (about -----feet by ----feet) while improving public access amenities. Construction costs are estimated to have been about $3.1 Million (2010). These costs do not include professional services and municipal staff time (design, environmental and regulatory approvals, project management, construction period services): These additional costs are estimated to be on the order of 40% of the construction costs.

References:

(1) http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_retreat.html#2

(2) City of Ventura, Administrative Report, SURFERS POINT MANAGED SHORELINE RETREAT PROJECT INITIAL PHASE PROJECT AWARD OF CONTRACT, May 5, 2010

(3) Philip Williams & Associates, Ltd. (PWA) , Surfers Point Waterside Improvements Construction Drawings and Specifications, Phase 1, 2010.

(4)Philip Williams & Associates, Ltd. (PWA) SURFER'S POINT MANAGED SHORELINE RETREAT & ACCESS RESTORATION Preliminary Design Prepared for RRM Design Group and the City of Ventura, August 2, 2005 PWA Ref. # 1708.

Description:

The Surfer’s Point project area includes approximately 1,800 linear feet of south-facing shoreline beginning just east of the Ventura River mouth (Figures 1, 2 and 3). The project described here is called Phase 1 which was constructed in 2010-2013 and consists of 1,100 linear feet. Surfer’s Point consists of the eastern portion of the river mouth delta area and has been modified substantially by man’s activities, including a riverbank levee, a rock revetment and fill and paving. The area is also heavily used for shore access and recreation. In particular, the cobble river mouth delta creates breaking wave conditions favorable for surfing and is a heavily utilized and well-known surfing break.

The area was filled and developed across the back beach and active shore. The State Fairgrounds exists in the inland area in what was previously part of the Ventura River estuary. Public parks operated by the City and State Parks were constructed along what was the beach between the Fairgrounds and the Ocean. In 1994, the shore was heavily damaged by waves and a portion of the bike – pedestrian path and parking lot were lost (Figure 2). Surfrider Foundation and the local shore users convinced the City of Ventura and the State Fairgrounds to consider managed retreat. The State of California funded the project, but only enough funds for a portion, called Phase 1, were available. Phase 1 was constructed in 2010-2011 (Figure 3). Phase one consisted of the western 1,100 feet of shore enhancement except that the dunes were not included. The City of Ventura and Surfrider Foundation partnered to complete the dunes in Phase 1 in 2013 (Figure 4).

The design of the beach restoration included removal of development, fill and quarry stone armor over about 70 to 100 feet of width and a depth of 6 feet for about 1,100 linear feet of shore. The excavation was backfilled with cobble and sand selected to be similar to native materials, and placed to conform with natural geometry to result in a natural morphology (Figure 5). Subsequently, dune sand was added and vegetated (Figure 4).

Elements included in the project (Phase 1) are:

- 1,100 feet of shore enhancement, including removal of paving and fill, and resulting in about 2.2 acres of restored dry beach and dunes (an average restored width of about 80 feet);
- 1,600 feet of new paved pedestrian trail;
- New road and parking lot; and
- New storm drainage system.

Construction costs for the project were about $2M (2010) plus $0.6M (2010) to pre-purchase the cobble and sand. The dune construction and vegetation was accomplished opportunistically using excess sand from a nearby beach (wind-blown sand was covering homes), volunteer and City labor and equipment and grants for limited materials: The value of the dune construction is estimated at $0.5M (2013). The total construction cost estimate is therefore estimated to have been $3.1M (2010 approximate). This amounts to $2,800 / linear foot of shore (2010), and about $1.4M / acre (2010) of restored dry beach and vegetated dunes (based on 1,100 feet of shore about 80 feet wide). These costs do not include professional services and municipal staff time (design, environmental and regulatory approvals, project management, and construction period services): These additional costs are estimated to be on the order of 40% of the construction costs.

Figure 1: Location of Surfers Point, Ventura, CA.

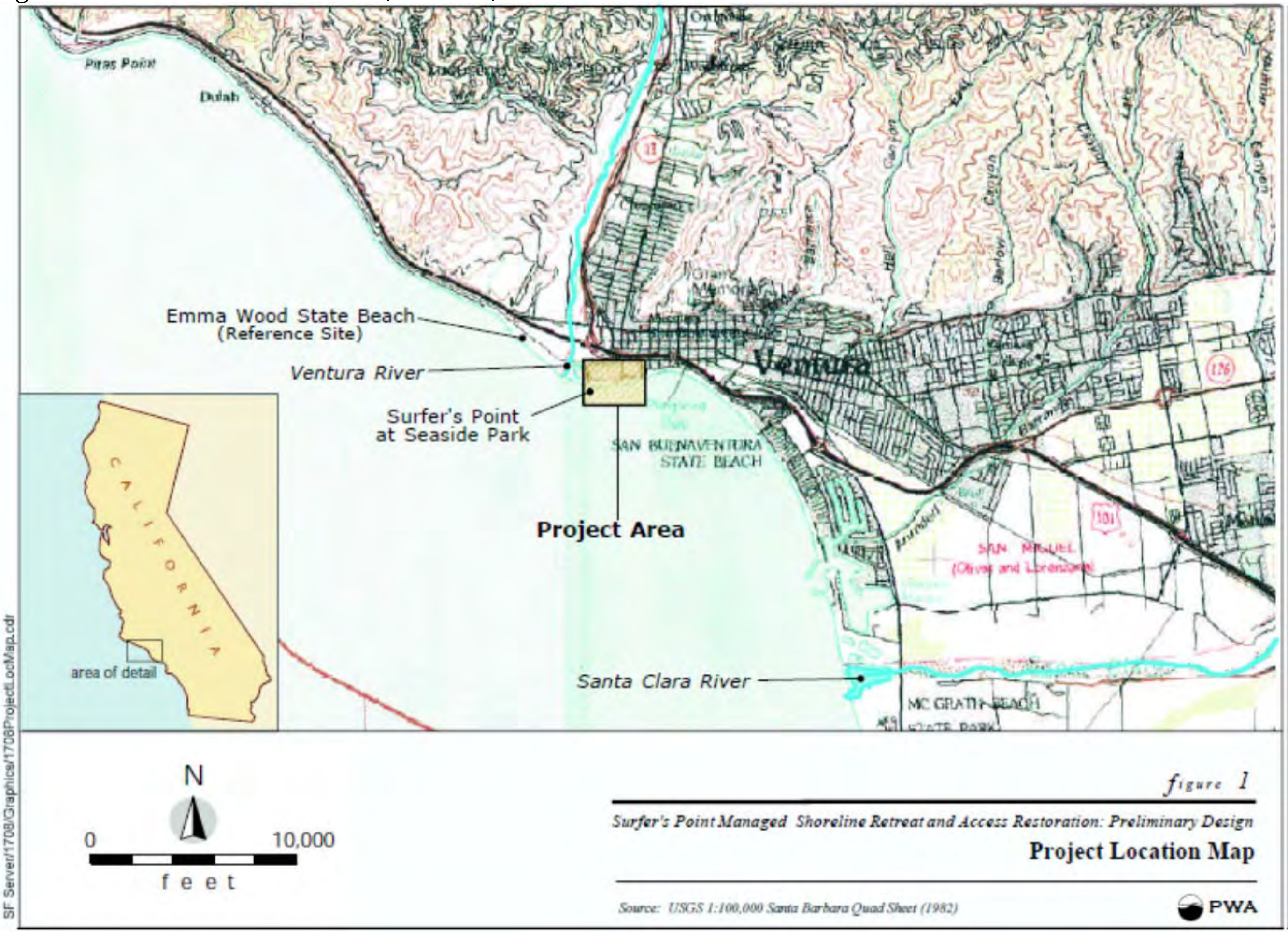
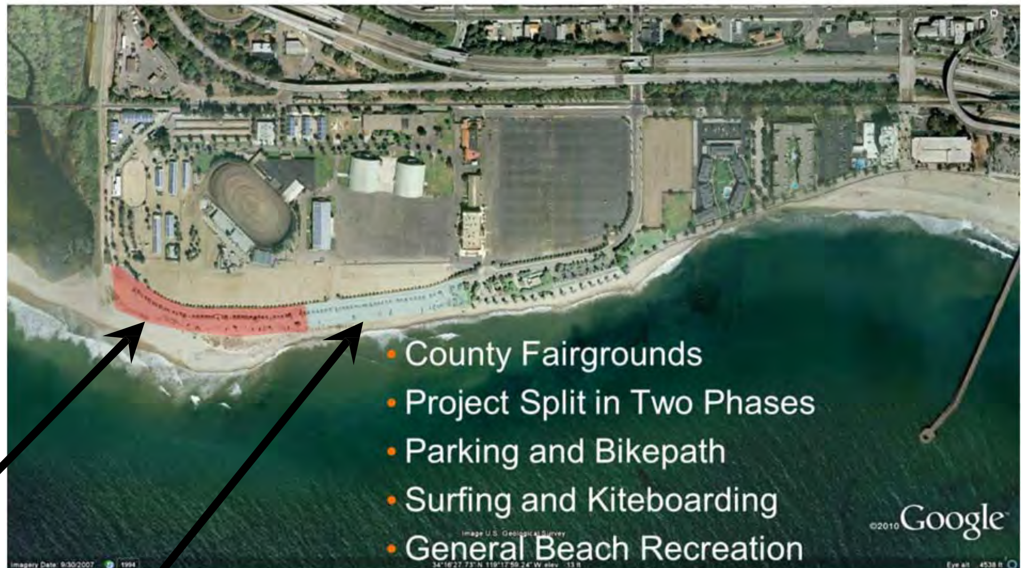


Figure 2: Pre-Project and Post Project photographs. Source: ESA.

Introduction and Background



Phase 1

Pre-project photograph

Phase 2

Post Phase 1 but Pre-Dunes

Photos courtesy of:
Rasmussen Construction,
Ventura County Fairgrounds,
City of Ventura

Figure 3: Project Elements. Source RRM Design Group.

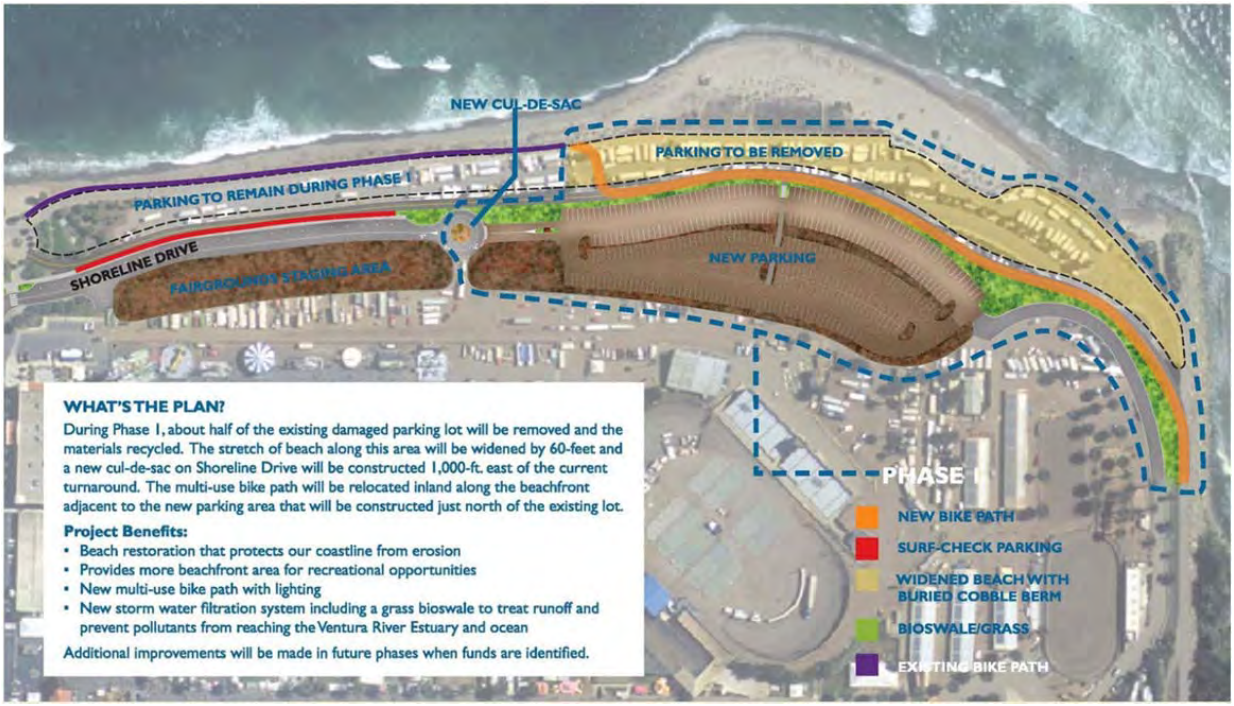


Figure 4. Vegetated dunes in Phase 1 area. Source: ESA

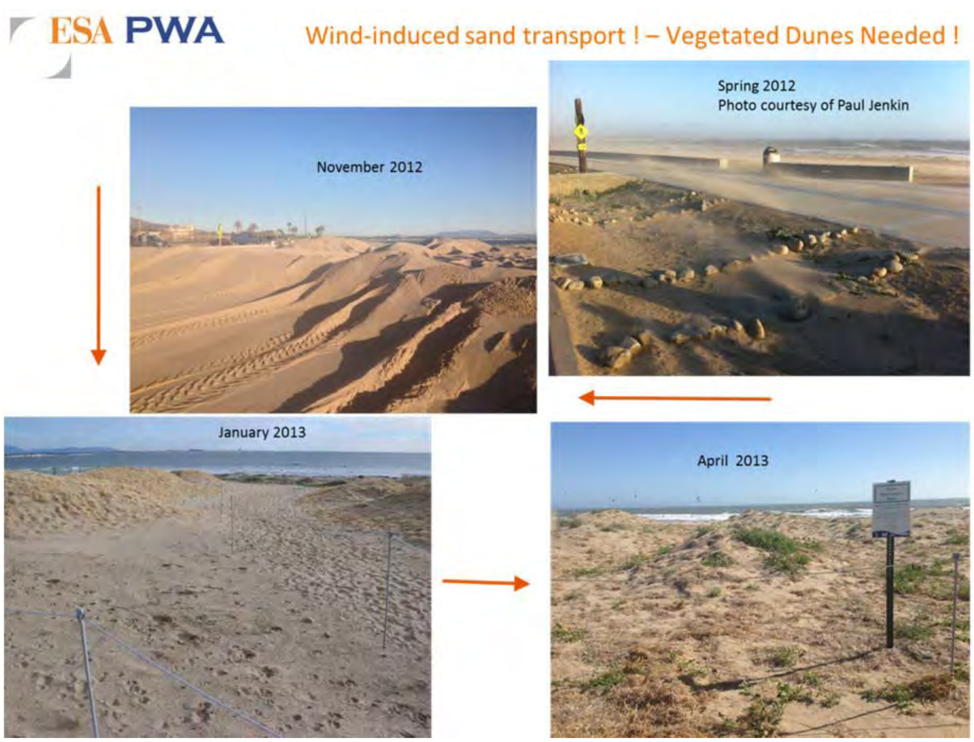
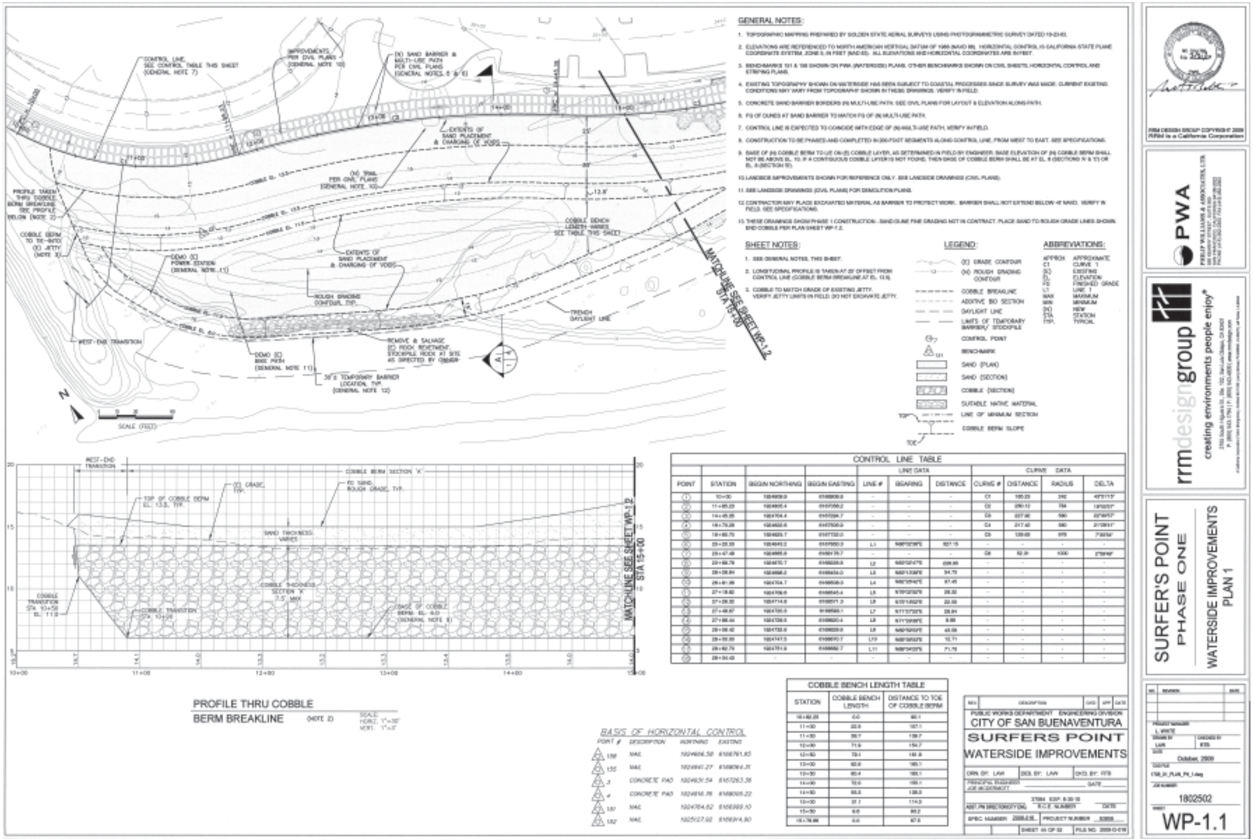
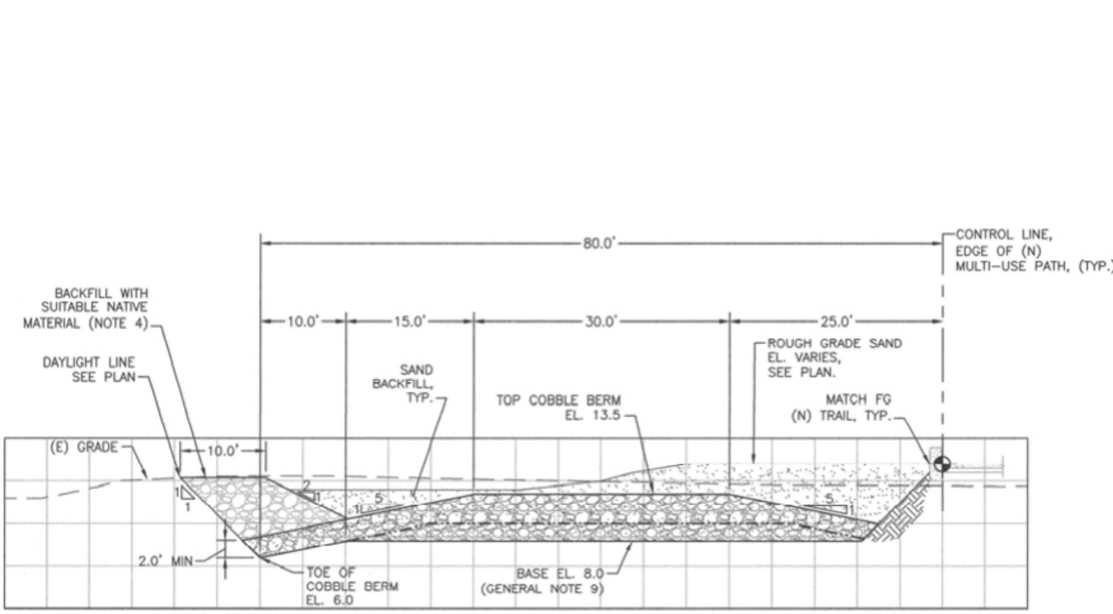


Figure 5: Plan and typical section of water side design. Source: PWA, 2010.





Ocean Beach Master Plan

Location: San Francisco, CA

Owners / Sponsors: City / County of San Francisco-Public Utilities Commission (PUC), Golden Gate National Recreation Area- National Park Service, California State Coastal Conservancy, San Francisco Planning + Urban research Association (SPUR)

Status: Conceptual design and planning, with interim implementation actions.

Summary: Restoration of 4,000 feet of shore by implementing a low-profile armoring of a buried sewer tunnel, removal of rock revetments previously constructed under emergency conditions, removing fill and development (roadway, parking and associated park elements), grading with native and imported sediments to establish stable geomorphology, planting, and construction of public facilities farther landward. The project requires to result in restoration of about 4.5 acres of dry beach (about 4,000 feet by 50 feet) while improving public access amenities. Costs about $4 Million (2004). Other elements (multi-objective creek and lagoon restoration, creation of storm water treatment wetlands, 2 miles of coastal trail, utilities relocation) resulted in additional costs of $6M and total costs of about $10M (2004). These costs do not include professional services and municipal staff time(design, environmental and regulatory approvals, project management, construction period services): These additional costs are estimated to be on the order of 40% of the construction costs.

References:

(1) SPUR, 2011 SPUR, AECOM, ESA PWA, Nelson\Nygaard, Sherwood Design Engineers, Phil D. King, PhD, 2012, Ocean Beach Master Plan, Prepared for State of California Coastal Conservancy, San Francisco Public Utilities Commission, and the National Park Service, Available online [1/9/14]: http://www.spur.org/publications/spur-report/2012-05-21/ocean-beach-master-plan .

(2) Battalio, R.T., 2014, Littoral processes along the Pacific and bay shores of San Francisco, California, USA, Shore & Beach, Vol. 82, No. 1, Winter 2014, pages 3 21.

(3) ESA, 2015 (in press). ESA,SPUR, Moffatt & Nichol, McMillen Jacobs Associates, AGS, Inc., Coastal Protection Measures & Management Strategy for South Ocean Beach, Ocean Beach Master Plan: Coastal Management Framework, Prepared for the CCSF Public Utilities Commission. Project D120925.00.

The Ocean Beach Master Plan (OBMP, SPUR 2012) study area encompasses the beach and adjacent lands from the high-water mark to the property line at the eastern edge of the Lower Great Highway, and from the beach's northern extent at the foot of the Cliff House to the Fort Funston bluffs (it excludes private property). This project focuses on the OBMP recommendations for the southern reach - South Ocean Beach (SOB) [Figure 1 Project Site] which is south of Sloat Boulevard where erosion hazards are chronic and jeopardize critical City and County of San Francisco (CCSF) infrastructure.

This area is in need of coastal protection due to the narrowing of SOB as a result of coastal dynamics and sediment transport. Over the years, CCSF responded to intense erosion jeopardizing city infrastructure with the construction of engineered revetments (boulder embankments) in order to protect the existing shoreline. However, implementation of these projects has affected the beach's natural conditions and access for recreational users. New information related to climate change, sea level rise, the impacts of several significant El Nino events, etc. have modified CCSF's approach to protect SOB and they are now focused on managed retreat. This updated thinking emphasizes the use of low impact technologies inland of the current shoreline that provide multiple benefits and opportunities for integrated management (e.g. protect critical infrastructure and provide for the protection and enhancement of natural resources).

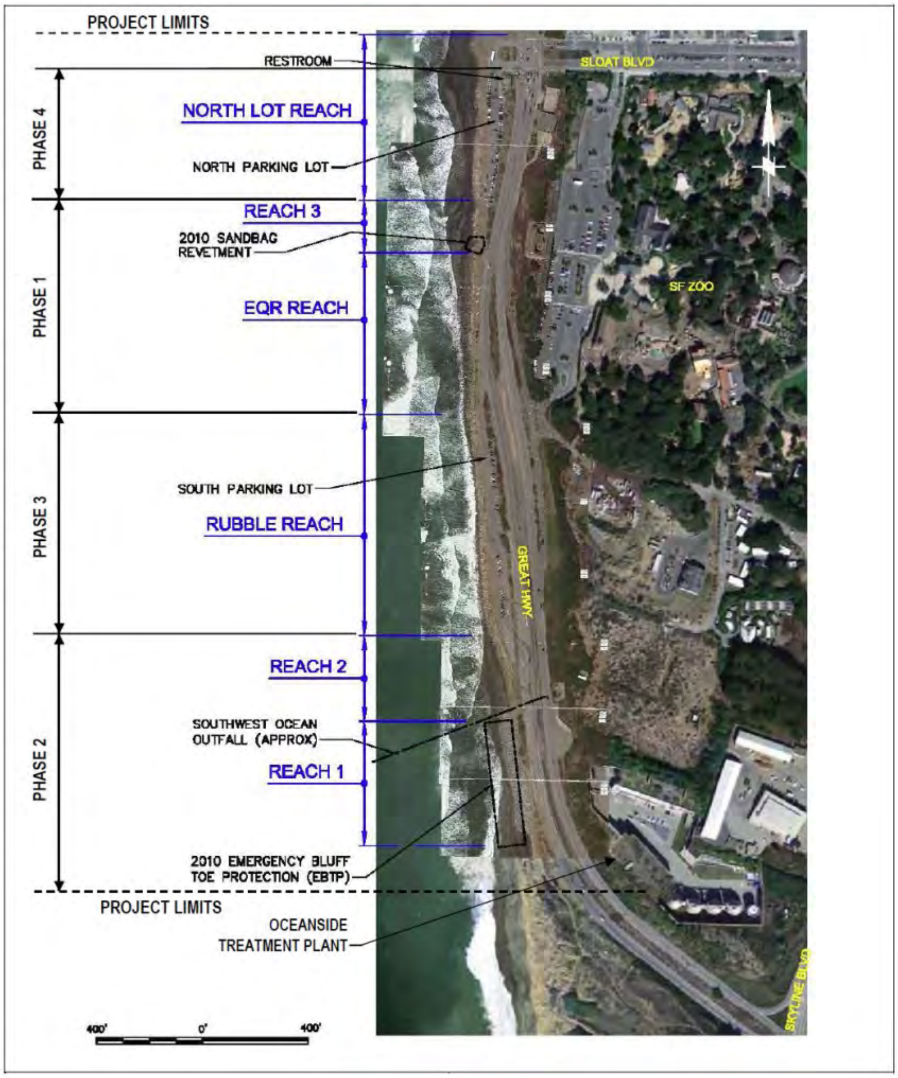
The goal of the project is to further develop long-term coastal protection measures and a management strategy using a multi-objective approach that both protects critical wastewater infrastructure (i.e. Lake Merced Tunnel) and promotes environmental stewardship. The findings and subsequent recommendations presented in this report are based on the team's coastal vulnerability and engineering feasibility analyses of coastal protection and management measures. These concepts were developed with the help of a Technical Advisory Committee. Conceptual drawings of the restored shore are shown in Figures 2,3, 4 and 5. As noted in the fourth category, further analysis (e.g. geotechnical, geo-structural, seismic response, etc.) be completed to inform a final decision on project buffers and triggers, and to inform the subsequent design stages.

The following table provides the estimated cost to implement the Ocean Beach Master Plan for the entire four mile shore (SPUR, 2012). The cost of $350M will maintain the multiple plan objectives through 2050 with higher rates of accelerated sea level rise. This will also mitigate risks associated with prior development that encroaches seaward of the historic shore (Battalio, 2014). Subsequent to this plan, a more detailed analysis has been carried out for the South Ocean Beach (SOB) area where coastal hazards are chronic and beach conditions are degraded (ESA, 2015 – in review). The Key Moves One and Two apply to this SOB area, with an approximate cost of $200M. The restored shore is expected to fluctuate between required sand placements, and will average about 50 feet with an additional 50 feet of sacrificial dune. Given that the existing beach width very narrow with essentially no dry beach at times, entire 50 feet is considered a restoration. Over the approximate 4,000 lineal feet of SOB, this amounts to about 4.5 acres of beach and about 9 acres of beach plus dune. The cost is therefore expected to be about $44M per acre of beach and about $22M per acre of beach and linear dune. These costs are high because of the many other improvements which include a new public park behind the beach, improved multi-modal traffic flow, and protection of valuable water treatment facilities and the public zoo.

Table of costs for implementation of the Ocean Beach Master Plan. Source: SPUR, 2012.

Key Move and Strategy	Estimate of Probable Cost
KEY MOVE 1: Re-route Great Highway	$48,917,077
Phased demolition, South of Sloat	$998,244
Zoo Road Access	$1,996,600
Reconfigure Sloat and Intersecitons	$11,889,840
Streetscape, bikeway, and coastal amenities	$9,316,523
Extend Muni L-Taraval Line to Zoo	$22,972,248
Reconfigure Zoo Entrance	$892,798
Coastal Trail to Fort Funston	$850,824
KEY MOVE 2: Introduce Multipurpose Coastal System	$147,052,260
Removal of rubble, revetments	$25,808,328
Protection measures (cap and cobble), phase 1	$26,952,588
Protection measures (cap and cobble), phase 2	$35,936,784
Protection measures (secondary structure) phase 3	$18,322,200
Beach Nourishment at Southern Reach (Sand)	$24,433,920
Constructed wetland	$15,598,440
KEY MOVE 3: Reduce Great Highway	$56,896,983
Narrow Hwy from 4 to 2 lanes	$44,968,431
Promenade, restrooms.amenities	$11,928,552
KEY MOVE 4: Native Dune Restoration	$35,240,000
Beach Nourishment (Sand Placement)	$24,433,920
Native Dune Restoration	$5,000,000
KEY MOVE 5: Connect GG Park with Beach	$46,090,797
Roadway and Driveway Reconfiguration	$2,011,462
Parking Lot Improvements, Amenities	$44,079,336
KEY MOVE 6: Bicycle/Pedestrian Improvements	$19,426,677
Roadway and Intersection Improvements	$18,392,123
Bikeway	$1,034,554
TOTAL	$353,623,794

Figure 1: South Ocean Beach multi-objective managed retreat project map. Source: ESA, 2015.



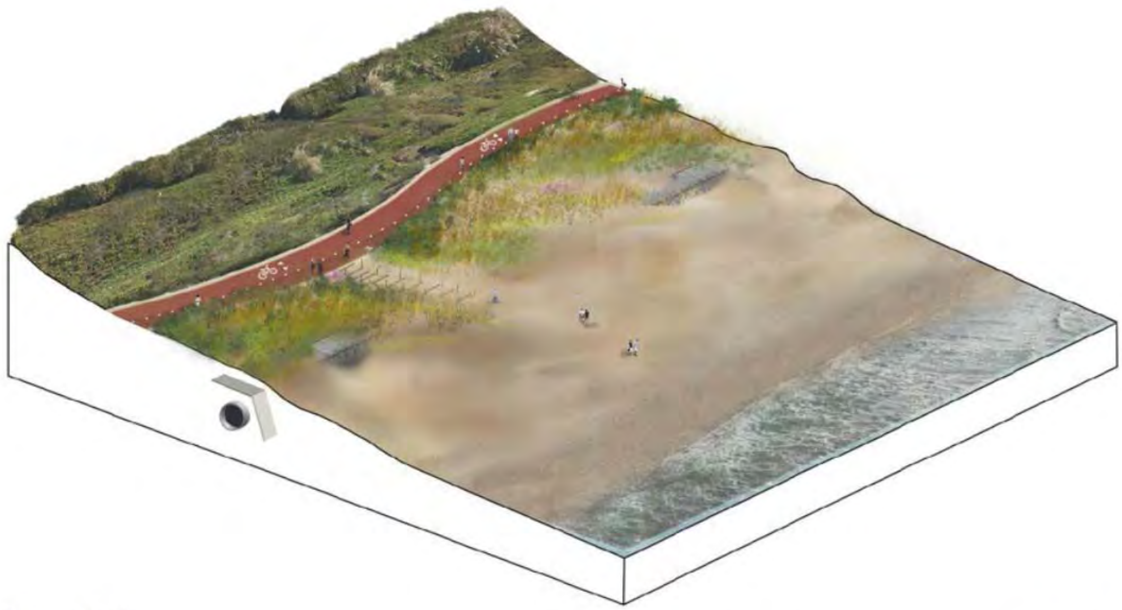
SOURCE: Moffatt & Nichol (2012)

Ocean Beach CMF: LMT Vulnerability & Feasibility . D120925.00

Figure i

Project Site and Definition of Reaches

Figure 2: Rendering of completed project. Source; ESA 2015.



Source: AECOM

Figure 5
Axon of the Ocean Beach Master Plan Long-Term Vision
for LMT Protection and Improved Access and Ecology

Figure 3: Enhancement Site plan

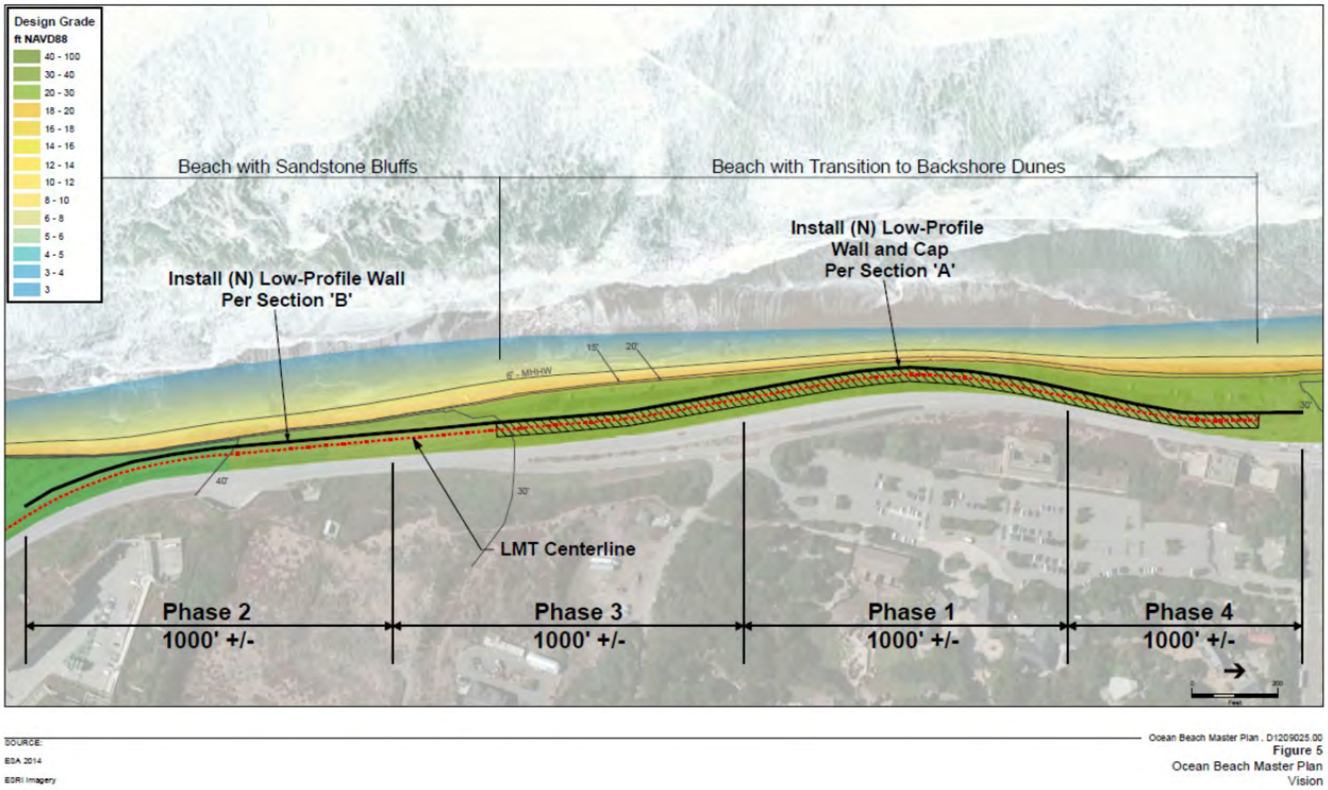
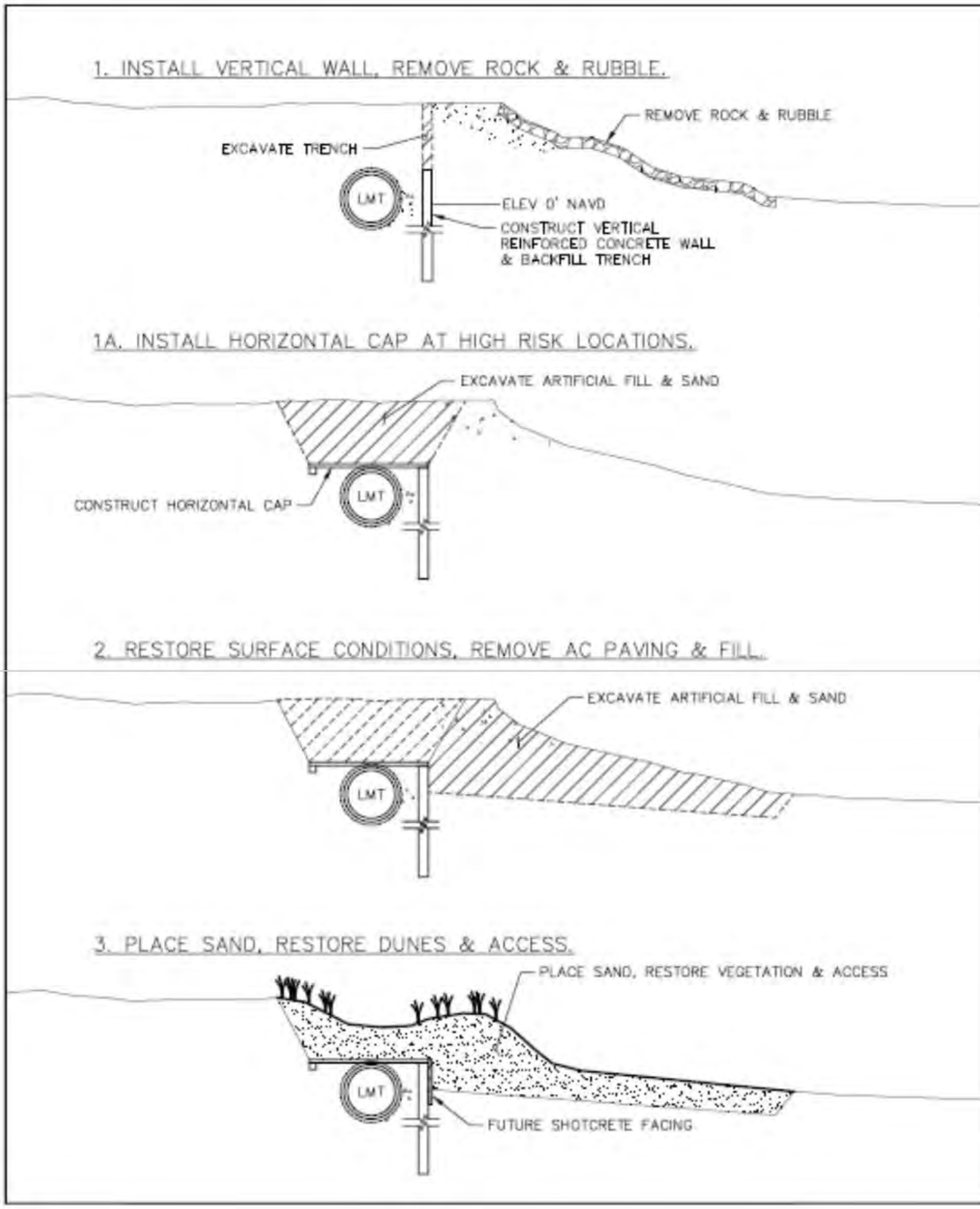


Figure 4: Typical implication schematic for low-profile infrastructure armoring and shore restoration at dune-backed shore. Source: ESA 2015.



SOURCE:

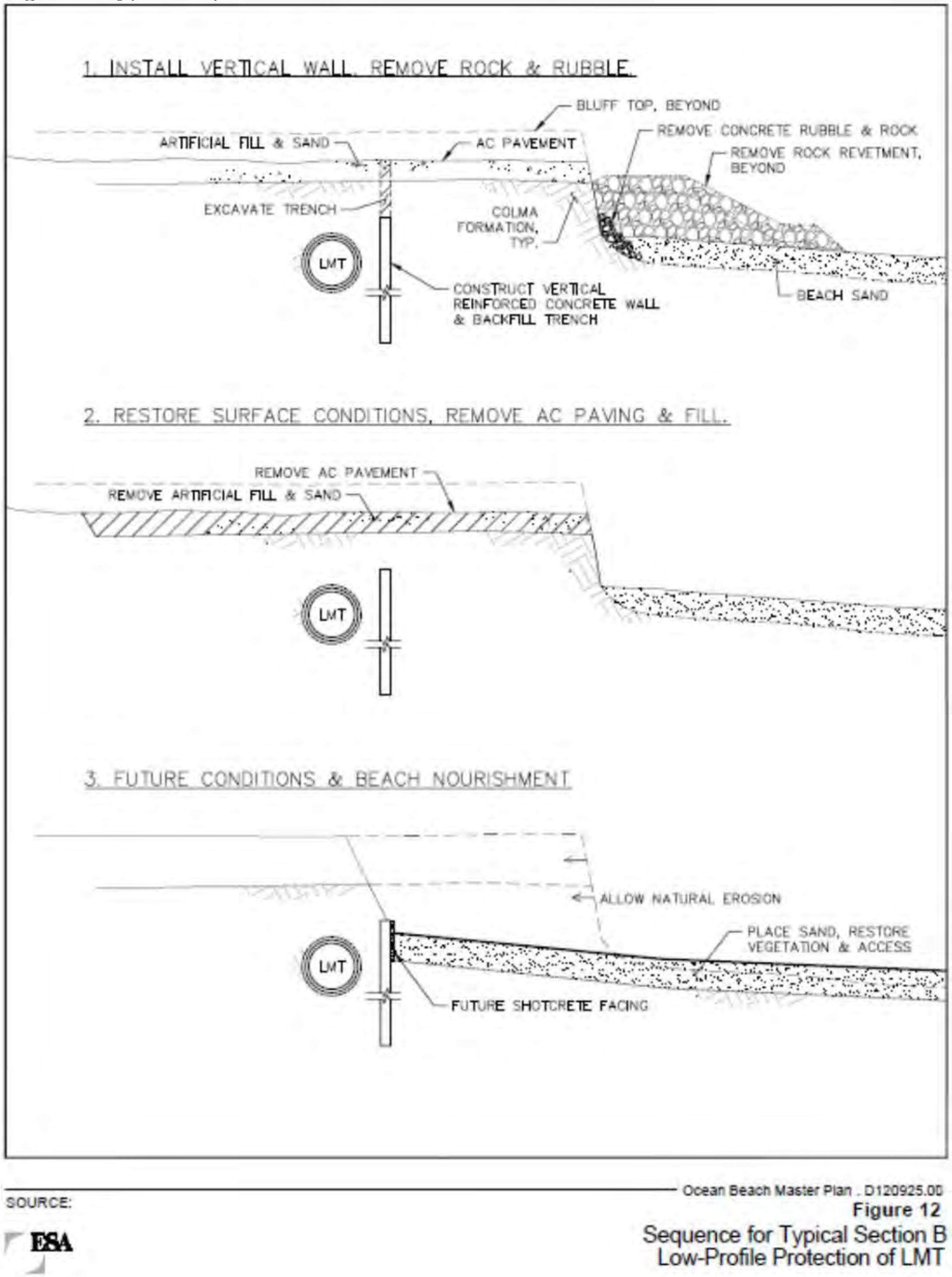
ESA

Ocean Beach Master Plan . D120925.00

Figure 11

Sequence for Typical Section A
Low-Profile Protection of LMT

Figure 5: Typical implementation schematic at bluff-backed shore. Source: ESA, 2015.



Goleta Beach Managed Retreat

Location: Goleta, CA

Owners / Sponsors: Santa Barbara County, Environmental Defense Fund, Surfrider Foundation

Status: In planning to preliminary design 1999-present.

Summary: Goleta Beach is a public park within the Santa Barbara County Park system. It includes about 2,700 linear feet of developed beach between a mesa and the mouth of Goleta Slough. The development includes extensive parking, lawn, restrooms, a pier and a restaurant, as well as Park facilities. The development was completed when the beach was wide and subsequent beach fluctuations have removed some of the fill and lawn, and replaced this area with beach. Rock revetment armoring exists along most of the shore, and is presently buried with sand on the western portion. Managed retreat has been contemplated within the context of reconfiguring the park to maintain existing amenities farther landward. However, some stakeholders prefer to armor the backshore to protect the existing park attributes. Consensus regarding park renovation has proven elusive. Estimates for the park renovation with retreat and beach restoration were developed three times between 2005 and 2015. The costs are about $2.4M per acre of beach restoration (2005), $3.0M per acre of beach restoration (2007) and $3.5M per acre of beach restoration (2011), with an overall range of -50% to +100% around each estimate. The proposed retreat and reconfiguration affected the shore primarily along the 1,100 linear feet west of the pier. However, the 2011 version affected only about one acre of new beach area over the western 700 feet of the park.

References:
(1) PWA 2005, Master Plan Goleta Beach County Park Shoreline Management Alternatives, Prepared by Philip Williams and Associates, Ltd. (PWA), Prepared for Santa Barbara County Parks, June 14, 2005, PWA REF. # 1743.01.

(2) PWA 2008. Goleta Beach County Park, Park Reconfiguration Alternative, Prepared for The Coastal Fund at UCSB, Surfrider Foundation – Santa Barbara Chapter, Environmental Defense Center, Prepared by Philip Williams & Associates, Ltd. November 24, 2008, PWA REF. #1940.00

(3) Penfield & Smith (P&S), 2011, Goleta Beach 2.0, 30% Preliminary Design Report, Summary of Findings, Prepared for the County of Santa Barbara Parks Department, Contract no. 19514.04/.06.

(4) ESA PWA, 2011, Goleta Beach Technical Memo on Erosion Mitigation Alternatives, Prepared for Penfield & Smith, Project Number 2051

Goleta Managed Retreat

Santa Barbara County Parks developed a master plan for the park that included managed retreat in 2005 (PWA, 2005). A complete park renovation was envisioned with a phased approach, with an initial action configured for a 20-year planning horizon. The initial action was focused on the western portion of the Park where a rock revetment was to be removed, and other features (utilities, parking, paving, lawn, restroom) demolished and replaced with new facilities located farther landward. The Plan was based on setting back constructed amenities landward of the zone of coastal processes, defined by the location of an extreme landward shoreline plus a spatial buffer. Reinforcement of armoring along the eastern park area was proposed to protect development (restaurant, sewer facilities, etc.) until a future date when additional park renovation could be pursued (conceptually, after 20 years). Given the concern by some stakeholders that the relocated amenities might still be subject to damages even if located landward, the County included an optional rock revetment at the landward limit of the coastal processes zone. Other alternatives were developed for subsequent environmental review: Beach Nourishment and Beach Stabilization. An evaluation of alternatives was accomplished, resulting in the following comparison:

Table 1 Summary of alternatives

	Existing Conditions	Beach Nourishment	Beach Stabilization	Managed Retreat
Lawn area	4.0	4.0	4.0	3.2 acres
Buffer area (sand or lawn)	-	-	-	1.3 acres
Beach area	3.0	4.5	4.5	4.5 acres
Parking spaces	550	550	550	550
Initial cost	-	$4.0M	$6.0M	$2.9M
Annual cost	-	$1.2M	$0.2M	-
20 year cost	-	$28.0M	$10.0M	$2.9-6.6M

The Managed Retreat alternative was found to be the lowest cost although approximately 0.8 acres of the existing 4.0 acres of lawn could be lost due to beach restoration. Taking the higher estimated cost of $6.6M (2005) and the higher estimated increase in beach area (2.8 acres) results in a cost of $2.4M (2005) per acre of beach restored. Taking the lower cost and the lower beach area results in a cost of $1.9M per acre. Other permutations result in a range of $1M to $4M per acre of restored beach, in 2005 dollars.

During subsequent environmental review, an improved Beach Stabilization concept called the “Permeable Groin” was developed and selected as a preferred approach. In this process, the Managed Retreat concept was re- designed and became exceedingly costly. During review of the EIR and associated technical studies, the likelihood that the “permeable groin” that would trap sand with no adverse effects but at a low cost was considered dubious, doubts about the new analysis grew. An update of the 2005 Park Master Plan “Managed Retreat” alternative was re-named “Park Reconfiguration Alternative” to avoid confusion, and compared to the EIR alternatives (PWA, 2008). The following table summarizes the findings (NOTE: the “Park Reconfiguration circa 2007 (below) is similar to the “Managed Retreat 2005 (above).)

Table 1. Summary of Alternatives (2007 dollars)

	Existing Conditions	Managed Retreat	Permeable Pier/ Pile Groin	Park Reconfiguration
Lawn area	4.0	2.87	4.0	4.2 acres
Buffer area (sand or lawn)	-	1.3	-	1.3 acres
Beach area	3.0	4.0	8.6	4.5 acres
Total area for recreation	7.0	8.5	12.6	10.0 acres
Alongshore length of lawn/beach	1,035	1,900	1,300	1,900 ft.
Parking spaces	594	594	594	594
Sand Pre-fill	-	100,000 yds^3	550,000 yds^3	30,000 yds^3
Initial cost	-	$7.5M	$8.7M	$4.7M
20 year cost	-	$11.1 M	$9.6M*	$8.4M

The Park Reconfiguration alternative appeared to be the most favorable. Note that the new alternative increased the area of lawn relative to the 2005 configuration. Costs were updated for consistency with the work by others, and included design and permitting costs of 17.5% of construction cost. The estimated cost for 1.5 to 2.8 acres of restored beach is $3M (2007) /acre, with a range from $1.7M to $6M per acre in 2007 dollars.

Goleta 2.0

The County of Santa Barbara re-started the park planning process and called it Goleta 2.0 (P&S, 2011). The Goleta Beach 2.0 managed retreat and erosion mitigation alternative was developed to a 30% complete level of design (P&S, 2011). The project description included:

- establishment of a landward transportation and utility corridor at the west end of the park
- protection of GSD's 36-inch sewer outfall pipe and vault near the restaurant
- Removing approximately 43,100 square feet of pavement in parking lots 6 & 7
- reestablishing a natural beach environment
- Removing the rock revetment with expired permits near the western end of the park;
- Relocating all major utilities outside of "coastal process zone;"
- Relocating a portion of the Coastal Bike Path outside of "coastal process zone;"
- Protecting relocated transportation and utility corridor and Highway 217 within "high erosion protection zone" by constructing a compacted earth berm at the western most 500 linear feet of the corridor;
- Protecting the existing Goleta Sanitary District sewer outfall pipe and vault by constructing a geo-textile core dune and buried cobble revetment; and,
- Increasing the safety of the bike path by increasing the width and raising the elevation relative to the existing parking lots.

The Goleta 2.0 Preliminary Design included less restoration than the 2008 and 2005 versions, with about one acre of new beach restored along the western 700 feet of shore, essentially from removing the western parking lot and rock revetment. The estimated cost was $3.5M (2011). The following table summarizes the estimate.

Engineer's Estimated Probable Cost of Construction

Project:	Goleta Beach 2.0	**30% Preliminary Design**
Location:	APN 071-200-017	
Client:	County of Santa Barbara	
W.O. No.:	12825.15	
Calc'd By:	mlo	
Path Name:	W:\...\19514\PHASE 04 - Goleta Beach 2.0\Project Estimates	
File Name:	19514.04_30Percent.xlsx	Date: **8/31/2011**

Penfield & Smith
111 East Victoria St.
Santa Barbara, CA 93101
(805)963-9532

SUMMARY OF COSTS				% CAPIT
Soft Costs Subtotal			**$350,000**	
Construction Costs Subtotal			**$2,186,144**	
General Construction Costs:		$56,500		
Site Demolition[1]:		$464,389		
Western Site Improvements:		$68,420		
Bike Path Improvements:		$228,450		
Utility Improvements[1]:		$151,815		
GSD Vault Protection:		$751,920		
Utility Work by Others[2]:		$464,650		
Contingency	25%		**$634,036**	
Inflation	10%		**$317,018**	
Total			**$3,487,198**	

Notes:

[1] Does not include costs for removal or construction of Reclaimed Water and High Pressure Gas Mains

[2] Includes costs for removal and construction of Reclaimed Water and High Pressure Gas Mains

Figure 1: Location of Goleta Beach. Source: P&S, 2011.

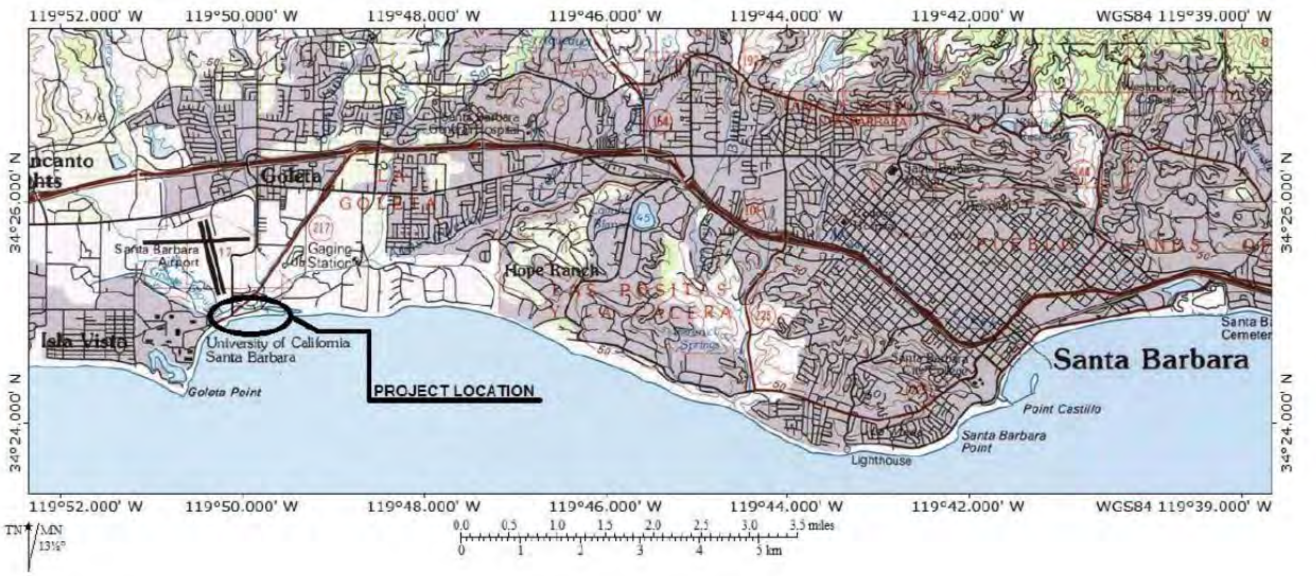


Figure 2. Managed retreat concept developed for Santa Barbara County Parks (Source:

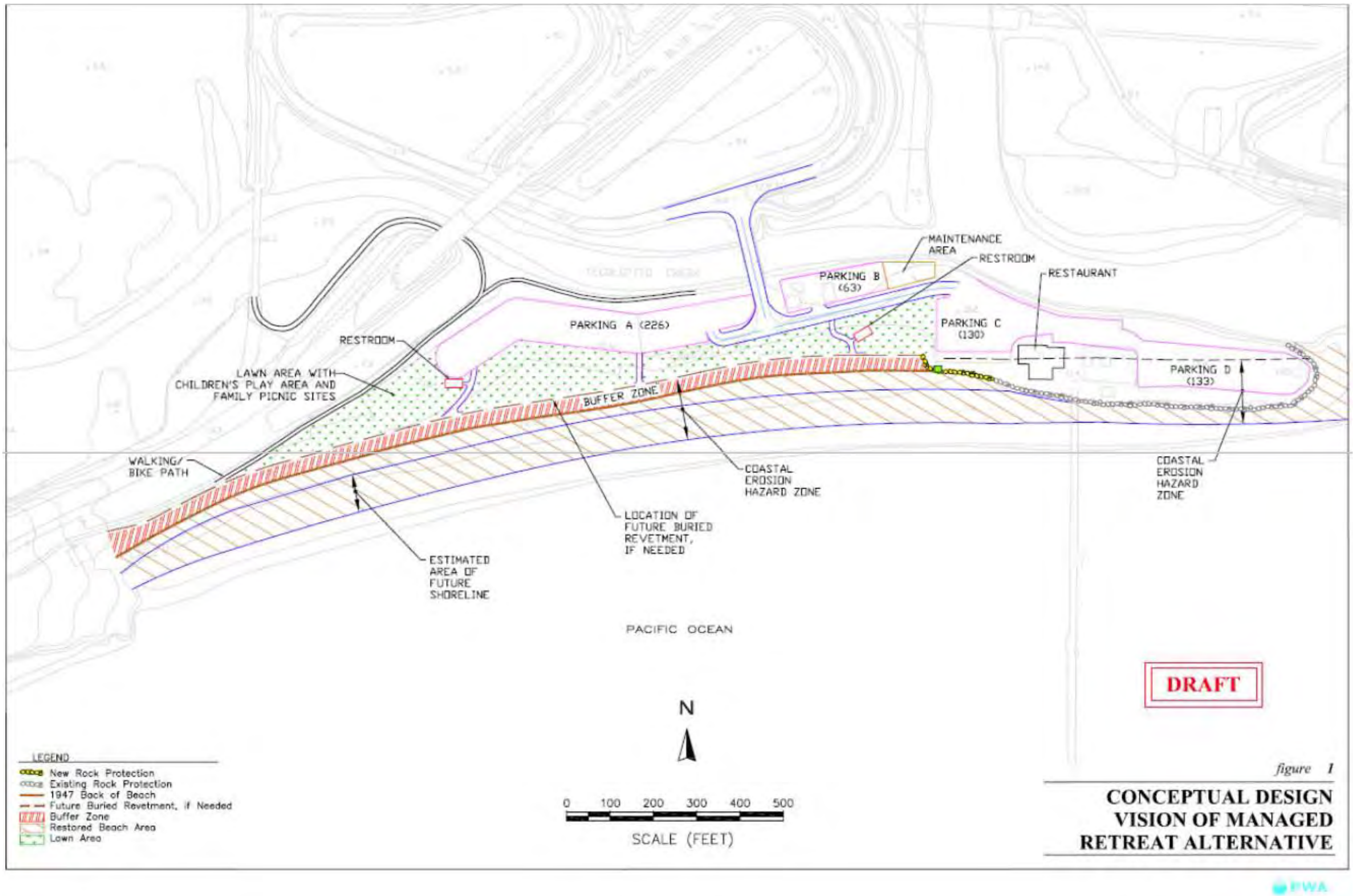


Figure 3: Schematic of the Park Reconfiguration Alternative (PWA, 2008).

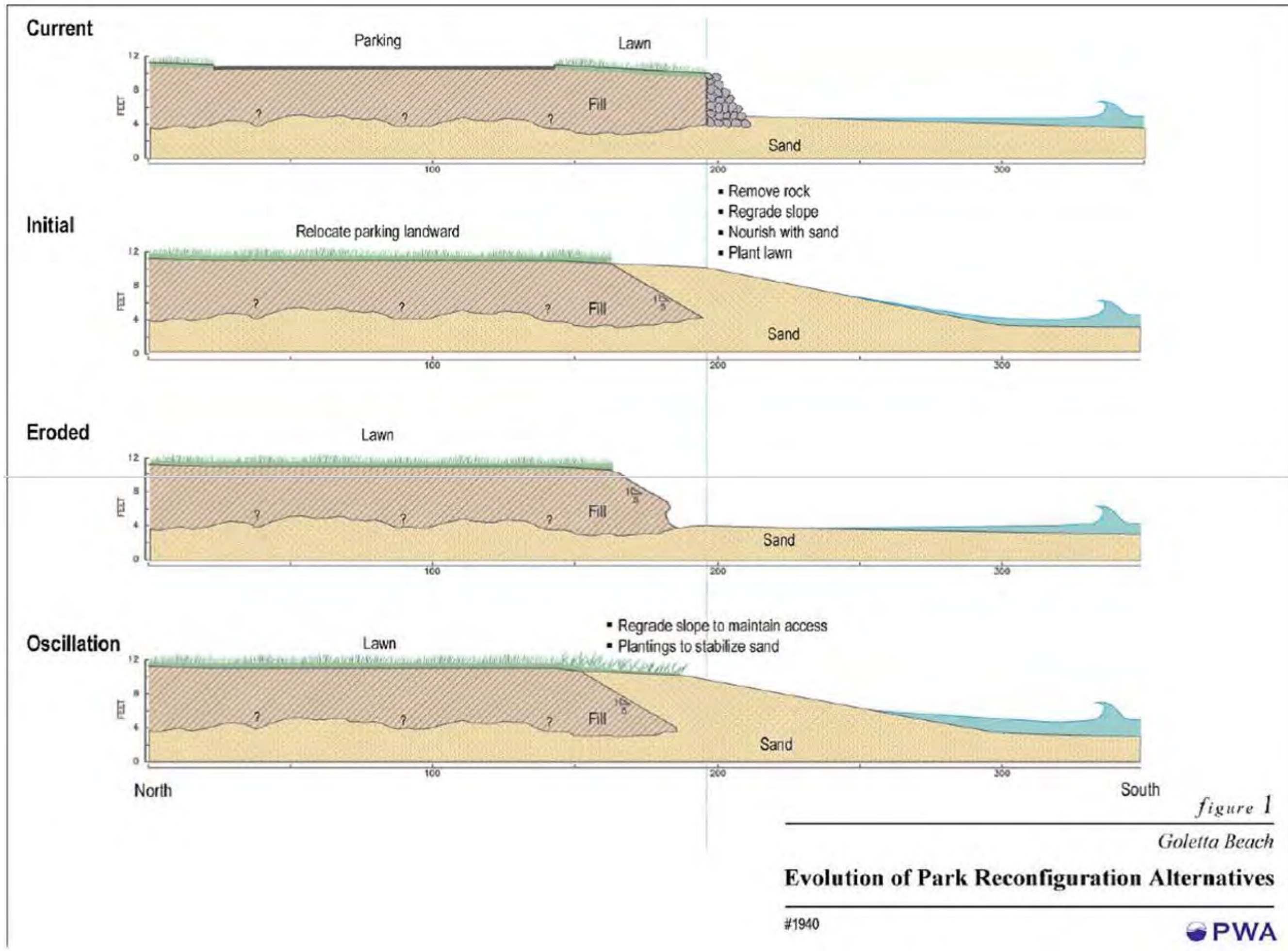
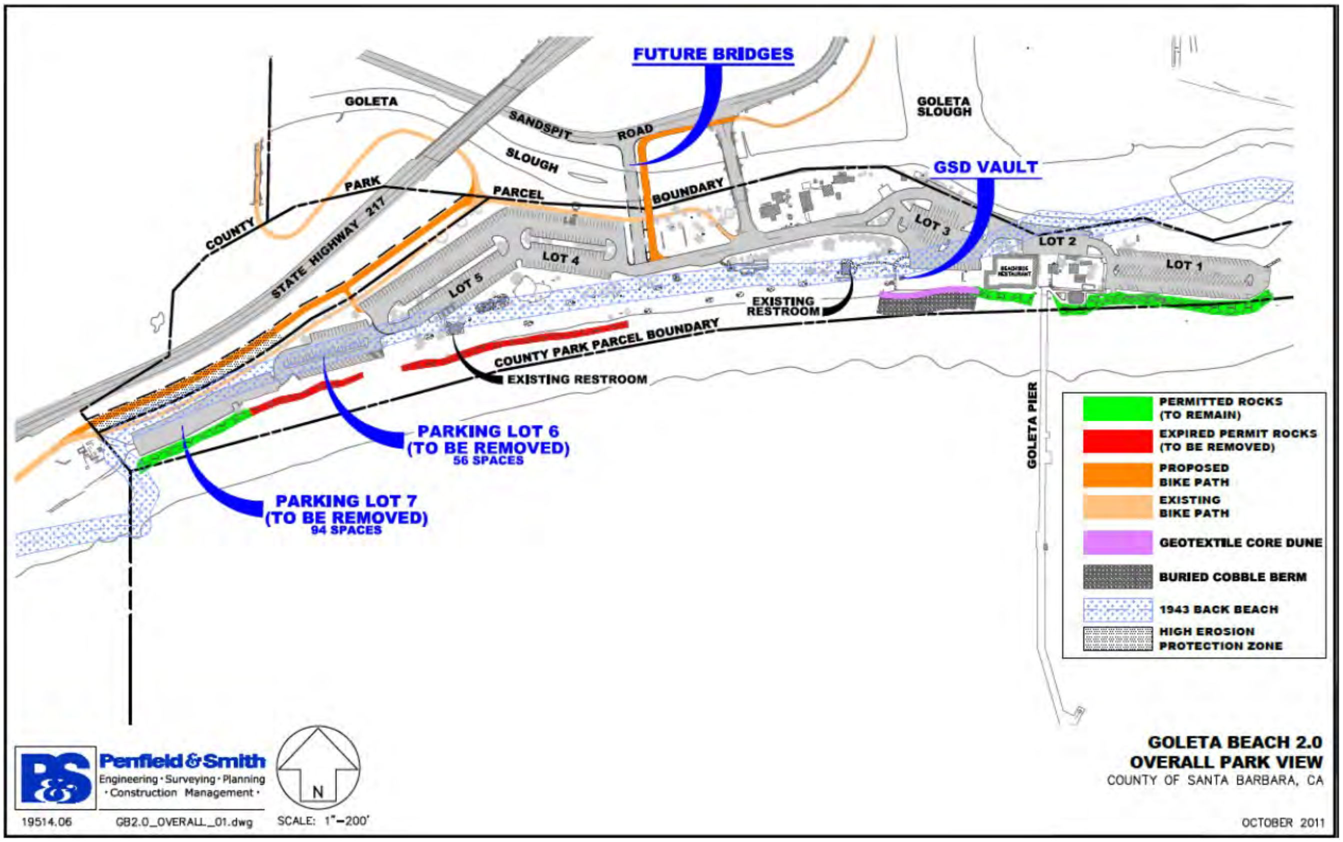


Figure 4: Goleta 2.0 plan. Source: P&S, 2011.



References

Airoldi, L., Abbiati, M., Beck, M.W., Hawkins, S.J., Jonsson, P.R., Martin, D., Moschella, P.S., Sundelöf, A., Thompson, R.C., Åberg, P., 2005. An ecological perspective on the deployment and design of low-crested and other hard coastal defence structures. Coastal Engineering 52: 1073-1087.

Arrow, K., Cropper, Gollier, Groom, Heal, Newell, Nordhaus, Pindyck, Pizer, Portney, Sterner, Tol, and Weitzman. 2014. Shou;ld Governments Use a Declining Discount Rate in Project Analysis, Review of Environmntal Economics and Policy, July 2014, pp. 1-19.

Arrow, K., Solow, R., Portney, P. R., Leamer, E. E., Radner, R., & Schuman, H. 1993. Report of the NOAA Panel on Contingent Valuation.

Atiyah, P. 2009. Non-Market Valuation and Marine Management: Using Panel Data Analysis to Measure Policy Impacts on Coastal Resources. Environmental Health Sciences. University of California Los Angeles, Los Angeles.

Bacchiocchi, F., Airoldi, L., 2003. Distribution and dynamics of epibiota on hard structures for coastal protection. Estuarine Coastal and Shelf Science 56: 1157-1166.

Banzhaf, S. H. 1996. Estimating Recreational Use Levels with Periodic Counts (No. T-9602). Triangle Economic Research.

Barbier, E. B., S. D. Hacker, C. Kennedy, E. W. Koch, A. C. Stier, and B. R. Silliman. 2011. The value of estuarine and coastal ecosystem services. Ecological Monographs 81: 169-193.

Barbour, M.G, T.M. de Jong, and B.M. Pavlik. 1985. Marine beach and dune plant communities. Physiological ecology of North American plant communities. pp. 296-322.

Barbour, M.G., and A.F. Johnson. 1988. Beach and dune. In Terrestrial vegetation of California, ed. M.G. Barbour, and J. Major, 223–262. New York: Wiley Interscience. Reprinted with supplement by California Native Plant Society, Sacramento, CA.

Barbour, M.G., T.M. de Jong, A.F. Johnson, 1976. Synecology of beach vegetation along the Pacific coast of the United States of America: a first approximation. Journal of Biogeography 3: 55-69.

Barros, F., 2001. Ghost crabs as a tool for rapid assessment of human impacts on exposed sandy beaches. Biological Conservation 97: 399- 404.

Bell, F. W., & Leeworthy, V. R. 1990. Recreational demand by tourists for saltwater beach days. Journal of Environmental Economics and Management, 18(3), 189–205. Retrieved from http://www.sciencedirect.com/science/article/B6WJ6-4CYH0R9-39/2/187be679972bae3d5b7c1d91ca655bf1

Bhat, M. G. 2003. Application of non-market valuation to the Florida Keys marine reserve management. Journal of Environmental Management, 67, 315–325.

Bilkovic, D.M., Roggero, M.M., 2008. Effects of coastal development on nearshore estuarine nekton communities. Marine Ecology Progress Series 358: 27-39.

Bird, E. 1996. Beach Management. Wiley & Sons, Chichester, England, 281 pp.

Bird, E. 2000. Coastal Geomorphology: An Introduction. Wiley & Sons, Chichester, England. 322 pp.

Bird, E.C.F., 2000. Coastal Geomorphology: An Introduction. Wiley, Chichester, 322 pp.

Bockstael, N., Costanza, R., Strand, I., Boynton, W., Bell, K., & Wainger, L. 1995. Ecological economic modeling and valuation of ecosystems. Ecological Economics, 14(2), 143-159.

Borja, A., T. C. Prins, N. Simboura, J. H. Andersen, T. Berg, J-C. Marques, J. M. Neto, N. Papadopoulou, J. Reker, H. Texeira and L. Uusitalo. 2014. Tales from a thousand and one ways to integrate marine ecosystem components when assessing the environmental status. Frontiers in Marine Science, DOI. 10.3389/fmars.2014.00072.

Bulleri, F., Airoldi, L., 2005. Artificial marine structures facilitate the spread of a non-indigenous green alga, Codium fragile ssp tomentosoides, in the North Adriatic Sea. Journal of Applied Ecology 42: 1063–1072.

Bulleri, F., Chapman, M.G., 2010. The introduction of coastal infrastructure as a driver of change in marine environments. Journal of Applied Ecology 47 (1), 26–35.

Burger, J., 1994. The effect of human disturbance on foraging behavior and habitat use in piping plover (*Charadrius melodus*). Estuaries 17(3): 695–701.

Caldwell, M., & Segall, C. H. 2007. No Day at the Beach: Sea Level Rise, Ecosystem Loss and Public Access Along the California Coast. Ecology Law Quarterly, 34, 533–555.

California Dept. of Boating and Waterways (2009) Orange County Coastal Regional Sediment Master Plan (CRSMP), April 2012: http://www.dbw.ca.gov/csmw/pdf/OCCRSMP_DraftReport.pdf.

California Dept. of Boating and Waterways. 2012. Coastal Regional Sediment Master Plan: Point Conception to Point Magu (CRSMP), April 2009: http://www.dbw.ca.gov/csmw/pdf/CRSMP_Report_FINAL_30Mar2011.pdf.

Cardiff, T. T. 2001. Conflict in the California Coastal Act: Sand and Seawalls. California Western Law Review, 38, 255.

Carlton, J.T., Hodder, J., 2003. Maritime mammals: terrestrial mammals as consumers in marine intertidal communities. Marine Ecology Progress Series 256: 271–286.

Carson, R. T., Flores, N. E., Martin, K. M., Wright, J. L., Economics, L., Feb, N., & Wn, J. L. 1996. Contingent Valuation and Revealed Preference Methodologies: Comparing Estimates for Quasi-Public Goods. Land Economics, 72(1), 80-99.

Chapman, D. J. and W. M. Hanneman. 2001. Environmental Damages In Court: The American Trader Case. The Law and Economics of the Environment: 319-367.

Chapman, D. J., & Hanneman, W. M. 2001. Environmental Damages In Court: The American Trader Case. In A. Heyes (Ed.), The Law and Economics of the Environment (pp. 319–367).

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

Chapman, M.G., Underwood, A.J., 2009. Comparative effects of urbanization in marine and terrestrial habitats. In: McDonnell, M.J., Hahs, A.K., Breuste, J.H. (Eds.).

Charlier, R.H., Chaineux, M.C.P., Morcos, S., 2005. Panorama of the history of coastal protection. Journal of Coastal Research 21(1): 79–111.

Chessman, B.C. 1995. Rapid assessment of rivers using macroinvertebrates: A procedure based on habitat-specific sampling, family level identification and a biotic index. Australian Journal of Ecology, 20, 122–129.

Christoffers, E.W., 1986. Ecology of the ghost crab Ocypode quadrata (Fabricius) on Assateague Island, Maryland and the impacts of various human uses of the beach on their distribution and abundance. Ph.D. Thesis, Michigan State University, Ann Arbor, MI, USA.

Colombini, I., Chelazzi, L., 2003. Influence of marine allochthonous input on sandy beach communities. Oceanography and Marine Biology: Annual Review 41:115–159.

Costanza, R., & Daly, H.E. 1992. Natural Capital and Sustainable Development. Conservation Biology, 6(1), 37-46.

Costanza, R., D'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. Van Den Belt, M. 1997. The value of the world's ecosystem services and natural capital. Nature, 387(6630), 253-260.

Costanza, R., Wilson, M. A., Troy, A., Voinov, A., Liu, S., & D'Agostino, J. 2006. The Value of New Jersey's Ecosystem Services and Natural Capital. Environmental Protection. Gund Institute for Ecological Economics. 177 pp.

Dale, V.H., & Beyeler, S.C. 2001. Challenges in the development and use of ecological indicators. Ecological Indicators, 1, 3–10.

Daly, H.E. 2005. Operationalising Sustainable Development by Investing in Natural Capital. In N. C. Sahu & A. K. Choudhurys (Eds.), Dimensions of Environmental and Ecological Economics Universities Press. 481-494 pp.

de Groot, R.S., Wilson, M.A., & Boumans, R.M.J.(2002). A typology for the classification, description, and valuation of ecosystem functions, goods and services. Ecological Economics, 41, 393-408.

de la Huz, R., Lastra, M., Junoy, J., Castellanos, C., & Vieitez, J.M. 2005. Biological impacts of oil pollution and cleaning in the intertidal zone of exposed sandy beaches: Preliminary study of the ‘‘Prestige’’ oil spill. Estuarine, Coastal and Shelf Science, 65, 19–29.

Defeo, O. 2003. Marine invertebrate fisheries in sandy beaches: an overview. Journal of Coastal Research SI, 35, 56–65.

Defeo, O., & Mclachlan, A. 2005. Patterns , processes and regulatory mechanisms in sandy beach macrofauna: A multi-scale analysis. Marine Ecology Progress Series, 295, 1-20.

Defeo, O., A. McLachlan, D. S. Schoeman, T. A. Schlacher, J. Dugan, A. Jones, M. Lastra, and F. Scapini. 2009. Threats to sandy beach ecosystems: a review. Estuarine, Coastal and Shelf Science 81, 1-12.

DeLuca, W.V., Studds, C.E., King, R.S., Marra, P.P., 2008. Coastal urbanization and the integrity of estuarine waterbird communities: threshold responses and the importance of scale. Biological Conservation 141 (11), 2669–2678.

Department of Fish and Game (DFG). 1999. California Fish and Game Code, Section 2853. Marine Life Protection Act.

Dethier, M.N., McDonald, K., Strathmann, R.R., 2003. Colonization and connectivity of habitat patches for coastal marine species distant from source populations. Conservation Biology 17: 1024–1035.

Dugan, J. 2012. Considering climate change for sandy beach ecosystems in southern California. A presentation at the Headwaters to Oceans conference, May 31, 2012.

Dugan J. E., D.M. Hubbard. 2006. Ecological responses to coastal armoring on exposed sandy beaches. Shore and Beach 74(1): 10-16.

Dugan J.E., D.M. Hubbard, I.F. Rodil, D. Revell. 2008. Ecological effects of coastal armoring on sandy beaches. Mar. Ecol. 29: 160-170Dugan J.E., D.M. Hubbard.

2010. Loss of coastal strand habitat in southern California: the role of beach grooming. Estuaries and Coasts 33(1): 67-77.

Dugan J.E., D.M. Hubbard, M. McCrary, M. Pierson. 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuarine Coastal Shelf Science 58S:133-148.

Dugan, J. E., D. M. Hubbard, and B. Quigley. 2013. Beyond beach width: steps toward identifying and integrating dynamic ecological envelopes with geomorphic features and datums for sandy beach ecosystems. Geomorphology 199: 95-105.

Dugan, J. E., D. M. Hubbard, I. F. Rodil, D. L. Revell, and S. Schroeter. 2008. Ecological effects of coastal armoring on sandy beaches. Marine Ecology 29, S1, 160-170. DOI: 10.1111/j.1439-0485.2008.00231.x

Dugan, J. E., D. M. Hubbard, M. D. McCrary, and M. O. Pierson. 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuarine, Coastal and Shelf Sciences 58S, 25-40.

Dugan, J. E., D. M. Hubbard. In press. Sandy beach ecosystems. Contributed chapter in Ecosystems of California (eds E. Zavaleta, H. Mooney) University of California Press.

Dugan, J. E., D.M. Hubbard, B.J. Quigley. 2013. Beyond beach width: steps toward identifying and integrating dynamic ecological envelopes with geomorphic features and datums for sandy beach ecosystems. Geomorphology 199: 95–105

Dugan, J. E., L. Airoldi, Chapman MG, Walker SJ, and Schlacher T. 2012. Estuarine and Coastal Structures: Environmental Effects, A Focus on Shore and Nearshore Structures. In: E. Wolanski and D. S. McLusky (eds.) Treatise on Estuarine and Coastal Science, Vol 8, pp. 17–41. Waltham: Academic Press.

Dugan, J. E., O. Defeo, E. Jaramillo, A. R. Jones, M. Lastra, R. Nel, C. H. Peterson, F. Scapini, T. Schlacher, and D. S. Schoeman. 2010. Give beach ecosystems their day in the sun. Science 329, 1146.

Dugan, J., L. Airoldi, M. G. Chapman, S. Walker & T. A. Schlacher. 2012. Estuarine and Coastal Structures: Environmental Effects: a focus on shore and nearshore structures. In: Human-induced Problems (Uses and Abuses) pp 17-41, in: Estuaries and Coasts (eds. M. Kennish, M. Elliot), Treatise on Estuarine and Coastal Science Vol. 8 Chapter 2, Elsevier.

Dugan, J.E. and D. M. Hubbard. 2010a. Loss of coastal strand habitat in southern California: The role of beach grooming. Estuaries and Coasts 33(1): 67- 77.

Dugan, J.E. and D. M. Hubbard. 2010b. Ecological effects of coastal armoring: a summary of recent results for exposed sandy beaches in southern California. In: Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, USGS Publications, pp. 187-193.

Dugan, J.E., & Hubbard, D.M. 2006. Ecological responses to coastal armoring on exposed sandy beaches. Shore and Beach, 74, 10–16.

Dugan, J.E., D. M. Hubbard, H.M.Page, J. Schimel. 2011. Marine macrophyte wrack inputs and dissolved nutrients in beach sands. Estuaries and Coasts 34(4): 839-850

Dugan, J.E., D.M. Hubbard, K.J. Nielsen, J. Altstatt and J. Bursek. 2015. Baseline characterization of sandy beach ecosystems along the south coast of California. Final report to California Sea Grant. https://caseagrant.ucsd.edu/sites/default/files/SCMPA-24-Final-Report_0.pdf

Dugan, J.E., Hubbard, D.M., & Lastra, M. 2000. Burrowing abilities and swash behavior of three crabs, *Emerita analoga* Stimpson, *Blepharipoda occidentalis* Randall and

Lepidopa californica Efford (Anomura, Hippoidea), of exposed sandy beaches. Journal of Experimental Marine Biology and Ecology, 255: 229-245.

Dugan, J.E., Hubbard, D.M., McCrary, M.D., & Pierson, M.O. 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuarine, Coastal and Shelf Science, 58S, 25–40.

Dugan, J.E., Hubbard, D.M., Page, H.M., Schimel, J. 2011. Marine macrophyte wrack inputs and dissolved nutrients in beach sands. Estuaries and Coasts in press.

Dugan, J.E., Hubbard, D.M., Rodil, I., Revell, D.L., & Schroeter, S. 2008. Ecological effects of coastal armoring on sandy beaches. Marine Ecology, 29, 160–170.

Dunford, R.W., Ginn, T.C., & Desvousges, W.S. 2004. The use of habitat equivalency analysis in natural resource damage assess- ments. Ecological Economics, 48 (1), 49–70.

Dwight, R.H., Brinks, M.V., Sharavana Kumar, G., Semenza, J.C. 2007. Beach attendance and bathing rates for Southern California beaches. *Journal of Ocean and Coastal Management* 50 (10), 847e858.

E. A. Smyder, K. L M. Martin, and R. E. Gatten Jr. 2002. Temperature effects on egg survival and hatching during the extended incubation period of California Grunion, Leuresthes tenuis. Copeia: 2002(2): 313-320.

Ekins, P., Simon, S., Deutch, L., Folke, C., & De Groot, R. 2003. A framework for the practical application of the concepts of critical natural capital and strong sustainability. Ecological Economics, 44, 165–185.

English, D. B. K., Kriesel, W., Leeworthy, V. R., & Wiley, P. C. 1996. Economic Contribution of Recreating Visitors to the Florida Keys/Key West. University of Georgia, the Southern Forest Research Station.

Feagin, R.A., D. J. Sherman, and W. E. Grant. 2005. Coastal erosion, global sea-level rise, and the loss of sand dune plant habitats. Frontiers in Ecology and the Environment 7(3), 359-364.

Feagin, R.A., Sherman, D.J., Grant, W.E., 2005. Coastal erosion, global sea-level rise, and the loss of sand dune plant habitats. Frontiers in Ecology and the Environment 7(3): 359–364.

Fletcher, C. H., R. A. Mullane and B. M. Richmond. 1997. Beach loss along armored shorelines in Oahu, Hawaiian Islands. Journal of Coastal Research 13, 209-215.

Fletcher, C.H., Mullane, R.A., Richmond, B.M., 1997. Beach loss along armored shorelines on Oahu, Hawaiian Islands. Journal of Coastal Research 13: 209–215.

Flick, R.E. and L. C. Ewing. 2009. Sand volume needs of southern California beaches as a function of future sea-level rise rates. Shore & Beach 77, 36-45.

Fu, Bo-Jie, Su, C, Wei, Y., Willet, I., Lu, Y., Liu, G., 2010. Double Counting in Ecosystem Services Valuation: Causes and Countermeasures. Ecological Research 26:1-14.

Glasby, T.M., Connell, S.D., 1999. Urban structures as marine habitats. Ambio 28, 595–598.

Glasby, T.M., Connell, S.D., Holloway, M.G., Hewitt, C.L., 2007. Nonindigenous biota on artificial structures: could habitat creation facilitate biological invasions? Marine Biology 151: 887–895.

Gollier, C., and Weitzman, M. 2010. How should the distant future be discounted when discount rates are uncertain? Economics Letters 107 (2010) 350–353.

Griggs, G. 1985. Living With the California Coast. Living With the Shore. Durham, NC: Duke University Press.

Griggs, G. 1998. California’s Coastline: El Nino, Erosion, and Protection. In U. of S. C. S. Grant (Ed.), California’s Coastal Natural Hazards, CSBPA Conference (pp. 36–55).

Griggs, G. 2005b. The Impacts of Coastal Armoring. Shore & Beach, 73(1), 13–22.

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., K. Patsch, and L. Savoy. 2005. Living with the Changing California Coast. University of California Press, Berkeley. 551 pp.

Griggs, G.B., 1998. The armoring of California’s coast. In: Magoon, O.T., Converse, H., Baird, B., Miller-Henson, M. (Eds.), California and the World Ocean ’97, Conference Proceedings. American Society of Civil Engineers, Reston, VA, pp. 515–526.

Griggs, G.B., 2005a. California’s retreating coastline: where do we go from here? In: Santa Barbara, C.A., Magoon, O.T., Converse, H., Baird, B., Miller-Henson, M. (Eds.), California and the World Ocean, Conference Proceedings, October 2002. American Society of Civil Engineers, Reston, VA, pp. 121–125.

Griggs, G. B. 2010. *The Effects of Armoring Shorelines—The California Experience*, *in* Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, May 2009: U.S. Geological Survey Scientific Investigations Report, at 77-84 (Hugh Shipman et al. eds., 2010).

Haab, T. C., & McConnell, K. E. 2002. Valuing Environmental and Natural Resources: The Econometrics of Non-Market Valuation (p. 326). Northhampton, MA: Edward Elgar Publishing Limited, Inc.

Hall, M.J., Pilkey, O.H., 1991. Effects of hard stabilization on dry beach widths for New Jersey. Journal of Coastal Research 7(3): 771–785.

Hampton and Zafonte. 2005. Resource Valuation. California Dept. of Fish and Wildlife. https://www.wildlife.ca.gov/OSPR/NRDA/Resource-Valuation.

Hanemann, M., Pendleton, L., Mohn, C., Hilger, J., Kurisawa, K., Layton, D., Busch, C., & Vasquez, F. (2004). Using revealed preference models to estimate the effect of coastal water quality on beach choice in Southern California. A Report from the Southern California Beach Valuation Project. 70 pp.

Harris, L., E. E.Campbell, R. Nel and D. Schoeman. 2014. Rich diversity, strong endemism, but poor protection: addressing the neglect of sandy beach ecosystems in coastal conservation planning. Diversity and Distributions 2014, 1-16.

Heberger, M., Cooley, H., Herrera, P., Gleick, P. H., & Moore, E. 2009. The Impacts of Sea-level rise on the California Coast. (C. C. C. Center, Ed.). Pacific Institute.

Heerhartz, S.M., M.N. Dethier, J.D. Toft, J.R. Cordell and A.S. Ogston. 2014. Effects of shoreline armoring on beach wrack subsidies to the nearshore ecotone in an estuarine fjord. Estuaries and Coasts 37(5): 1256-1268.

Howe, MA, PH Geissler, BA Harrington. 1989. Population trends of North American shorebirds based on the International Shorebird Survey. Biological Conservation 49: 185-199

Hubbard, D. M. and J. E. Dugan 2003. Shorebird use of an exposed sandy beach in southern California. Estuarine, Coastal, and Shelf Science 58S, 169-182.

Hubbard, D. M., & Dugan, J. E. 2003. Shorebird use of an exposed sandy beach in southern California. Science, 58 (Supplement 1), 41-54.

Hubbard, D.M., J.E. Dugan. 2003. Shorebird use of an exposed sandy beach in southern California. Estuarine Coastal Shelf Science 58S: 169-182.

Jackson, N.L., Smith, D.R., Nordstrom, K.F., 2008. Physical and chemical changes in the foreshore of an estuarine beach: implications for viability and development of horseshoe crab Limulus polyphemus eggs. Marine Ecology Progress Series 355: 209–218.

James, J. J. R. 2000. From beaches to beach environments: linking the ecology, human use, and management of beaches in Australia. Ocean and Coastal Management 43, 495-514.

Jaramillo E., J. Dugan, H. Contreras. 2000. Abundance, tidal movement, population structure and burrowing rate of Emerita analoga (Stimpson 1857) (Anomura, Hippidae) at a dissipative and a reflective beach in south central Chile. Mar. Ecol. Napoli 21(2): 113-127.

Jaramillo, E, J.E. Dugan, D.M. Hubbard, D. Melnick. M. Manzano, C. Duarte, C. Campos, R. Sánchez. 2012. Ecological legacies of extreme events: footprints of the 2010 earthquake along the Chilean coast. PloS ONE. 7(5): e35348

Jaramillo, E, JE Dugan, DM Hubbard, D Melnick. M Manzano, C Duarte, C. Campos, R. Sánchez. Ecological implications of extreme events: footprints of the 2010 earthquake along the Chilean coast. PLoS One 7(5), e35348

Jaramillo, E., Contreras, H., Bollinger, A., 2002b. Beach and faunal response to the construction of a seawall in a sandy beach of south central Chile. Journal of Coastal Research 18(3): 523–529.

Jaramillo, E., Dugan, J., Contreras, H., 2002a. Abundance, tidal movement, population structure and burrowing rate of Emerita analoga (Stimpson 1857) (Anomura, Hippidae) at a dissipative and a reflective beach in south central Chile. Marine Ecology Napoli 21(2): 113–127.

Johnson P. B., K. L. Martin, T. L. Vandergon, R. L. Honeycutt, R. S. Burton and A. Fry. 2009. Microsatellite and mitochondrial genetic comparisons between northern and southern populations of California Grunion Leuresthes tenuis. Copeia 2009, 465-474.

Kendall, M.A., Burrows, M.T., Southward, A.J., Hawkins, S.J., 2004. Predicting the effects of marine climate change on the invertebrate prey of the birds of rocky shores. Ibis 146(S1): 40–47.

Kersten, M., Piersma, T., 1987. High levels of energy expenditure in shorebirds: metabolic adaptations to an energetically expensive way of life. Ardea 75: 175–187.

King, P. 1999. The Fiscal Impact of California Beaches, A report commissioned by the California Department of Boating and Waterways. Public Research Institute, San Francisco University 1999.

King, P. 2001. Overcrowding and the Demand for Beaches in Southern California. A Report prepared for the Department of Boating and Waterways.

King, P. 2006. The Economics of Regional Sediment Management in Ventura and Santa Barbara Counties: A Pilot Study Interim Report To The Coastal Sediment Management Workgroup. (T. B. E. A. for C. O. and N. (BEACON), Ed.).

King, P. G. 2001 Economic Analysis of Beach Spending and the Recreational Benefits of Beaches in the City of San Clemente, San Francisco State University.

King, P. G. 2006. Estimating Attendance at California's Beaches: An Overview with an Analysis of Data from South Carlsbad and the City of Encinitas. San Diego: California and World Ocean Conference.

King, P. G. 2014 data collected at beaches in San Francisco, Daly City, Pacifica and Inner San Francisco Bay for Coastal Regional Sediment Master Plans, reports forthcoming.

King, P., & McGregor, A. 2012. Who's Counting: An Analysis of Beach Attendance Estimates in Southern California. Prepared for the California Department of Boating and Waterways.

Klapow, L.A., 1972. Fortnightly molting and reproductive cycles in the sand-beach isopod, Excirolana chiltoni. Biological Bulletin 143: 568–591.

Kraus, N.C., McDougal, W.G., 1996. The effects of seawalls on the beach: part 1, an updated literature review. Journal of Coastal Research 12(3): 691–701.

Landry, C. E., & Hindsley, P. 2011. Valuing Beach Quality with Hedonic Property Models. Land Economics, 87(1), 92–108.

Lawrenz-Miller, S. 1991. Grunion spawning versus beach nourishment: nursery or burial ground? Proceedings of the 7th Symposium on Coastal and Ocean Management. Coastal Zone '91, 3, 2197-2208.

Leeworthy, V. R. 1995 Transferability of Bell and Leeworthy Beach study to Southern California Beaches. Memo to David Chapman, June 22 (Exhibited 939) reported in Chapman, David and Michael Hanemann 2001.

Leeworthy, V. R. and P. C. Wiley. 1993. Recreational Use Value for Three Southern California Beaches. Rockville, Maryland, Strategic Environmental Assessments Division, Office of Ocean and Resource Conservations and Assessment, National Ocean and Atmospheric Administration.

Leeworthy, V. R., & Bowker, J. M. 1997. Nonmarket Economic User Value of the Florida Keys/Key West. Publisher?

Leeworthy, V. R., Bowker, J. M., Hospital, J. D., & Stone, E. A. 2005. Projected Participation in Marine Recreation: 2005 & 2010. U.S. Department of Commerce National Oceanic and Atmospheric Administration National Ocean Service Special Projects Silver Spring, Maryland.

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.

Lew, D. K. and D. M. Larson. 2005. Valuing Recreation and Amenities at San Diego County Beaches. Coastal Management 33: 71-85.

Lipton, D. W., Wellman, K., & Weifer, S. and R. F. 1995. Economic Valuation of Natural Resources - A Handbook for Coastal Resource Policymakers. NOAA Coastal Ocean Program Decision Analysis Series 5. (p. 131). Silver Spring, MD: NOAA Coastal Ocean Office.

Llewellyn, P. J. and S.E. Shackley. 1996. The effects of mechanical beach-cleaning on invertebrate populations. British Wildlife 7, 147-155.

Loomis, J. B., & Rosenberger, R. S. 2006. Reducing barriers in future benefit transfers: Needed improvements in primary study design and reporting. Ecological Economics, 60, 343–350.

Lucrezi, S., Schlacher, T.A., Walker, S.J., 2009. Monitoring human impacts on sandy shore ecosystems: a test of ghost crabs (Ocypode spp.) as biological indicators on an urban beach. Environmental Monitoring and Assessment 152: 413–424.

Manning L.M., C.H. Peterson, and M.J. Bishop 2014. Dominant macrobenthic populations experience sustained impacts from annual disposal of fine sediments on sandy beaches. Marine Ecology Progress Series 508:1-15.

Manning, L.M., C.H. Peterson, and S.R. Fegley 2013. Degradation of surf zone foraging habitat driven by persistent sedimentological modifications caused by beach nourishment. Bulletin Marine Science 89(1): 83-106.

Martin, D., Bertasi, F., Colangelo, M.A., de Vries, M., Frost, M., Hawkins, S.J., Macpherson, E., Moschella, P.S., Satta, M.P., Thompson, R.C., Ceccherelli, V.U.,

2005. Ecological impact of coastal defence structures on sediments and mobile infauna: evaluating and forecasting consequences of unavoidable modifications of native habitats. Coastal Engineering 52: 1027–1051.

Martin, K. L. M. 2015. Beach-spawning Fishes: Reproduction in an Endangered Ecosystem. CRC Press, Taylor & Francis Group, Boca Raton, FL, USA.199 pp. .

Martin, K. L. M., K. A. Hieb, and D. A. Roberts. 2013. A southern California icon surfs north: local ecotype of California Grunion Leuresthes tenuis (Atherinopsidae) revealed by multiple approaches during temporary habitat expansion into San Francisco Bay. Copeia 2013, 729-739. DOI 10.1643/CI-13-036.

Martin, K., T. Speer-Blank, R. Pommerening, J. Flannery, and K. Carpenter. 2006. Does beach grooming harm grunion eggs? Shore & Beach 74, 17-22.

Martin, K.L.M. and J.G. Raim. 2014. Avian predators target nocturnal runs of the beach-spawning marine fish, California Grunion, *Leuresthes tenuis* (Atherinopsidae). Bulletin of the Southern California Academy of Science 113(3).

Martínez, M.L., Intralawan, A., Vázquez, G., Pérez-Maqueo, O., Sutton, P., & Landgrage, R. 2007. The cost of our world: ecological, economic and social importance. Ecological Economics, 63, 254-272

McLachlan, A. and A. C. Brown. 2006. The Ecology of Sandy Shores, 2nd Ed. Academic Press, San Diego, California. 373 pp.

McLachlan, A., Jaramillo, E., 1995. Zonation on sandy shores. Oceanography and Marine Biology: An Annual Review 33: 305–335.

McLachlan, A., Wooldridge, T., Van der Horst, G., 1979. Tidal movements of the macrofauna on an exposed sandy beach in South Africa. Journal of Zoology (London) 188: 433–442.

Miles, J.R., Russell, P.E., Huntley, D.A., 2001. Field measurements of sediment dynamics in front of a seawall. Journal of Coastal Research 17(1): 195–206.

Moiser, A.E., Witherington, B.E., 2002. Documented effects of coastal armoring structures on sea turtle nesting behavior. In: Mosier A., Foley A., Brost B. (Eds)., Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Tech. Memo. NMFS-SEFSC-477.

Morrison, RIG, Y Augry, RW Butler, GW Beyersbergen, GM Donaldson, CL Gratto-Trevor, P Wicklin, VH Johnston, RK Ross. 2001. Declines in North American shorebird populations. Wader Study Group Bulletin 94: 34-38.

Naeem, S., ONeill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387(6630): 253–260.

Nelsen, C. 2012. Collecting and using Economic Information to Guide the Management of Coastal Recreational Resources in California. University of California, Los Angeles.

Nelsen, C., Pendleton, L., & Vaugh, R. 2007. A Socioeconomic Study of Surfers at Trestles Beach. Shore & Beach, 75(4), 32–37.

Neuman, K.K. L.A. Henkel, G.W. Page 2008. Shorebird Use of Sandy Beaches in Central California. Waterbirds, 31(1): 115-121.

Niles, L.J., Bart, J., Sitters, H.P., Dey, A.D., Clark, K.E., Atkinson, P.W., Baker, A.J., Bennett, K.A., Kalasz, K.S., Clark, N.A., Clark, J., Gillings, S., Gates, A.S., Gonzalez, P.M., Hernandez, D.E., Minton, C.D.T., Morrison, R.I.G., Porter, R.R., Ross, R.K., Veitch, C.R., 2009. Effects of horseshoe crab harvest in Delaware Bay on red knots: are harvest restrictions working? BioScience 59(2): 153–164.

Nordstrom, K.F., 2000. Beaches and Dunes of Developed Coasts. Cambridge University Press, Cambridge.

NRC 2007. Mitigating shoreline erosion along sheltered coasts. Ocean Study Board, National Research Council. National Academies Press, Washington, D.C.

NRC, N. R. C. 2004. Valuing Ecosystem Services: Toward Better Environmental Decision-Making . Washington, D.C.: National Academies Press.

Orme, A. R., G. B. Griggs,, D. L. Revell, J. G. Zoulas, C. C. Grandy, and H. Koo. 2011. Beach changes along the southern California coast during the 20th century: a comparison of natural and human forcing factors. Shore & Beach 79, 38-50.

Page, Gary W., Lynne E. Stenzel, G. W. Page, J. S. Warriner, J. C. Warriner and P. W. Paton. 2009. Snowy Plover (Charadrius nivosus), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/154

Parsons, G. R. 2003. The Travel Cost Model, Chapter 9. In T. B. P. Champ and K. Boyle. (Ed.), Primer on Non-market Valuation . Norwell: Kluwer Academy.

Pendleton, L. 2008. The Economic and Market Value of Coasts and Estuaries: What's At Stake? (p. 182). Restore America's Estuaries.

Pendleton, L. and J. Kildow. 2006. The Non-market Value of Beach Recreation in California. Shore & Beach 74(2): 34-37.

Pendleton, L., & Kildow, J. 2005. The Economic Impact of California Beaches: Expenditures and Non-Market Values for Day Use Visitors. California Ocean Economics Report. California Resources Agency.

Pendleton, L., & Kildow, J. 2006. The Non-market Value of Beach Recreation in California. Shore & Beach, 74(2), 34–37.

Pendleton, L., Mohn, C., Vaughn, R.K., King, P., & Zoulas, J.G. 2012. Size matters: the economic value of beach erosion and nourishment in Southern California. Contemporary Economic Policy, 30(2), 223-237.

Pendleton, L., P, King., Mohn, C., Webster, D.G., Vaughn, R., & Adams, A. 2011. Estimating the potential economic impacts of climate change on Southern California beaches. Climatic Change, 109(S1), 277-298.

Peterson, C.H., 1991. Intertidal zonation in sand and mud. American Scientist 79(3): 236-249.

Peterson, C. H. and M. J. Bishop. 2005. Assessing the environmental impacts of beach nourishment. Bioscience 55(10), 887-896.

Peterson, C. H., D. H. M. Hickerson and G. G. Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. Journal of Coastal Research 16, 368-37.

Peterson, C. H., M. J. Bishop, G. A. Johnson, L. M. D'Anna, and L. M. Manning. 2006. Exploiting beach filling as an unaffordable experiment: benthic intertidal impacts propagating upwards to shorebirds. Journal of Experimental Marine Biology and Ecology 338, 206-221.

Peterson, C.H., M.J. Bishop, L.M. D'Anna and G.A. Johnson. 2014. Multi-year persistence of beach habitat degradation from nourishment using coarse shelly sediments. Science of the Total Environment 487: 481-492.

Pilkey, O. H. and A. G. Cooper. 2014. The Last Beach. Duke University Press, 256 pp.

Polis, G.A., Hurd, S.D., 1996. Linking marine and terrestrial food webs: allochthonous input from the ocean supports high secondary productivity on small island and coastal land communities. American Naturalist 147: 396–423.

Quetier, F. & Lavorel, S. 2011. Assessing ecological equivalence in biodiversity offset schemes: Key issues and solutions. Biological Conservation

Ranwell, D.S. & Boar, R. 1986. Coast dune management guide. Institute of Terrestrial Ecology, HMSO, London.

Ray, G. 2008. Habitat Equivalency Analysis : A Potential Tool for Estimating Environmental Benefits. Analysis (p. 9). Vicksburg, MS.

Reeves, B., Bookhein, B., Berry, H., 2003. Using ShoreZone inventory data to identify potential forage fish spawning habitat. Abstract from the 2003 Georgia Basin/Puget Sound Research Conference.

Revell D.L., J.E. Dugan, D.M. Hubbard. 2011. Physical and ecological responses to the 1997-98 El Nino. Journal of Coastal Research 27(4): 718-730.

Rice, C. 2006. Effects of shoreline modification on a northern Puget Sound beach: Microclimate and embryo mortality in surf smelt (*Hypomesus pretiosus*). Estuaries and Coasts 29, 63-71.

Roberts D., R. N. Lea and K. L. M. Martin. 2007. First record of the occurrence of the California Grunion, *Leuresthes tenuis*, in Tomales Bay, California; a northern extension of the species. California Fish & Game 93, 107-110.

Roberts, C. M., Branch, G., Bustmante, R. H., Castilla, J. C., Dugan, J., Halpern, B. S., & Lafferty, K. D. 2003. Application of ecological criteria in selecting marine reserves and developing reserve networks. Ecological Applications, 13(sp1), 215-228.

Rodil, I.F, E. Jaramillo, D.M. Hubbard, J.E. Dugan, D. Melnick, C. Velasquez. 2015. Responses of dune plant communities to continental uplift from a major earthquake: sudden releases from coastal squeeze. PloS ONE DOI:10.1371/journal.pone.0124334

Rosenberger, R. S., & Loomis, J. B. 2000. Benefit Transfer of Outdoor Use Recreation Values. Gen. Tech. Rep. RMRS-GTR-72. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 59 p. (p. 59). Fort Collins, CO.

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

San Diego Association of Governments. 2014. SANDAG Regional Beach Monitoring Program, prepared by Coastal Frontiers Corporation.

Scapini, F. and O. Ottaviano. 2010. The possible use of sandhoppers as bioindicators of environmental stress on sandy beaches. Vol. 21, 33-44. ISSN: 1130-4251.

Schlacher, T. A., D. S. Schoeman, A. R. Jones, J. E. Dugan, D. M. Hubbard, O. Defeo, C. H. Peterson, M. A. Weston, B. Maslo, A. D. Olds, F. Scapini, R. Nel, L. R. Harris, S. Lucrezi, M. Lastra, C. M. Huijbers, and R. M. Connolly. 2014. Metrics to assess ecological condition, change, and impacts in sandy beach ecosystems. Journal of Environmental Management 144, 322-335.

Schlacher, T. A., D. S. Schoeman, J. Dugan, M. Lastra, A. Jones, F. Scapini, and A. McLachlan. 2008. Sandy beach ecosystems: key features, sampling issues, management challenges and climate change impacts. Marine Ecology 29, 70-90.

Schlacher, T., J. E. Dugan, D. S. Schoeman, M. Lastra, A. Jones, F. Scapini, A. McLachlan, and O. Defeo. 2007. Sandy beaches at the brink. Diversity and Distributions 13: 556–560.

Schlacher, T.A., Lucrezi, S., & Robinson, W. (2010). Can storms and shore armouring exert additive effects on sandy-beach habitats and biota? Marine and Freshwater Research, 61, 951–962.

Schlacher, T.A., Schoeman, D.S., Dugan, J., Lastra, M., Jones, A., Scapini, F., & McLachlan, A. (2008). Sandy beach ecosystems: key features, management challenges, climate change impacts, and sampling issues. Marine Ecology, 29, 70–90.

Schlacher, T.S., A.R. Jones, J. E. Dugan, M. Weston, L. Harris, D. S. Schoeman, D. Hubbard, F. Scapini, R. Nel, M. Lastra, A. McLachlan, C.H. Peterson. 2014. Chapter 5: Open-coast sandy beaches and coastal dunes. J. Lockwood, B. Mazlo (Eds.) pp 37-94 In: Coastal Conservation. Cambridge University Press, Series in Conservation Biology

Schooler, N. K., J. E. Dugan, D.M. Hubbard. 2014. Detecting change in intertidal species richness over time on sandy beaches: calibrating across sampling designs. Estuarine, Coastal and Shelf Science 150: 58-66.

Sherman, D.J., Barron, K.M., & Ellis, J.T. 2002. Retention of beach sands by dams and debris basins in southern California. Journal of Coastal Research, 36(SI), 662–674.

Sobocinski, K.L., Cordell, J.R., Simenstad, C.A., 2010. Effects of shoreline modifications on supratidal macroinvertebrate fauna on Puget Sound, Washington beaches. Estuaries and Coasts 33, 699–711. doi:10.1007/s12237-009-9262-9.

Toft, J.D., Cordell, J.R., Simenstad, C.A., Stamatiou, L.A., 2007. Fish distribution, abundance, and behavior along city shoreline types in Puget Sound. North American Journal of Fisheries Management 27, 465–480.

Viola, S., J. E. Dugan, D. M. Hubbard, N.K. Schooler. 2014. Burrowing in beach fill, implications for recovery of sandy beach ecosystems. Estuarine, Coastal and Shelf Science150: 142-148.

Wallmo, K. 2003. Assessment of Techniques for Estimating Beach Attendance. (N. O. and A. A. Damage Assessment Center, Ed.). Silver Springs.

Wiegel, R.L., 2002a. Seawalls, seacliffs, beachrock: what beach effects? Part 1. Shore and Beach 70 (1), 17–27.

Wiegel, R.L., 2002b. Seawalls, seacliffs, beachrock: what beach effects? Part 2. Shore and Beach 70 (2), 13–22.

Wiegel, R.L., 2002c. Seawalls, seacliffs, beachrock: what beach effects? Part 3. Shore and Beach 70 (3), 2–14.

Wood, D.W., Bjorndal, K.A., 2000. Relation of temperature, moisture, salinity and slope to nest site selection in loggerhead sea turtles. Copeia 2000, 119–128.

Yates, M. L., R. T. Guza, W. C. O'Reilly, and R. J. Seymour. 2009. Overview of seasonal sand level changes on southern California beaches. Shore & Beach 77: 39-46.

Zhang, K., B. C. Douglas, and S. P. Leatherman. 2004. Global warming and coastal erosion. Climate Change 64: 41-58.

Zhuang, J., Liang, Z., Lin, T., & Guzman, F. De. 2007. Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey (p. 51).

Appendix B. Scope of Work for Academic Assistance

EXHIBIT A
(Interagency Agreement)

STATEMENT OF WORK

1. The California Coastal Commission ("the Commission") hereby contracts with San Francisco State University (SFSU) to provide services in accordance with the specifications stated in the Scope of Work, pursuant to the Project of Special Merit Grant Award from National Oceanic and Atmospheric Administration's Office of Ocean and Coastal Resource Management (NOAA-OCRM). The federal award documents for NOAA grant #NA12NOS4190026 are incorporated herein by this reference.

2. The term of this agreement will be for a period of eighteen (18) months from July 1, 2013 to December 31, 2014. There is an amendment option to extend the term of the agreement for an additional six (6) month time period under the same terms and conditions.

3. The project representatives during the term of this agreement will be:

Requesting Agency: California Coastal Commission	Providing Agency: San Francisco State University, Office of Research & Sponsored Programs
Name: Michelle Jesperson, Federal Programs Manager	Name: Janet Framiglio, ORSP Contract Coordinator
Address: 45 Fremont Street, Suite 2000 San Francisco, CA 94105	Address: 1600 Holloway Avenue, ADM 471 San Francisco, CA 94132
Phone: (415) 904-5297	Phone: (415) 405-0739
Fax: (415) 904-5400	Fax: (415) 338-2493

Direct all inquiries to:

Requesting Agency: California Coastal Commission	Providing Agency: San Francisco State University
Section/Unit: Federal Programs	Section/Unit: Office of Research & Sponsored Programs
Attention: Michelle Jesperson	Attention: Susan Pelton, Manager
Address: 45 Fremont St., Suite 2000 San Francisco, CA 94105	Address: 1600 Holloway Avenue, ADM 471 San Francisco, CA 94132
Phone: (415) 904-5297	Phone: (415) 338-7090
Fax: (415) 904-5400	Fax: (415) 338-2493

4. Scope of Work

SCOPE OF WORK

Improved Valuation of Impacts to Recreation, Public Access, and Beach Ecology from Shoreline Armoring in California

I. Introduction

The purpose of this work is to build upon ongoing efforts by the California Coastal Commission to mitigate proportionally and appropriately for the impacts to recreation, public access, and beach ecology, resulting from changes to shoreline sand supply and coastal processes, caused by shoreline armoring. For this project, Commission staff will work with beach ecologists and economists to assess California beach resources and develop valuation methods that will better account for the impacts of permitting shoreline armoring projects. The Commission's Senior Coastal Engineer will provide technical expertise on coastal processes and shoreline changes to assist the beach ecologists and economists with their analyses. This information will then be used to develop a set of mitigation options to appropriately offset any losses caused by such projects.

II. Background

An issue of major concern facing California today is the loss of beaches due to natural processes and anthropogenic factors. Since much of the coast is developed, beach loss puts development at risk from erosion and inundation. Now and into the future, accelerated sea level rise and extreme storm events are anticipated outcomes of climate change that will further increase beach losses, risks to development, and the resulting demand for both hard and soft protective options, such as shoreline armoring (seawalls and rip rap) and beach replenishment. These protective options often have unintended recreational, public access, and ecological consequences that need to be better understood, evaluated, avoided, and/or appropriately mitigated for when necessary.

The mission of the Coastal Commission is to "*Protect, conserve, restore, and enhance environmental and human-based resources of the California coast and ocean for environmentally sustainable and prudent use by current and future generations*." The Coastal Commission, or local government as appropriate, is charged with reviewing applications for coastal development permits to ensure proposed projects are consistent with the California Coastal Act policies or relevant Local Coastal Program where applicable. Detailed information on Coastal Act policies related to shoreline armoring can be found in **Attachment A.**

Coastal Act Section 30235 states:

> *"Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fishkills should be phased out or upgraded where feasible."*

Accordingly, Section 30235 only requires the Commission to authorize the construction of shoreline protective structures when the structures are required to serve coastal dependent uses or protect existing structures or public beaches in danger from erosion. The Coastal Act provides these limitations because shoreline armoring can have a variety of impacts on coastal resources, including effects on sand supply, public access and recreation, coastal views, natural landforms, marine resources, and overall shoreline beach dynamics on and off site. While the Coastal Act allows for shoreline armoring as outlined above, it is the Commission's policy to consider all options that will avoid impacts to coastal resources to the maximum extent possible and only to mitigate for any unavoidable impacts.

Over the years, the Commission has applied methods to quantify some of the typical impacts to sand supply and coastal processes caused by shoreline armoring including:

(1) The physical encroachment onto the beach from constructing the structure.
(2) The future loss of beach that will occur when the nearshore beach continues to erode and the back beach remains fixed.
(3) The future loss of beach sand that would have been contributed to the littoral cell from back shore erosion.

The first two of these factors represent physical losses of beach area which have significant consequences to recreation, public access, and beach ecology. The third factor has direct effects on the available sand supply and the ability of beaches to form and expand. Once the impacts to beach area and sand supply are quantified, those quantities are then used to establish mitigation requirements. The loss of sand supply and recreational opportunities is typically assigned a monetary value; however, there may also be other appropriate mitigation options to offset the losses. In-kind mitigation is the Commission's preferred alternative but is often not possible. **Attachment B** provides detail on the Coastal Commission's current valuation methods, as well as mitigation requirements that have been used to offset impacts quantified by these methods.

While the Commission's review of shoreline armoring has generally focused on those impacts that can be quantified and directly attributed to armoring, the Commission is aware that hard structures can have many other impacts on the coast. Hard structures can increase beach scour, cause end effects, and change the visual and community character of the beach, to list a few. These changes may be temporary or long-term. Some impacts, such as scour, may have cumulative impacts, with small amounts of sand being pulled offshore during each scour event. These impacts do not easily fit into any quantitative metrics; however, they are important changes to the beach that should not be overlooked in any evaluation of the overall impacts and resulting consequences from shoreline armoring. If and when quantitative metrics are developed for assessing such changes, the Commission will evaluate the benefit of adding them to the existing methods used to determine shoreline armoring impacts.

The Commission's current valuation methods, as applied to shoreline armoring projects, have only been used to address impacts to recreation and public access. The methods have not been used to address any of the impacts to the beach ecosystem (e.g. loss of ecosystem services, adverse impacts to beach organisms). In addition, the Commission has considered mitigation in the form of beach replenishment to offset losses to recreation; but the Commission has not consistently accounted for the potential adverse impacts beach replenishment may have on beach ecology.

To better evaluate the impacts of shoreline armoring and help establish mitigation alternatives for the impacts to recreation, public access, and beach ecology, the Commission is looking to develop more comprehensive valuation methods. Any new valuation methods should meet the following criteria to be useful to the Commission:

- Must be linked to beach resources that are impacted by shoreline armoring (**Attachment C** provides some examples found in the scientific literature).
- Must be applicable to a variety of California beaches that vary in size (wide, narrow, pocket) and material (sandy, cobble, boulder) as the methods will be utilized throughout California.
- Data required for the methods must be readily available in the peer-reviewed literature, government reports, and/or easily collected with limited resources (**Attachment D** details site specific information commonly requested from applicants for shoreline armoring projects).
- Must be relatively straightforward as it will be employed by coastal analysts and managers who will be under tight deadlines.
- Results from the methods must be in the form of a quantifiable currency (e.g. USD, number of acres, amount of larvae, biomass) so that they may logically lead to appropriate, site specific mitigation options.

With improved and more comprehensive valuation methods the immediate, future, and cumulative impacts of shoreline armoring can be reduced and better mitigated.

III. Scope

Goal: This work will produce valuation methods that can be used to assess the impacts and appropriate mitigation options for shoreline armoring projects throughout California, and assist Commission staff in better protecting the recreation, public access, and ecological values of California beaches.

The *objectives* we seek to meet in achieving this goal are to:

1. Develop a method to estimate the value of ecological beach resources that can be used to assess ecological losses that may result from shoreline armoring.

2. Develop a method to estimate the value of recreation and public access beach resources that can be used to assess recreation and access losses that may result from shoreline armoring.

3. Apply the recreation and public access valuation method (and the ecological valuation method depending on its state of development) to one or more real world case studies to evaluate its effectiveness for various beach conditions.

IV. Tasks and Schedule

Task 1: Kick Off Meeting
Timeline: 1 month, July 2013

1. **Conduct an in person kick off meeting** with all consultants and Commission staff involved in the project to discuss project objectives, deliverables, schedule, and the expectations of the consultants.

Task 2: Development of Ecological Valuation Method
Timeline: 15 months, August 2013-October 2014

Percent of Project Funding: 40%

2.1 Conduct a review of:

a) The ecological components and features of beaches and the existing information on qualitative and quantitative responses (losses) of these ecological resources to impacts imposed by shoreline armoring.

Consultants Responsible: Karen Martin, Dave Hubbard, and Jenny Dugan.

Deliverable (a): A report that identifies the ecological resources and features of beaches that respond to shoreline armoring and qualitatively describes the state of existing knowledge on impacts to (losses of) these ecological resources that occur when a shoreline is armored, identifying information gaps and needs.

b) The tools/models/methods that have been or could be applied in the valuation of beach ecological resources (identified in 2.1 (a)) to account for the quantitative and qualitative impacts to (losses of) these resources that can result from shoreline armoring (identified in 2.1 (a)). The tools, models, and methods could include (but are not limited to) Natural Capital Project InVEST models, Habitat Equivalency Analysis, Standard Assessment Methodology, Compensatory Mitigation Value-Transfer, Hedonic Analysis, and Spatial Analysis.

Consultants responsible: Phil King and Chad Nelson in consultation with Karen Martin, Dave Hubbard, and Jenny Dugan.

Deliverable (b): A report that describes the various tools, models, and methods that could be applied in the valuation of the beach ecological resources and the impacts to (losses of) these resources from shoreline armoring. For each method detail the analytical steps, an assessment of the data needs and feasibility of obtaining that data, describe the parameters that must be measured for use in the analysis, and describe the output that results from the method.

Deadline for Task 2.1: March 2014

2.2 Meeting/Consultation: Present to/consult with Commission staff on the outcomes of 2.1 (a) and (b) and the conclusions regarding the best approach to pursue for a beach ecological valuation method. Get direction from Commission staff on the feasibility and utility of the chosen approach.

Consultants Responsible: Phil King, Chad Nelson, Karen Martin, Dave Hubbard, and Jenny Dugan.

Deadline for Task 2.2: May 2014

2.3 Ecological Valuation Method: Based on the outcomes of 2.1 & 2.2, initiate development of an ecological valuation method to estimate the ecological value of California beaches that can be used to assess the ecological impacts/losses (as a quantifiable currency; e.g. USD, number of acres, amount of larvae, biomass) associated with specified changes to the beach resulting from shoreline armoring. Armoring changes could include direct loss of the beach from encroachment, loss of new sand to the beach and littoral cell from preventing inland erosion, or progressive loss of the beach due to sea level rise against a fixed back beach. Document the rationale supporting the chosen approach including the feasibility and utility of the proposed approach for economically valuing beach ecology. Depending on the state of the ecological method development, show application of the method through one or more case studies that are not active Coastal Commission projects.

Consultants Responsible: Phil King, Chad Nelson, Karen Martin, Dave Hubbard, and Jenny Dugan.

Deliverable: A report of the ecological valuation method and rationale for the method, including the analytical steps, the parameters that must be measured for use in the analysis, how to obtain the necessary measurements, and the outputs that will result from the method. If feasible based on the state of the ecological method development, include a write-up of one or more case studies demonstrating application of the method to specific situations.

Consultation: Meet with Commission staff to review the final method and gather feedback.

Deadline for Task 2.3: October 2014

<u>Task 3: Development of Recreation and Access Valuation Method</u>
Timeline: 15 months, August 2013-October 2014
Percent of Project Funding: 40%

3.1 Conduct a review of the tools/models/methods that have been applied in the valuation of recreation and public access resources provided by beaches (on the beach and within nearshore waters) and the quantitative and qualitative changes to these resources that can result when shoreline armoring occurs. The purpose of the review is to provide background for the economic valuation tool developed in this project.

Consultants Responsible: Phil King and Chad Nelson.

Deliverable: A report that describes these tools, models, and methods. For each method detail the analytical steps, describe the parameters that must be measured for use in the analysis, and describe the outputs that will result from the method.

Deadline for Task 3.1: March 2014

3.2 Meeting/Consultation: Meet with relevant Coastal Commission staff to discuss the following:

a. The format/usability of a recreation/public access method for coastal managers.
b. What data should be required by the applicant (or where applicant does not provide the data, what assumptions should be made).
c. What, if any, data inputs Coastal Commission staff could/should supply.
d. Format/features of the user manual for the user-friendly method.
e. Discuss specific case studies to be used in the project.

Consultants Responsible: Phil King and Chad Nelson.

Deadline for Task 3.2: May 2014

3.3 Develop a recreation and public access valuation method, based on the results of 3.1 and 3.2, to estimate the value of recreation and public access resources provided by California beaches that can be used to assess the public access and recreation losses associated with specified changes to the beach resulting from armoring projects. Armoring changes could include direct loss of the beach from encroachment, a loss of new sand to the beach and littoral cell from preventing inland erosion, or progressive loss of the beach due to sea level rise against a fixed back beach. Show application of the method through one or more case studies that are not active Coastal Commission projects. (Phil and Chad)

Consultants Responsible: Phil King and Chad Nelson.

Deliverable: (a)A user-friendly method which values recreation and public access based on key inputs/parameters (e.g., attendance, beach width over time, amenities, access) approved by Coastal Commission staff. The method may also allow staff to choose from a taxonomy of beach types (e.g., heavily used southern California beach with full amenities and access, narrow northern California beach with few amenities, etc.). (b) A short (~ 15-20 page) user manual along with a technical appendix or paper explaining the method in more detail and write-up of one or more case studies demonstrating application of the method to specific situations.

Consultation (in person): Meet with Commission staff to review final methodology and gather feedback.

Deadline for Task 3.3: October 2014

Task 4 Write Up Final Report
Timeline: 3 months, October 2014-December 2014
Percent of Project Funding: 20%

The team will write up a final report incorporating memos and research discussed above. The report will be thorough enough to cover clearly all issues and information required by this Scope of Work. It is anticipated that the earlier deliverables will be sections of the final report and that the full report will be approximately 50 pages. CCC staff will have 6 weeks to review.

Consultants Responsible: Phil King, Chad Nelson, Karen Martin, Dave Hubbard, and Jenny Dugan.

Deadline for Task 4: December 2014

V. Project Budget

The total amount allocated for this agreement is $117,100. The project budget has been allocated as a percentage for each task.

Consultant Responsible	Percent Time on Task	Budget Allocation	Overhead Rate	Overhead Cost	Total Cost
Task 2: Development of Ecological Valuation Method (40%)					
Karen Martin	10%	10,000	15%	1,500	11,500
Dave Hubbard	10%	10,000	15%	1,500	11,500
Jenny Dugan	10%	10,000	30%	3,000	13,000
Phil King	5%	5,000	15%	750	5,750
Chad Nelsen	5%	5,000	15%	750	5,750
Task 3: Development of Recreation and Access Valuation Method (40%)					
Phil King	20%	20,000	15%	3,000	23,000
Chad Nelsen	20%	20,000	15%	3,000	23,000
Task 4: Write Up Final Report (40%)					
Karen Martin	4%	4,000	15%	600	4,600
Dave Hubbard	4%	4,000	15%	600	4,600
Jenny Dugan	4%	4,000	30%	1,200	5,200
Phil King	4%	4,000	15%	600	4,600
Chad Nelsen	4%	4,000	15%	600	4,600
Total Cost		100,000		17,100	**117,100**

VI. Progress/Compliance

Periodic consultations have been scheduled and linked to individual deliverables to ensure the outcomes of the project will be relevant, realistic, and useful for the Commission staff's project review process. Other communication can be arranged as needed by the project work. The primary points of contact within the Commission will be Jonna Engel and Lesley Ewing. Consultations will be scheduled by the primary points of contact and can be in person or by phone call, depending on discussion topics and consultant availability. A Steering Committee made up of Commission staff members and one out of state coastal manager will periodically review the products being produced and provide feedback to the primary points of contact to be relayed to the consultants. Other Commission staff may assist with scheduling and project management as appropriate. Below is a table summarizing the tasks, deliverables, consultations, and deadlines.

Task #	Description	Deliverable	Consultation	Deadline
Task 1	**Kick Off Meeting**			
1.	Conduct an in person meeting with all consultants and Commission staff to discuss the project and expectations of the consulting team.			July 2013
Task 2	**Development of Ecological Valuation Method**			
2.1	Review of beach ecological resources and tools/models/methods	Report on resources and tools/models/methods		March 2014
2.2	Present to/consult with Commission staff on the outcomes of 2.1			May 2014

Task #	Description	Deliverable	Consultation	Deadline
2.3	Initiate development of an ecological beach resource valuation method	Method and method rationale	In person meeting with Commission Staff	October 2014
Task 3	**Development of Recreation and Access Valuation Method**			
3.1	Review of public access and recreation resources and tools/models/methods	Report on tools/models/methods		March 2014
3.2	Meet with Commission staff to discuss format and features of method and user manual.			May 2014
3.3	Develop a recreation and public access valuation method	Method and Manual	In person meeting with Commission Staff	October 2014
Task 4	**Final Report**			
4.1	Write-up a final report	Final Report		December 2014

VII. End Product Delivery

All mid-project deliverables, including references, should be delivered to the primary points of contact via email in word or pdf format by the designated scheduled deadline.

VIII. Attachments

Attachment A: Select Coastal Act Policies Specifically Applicable to Shoreline Protection Projects

Attachment B: Methods Used by the California Coastal Commission to Evaluate and Mitigate for Beach Recreation and Access Impacts

Attachment C: Linking Recreational and Ecological Beach Characteristics with Physical Characteristics of Beaches Impacted by Shoreline Armoring

Attachment D: Information Commonly Requested from Applicants for Shoreline Armoring Projects

Attachment A
Select Coastal Act Policies Specifically Applicable to Shoreline Protection Projects

Construction altering natural shoreline

Coastal Act Section 30235 addresses the use of shoreline protective devices:

> ***30235.*** *Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fish kills should be phased out or upgraded where feasible.*

Minimization of adverse impacts

Coastal Act Section 30253 addresses the need to ensure long-term structural integrity, minimize future risk, and to avoid landform altering protective measures in the future. Section 30253 provides, in applicable part:

> ***Section 30253.*** *New development shall do all of the following:*
>
> *(1) Minimize risks to life and property in areas of high geologic, flood, and fire hazard.*
>
> *(2) Assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs.*

Public access and recreation

Coastal Act Sections 30210 through 30214 and 30220 through 30224 specifically protect public access and recreation. In particular:

> ***30210.*** *In carrying out the requirement of Section 4 of Article X of the California Constitution, maximum access, which shall be conspicuously posted, and recreational opportunities shall be provided for all the people consistent with public safety needs and the need to protect public rights, rights of private property owners, and natural resource areas from overuse.*
>
> ***30211.*** *Development shall not interfere with the public's right of access to the sea where acquired through use or legislative authorization, including, but not limited to, the use of dry sand and rocky coastal beaches to the first line of terrestrial vegetation.*
>
> ***30213.*** *Lower cost visitor and recreational facilities shall be protected, encouraged, and, where feasible, provided. Developments providing public recreational opportunities are preferred. …*
>
> ***30221.*** *Oceanfront land suitable for recreational use shall be protected for recreational use and development unless present and foreseeable future demand for public or commercial recreational activities that could be accommodated on the property is already adequately provided for in the area.*
>
> ***30223.*** *Upland areas necessary to support coastal recreational uses shall be reserved for such uses, where feasible.*

Coastal Act Section 30240(b) also protects parks and recreation areas, such as the adjacent beach area. Section 30240(b) states:

> ***30240(b).*** *Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas.*

Visual resources

Coastal Act Section 30251 states:

> ***Section 30251.*** *The scenic and visual qualities of coastal areas shall be considered and protected as a resource of public importance. Permitted development shall be sited and designed to protect views to and along the ocean and scenic coastal areas, to minimize the alteration of natural land forms, to be visually compatible with the character of surrounding areas, and, where feasible, to restore and enhance visual quality in visually degraded areas. New development in highly scenic areas such as those designated in the California Coastline Preservation and Recreation Plan prepared by the Department of Parks and Recreation and by local government shall be subordinate to the character of its setting.*

Coastal Act Section 30240(b), previously cited, also protects the aesthetics of beach recreation areas Section 30240(b) states:

> ***Section 30240(b):*** *Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas.*

Marine resources

Coastal Act Sections 30230 and 30231 provide:

> ***Section 30230.*** *Marine resources shall be maintained, enhanced, and where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.*

> ***Section 30231.*** *The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of ground water supplies and substantial interference with surface water flow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of natural streams.*

Attachment B
Methods Used by the California Coastal Commission to Evaluate and Mitigate for Beach Recreation and Access Impacts

Overview

The protection and enhancement of beach access and public recreational uses of the coast are fundamental tenets of the California Coastal Act. Throughout the years, the Commission has acted to improve beach conditions through access dedications, offers to dedicate access and open space, through certification of Local Coastal Programs and through project review and permit conditions that avoid or minimize physical impacts to beach areas. The installation or expansion of seawalls, revetments and other back shore protection structures is one of the main actions that can have an adverse impact on beaches as well as on the various opportunities for using the beach. This paper will provide a short summary of the recent Commission approaches to beach and recreation use protection and the Coastal Act basis for these efforts.

Impacts from Armoring and Mitigation Required by the Coastal Act

In the mid-1990's, Commission staff noticed several disturbing trends in shore protection – the first were applications for larger and more massive seawalls to protect coastal bluffs (Figure 1), and the second was the proliferation of shore protection being placed on lands that could be considered public beach, either due to the ambulatory nature of the Mean High Tide Line, to an offer to dedicate access, or to a prior determination of state interest. Adverse impacts to beach areas and beach access has long been a concern for coastal managers and the California Coastal Act addresses those concerns through general requirements to avoid adverse impacts to coastal resources whenever possible, to minimize unavoidable impacts and then to mitigate for unavoidable impacts if possible – especially impacts to local sand supply. The basis for this comes from Section 30235 of the California Coastal Act that states, "Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fishkills should be phased out or upgraded where feasible."

Figure 1: Large soldier pile seawall.

The tests for shoreline protection are that

1. there is a coastal dependent use, existing structure or public beach;
2. that the coastal dependent use, existing structure or public beach is in danger from erosion,
3. that the structure avoid or minimize impacts on coastal resources and
4. that the structure eliminate or mitigate adverse impacts on local shoreline sand supply.

This leads to an analysis of the need for the project, identification of alternatives that would avoid the need for shoreline armoring, and then designs that minimize the impacts from shoreline armoring that is found to be needed. In order to minimize impacts from unavoidable shore protection, the Commission discouraged massive engineered seawalls and revetments in favor of seawalls that were more in line with the profile of the bluff and that could be colored and texturized to mimic natural bluff features (Figure 2).

Figure 2: Photo of Seawall at Pleasure Point. Designed and built to blend with natural bluff conditions.

The Commission also developed and implemented a method for quantifying many of the impacts to beach areas from the installation of shore protection structures. The Commission worked through the process of quantifying impacts with the thought that it might be easier to develop mitigation for quantifiable impacts. Seawall impacts are not limited to those that can be easily quantified – there are also temporary but recurring impacts due to scour, longer term impacts due to end effects, and visual impacts, which can result in permanent changes to the character of the coast. In addition, if a seasonal eroded beach condition occurs with greater frequency due to the placement of a shoreline protective device, then the subject beach would also accrete at a slower rate. Morever, if the seawall is subject to wave action on a frequent basis, then beach scour during the winter season will be accelerated because there is less beach area to dissipate the wave's energy. And, even if these beach changes are reversible or short-lived, the beach disturbances may result in changes to the ecosystems function that last long after physical recovery. However, the three aspects of the impacts of shore protection that have been regularly quantified are:

1. the physical encroachment from placing the structure on the beach;
2. the long-term denial of new beach area due to fixing the back location of the beach on an eroding shoreline, often termed passive erosion; and
3. the denial of sediment to the littoral cell from halting bluff erosion.

Figures 3-7 show these aspects of seawall impacts and the general equations for calculating these impacts are shown in **Table 1**. This method provided a means to quantify both a volume of sand lost to the littoral cell and an area of beach that would be lost for public access and recreation.

Over the years, the Commission had taken various steps to require that new seawall projects mitigate for unavoidable impacts. As noted in the 1997 Report on In-Lieu Fee Beach Sand Mitigation Program: San Diego County:

> "The California Environmental Quality Act (CEQA) guidelines provide a definition of mitigation for purposes of CEQA. Section 15370 of the CEQA guidelines define mitigation as:
>
> 1) Avoiding the impact altogether by not taking a certain action or parts of an action.
>
> 2) Minimizing impact by limiting the degree or magnitude of the action and its implementation.
>
> 3) Rectifying the impact by repairing, rehabilitating, or restoring the impacted environment.
>
> 4) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
>
> 5) Compensating for the impact by replacing or providing substitute resources or environments.
>
> This definition provides several alternative forms of mitigation. In mitigation by avoidance, adverse impacts are avoided altogether through alteration of project location, design, or other related aspects. Commission staff typically recommends mitigation by avoidance, if feasible, since it is the best way to prevent direct adverse impacts to public access and sand supply in association with a shoreline protective device. However, if the Commission is required to approve a shoreline altering device to protect an existing structure in danger from erosion, minimizing, rectifying or reducing project impacts are forms of mitigation that diminish the severity of the project related impacts and are required under Section 30235. Although these forms of mitigation can result in alterations to the project design, the overall integrity of the project can be preserved."[1]

Options for Mitigation of Seawall Impacts

Options for mitigation are evolving; there has not been one universal mitigation option that covers all parts of the state or all impact situations. And, since the best mitigation is something that provides immediate and lasting benefits to the coastal region that is being affected, in-situ mitigation, while difficult to develop, is normally encouraged. When actual site improvements are not possible, the commission has considered some off-site improvements, and as a final option has considered in-lieu mitigation. Over the years, the Commission has generally used four different mitigation approaches. These approaches have connected the in-lieu mitigation to either the land value (as either the cost to

[1] Sarb, Sherilyn and Lesley Ewing (1997) Report on In-Lieu Fee Beach Sand Mitigation Program: San Diego County, http://www.coastal.ca.gov/pgd/sand1.html, last revised 25April 2012.

undertake nourishment that would create an area of beach equivalent to the area lost or the value of bluff or back beach land equivalent to the lost beach area) or to the user value (either the reduced quality of the beach experience as the available beach narrows or the lost opportunity to visit the beach).

LAND VALUE METHODS

In-Lieu Beach Sand Mitigation Program: The first In-Lieu Beach Sand Mitigation Program was developed for San Diego County, where much of the beach seaward of the coastal bluffs was already public beach. Installation of a seawall would encroach onto public beach, prevent the formation of new public beach that would occur through landward movement of the shoreline, and prevent the addition of coastal bluff sands to the littoral cell. The In-Lieu Beach Sand Mitigation Program mitigated for all three of these impacts through a sand replenishment fund. The volume of sand denied to the littoral cell was quantified directly as a volume of sand. The area losses were quantified for a specified length of erosion (normally 20 to 25 years) and the area of beach lost was converted to a volume of sand, based on the amount of sand that would be needed to build an equivalent area of beach through beach nourishment. The fee was then determined by obtaining three estimates for providing this volume of beach compatible sand to the beach adjacent to the project site. This method is shown in Table 1. In San Diego County, over $1.2 million has been provided to the Beach Sand Mitigation Program as of the end of 2011 and much of those funds have come from the In-Lieu Beach Sand Mitigation Fee.

Assessor Values

Recent projects with impacts to coastal recreation have attempted to determine the cost for purchasing an area of beach equivalent to the area lost. Since beach land is rarely for sale, the equivalent area of unimproved beachfront (or blufftop) land has been used as a close substitute for the value of beach land. Information on land costs has been developed from web sites such as Zillow and from local appraisals (see for example, CDP #6-07-133 (Li), or 6-09-033 (Garber et al.)).

USER VALUE METHODS

Recreation and Visitor Value Losses: A second in-lieu effort has been to look at the recreational and visitor value that is associated with the lost beach area. The Commission first undertook this type of analysis in Monterey County, for a large condominium project known as Ocean Harbor House where there is a high rate of erosion and waves were likely to be breaking on the shore protection within a few decades. The beach that then fronted the development was expected to become an intertidal beach. The quantified impacts to the beach were the encroachment, denial of formation of new beach from fixing the back beach location and denial of bluff sand to the littoral cell – the same three elements that are quantified in the In-Lieu Beach Sand Mitigation Program. But, unlike in San Diego, Monterey had no on-going program for beach nourishment; thus, the Commission sought to acquire other beach property within the area to replace the loss or mitigation for the beach area losses attributable to the project. Staff provided the Commission with three options for determining appropriate value for beach land:

1. the dollar amount assuming the In-Lieu Beach Sand Mitigation Program could be implemented in the area,
2. a real estate assessment of the value of beach area, and
3. a beach valuation approach that identified what monetary value a beach user would place of the beach, based upon a travel-cost model.

The Commission used the third option, and this was subsequently upheld in a court ruling related to the Commission's right to implement such mitigation (CDP 3-02-024 and Superior Court of California, County of Monterey, Case No. M73109).

Recreational Losses Associated with Gradual Beach Loss: After the Ocean Harbor House project, the Commission began to include recreation and access mitigation for shoreline armoring projects elsewhere in the state. The Commission continued to require mitigation for the lost littoral sand based on the dollar cost to replace an equivalent volume of sand. For recreation, the Commission used a modified travel-cost method to determine the value of a trip to the beach and then quantified the recreational losses based on the reduction in recreational beach area that could be attributed to the shore protection (Las Brisas; CDP # 6-04-156). This method, however, required too much input data and, at that time, it was not easily transferred to other shoreline protection projects.

Figure 3

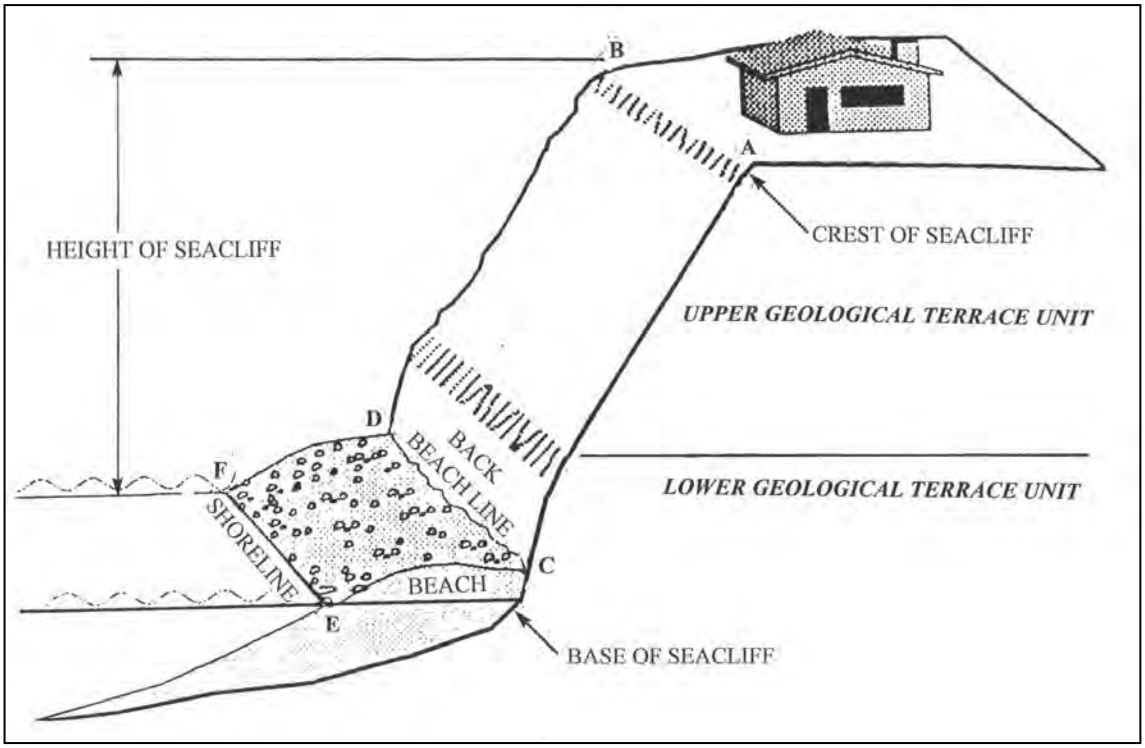


Figure 4

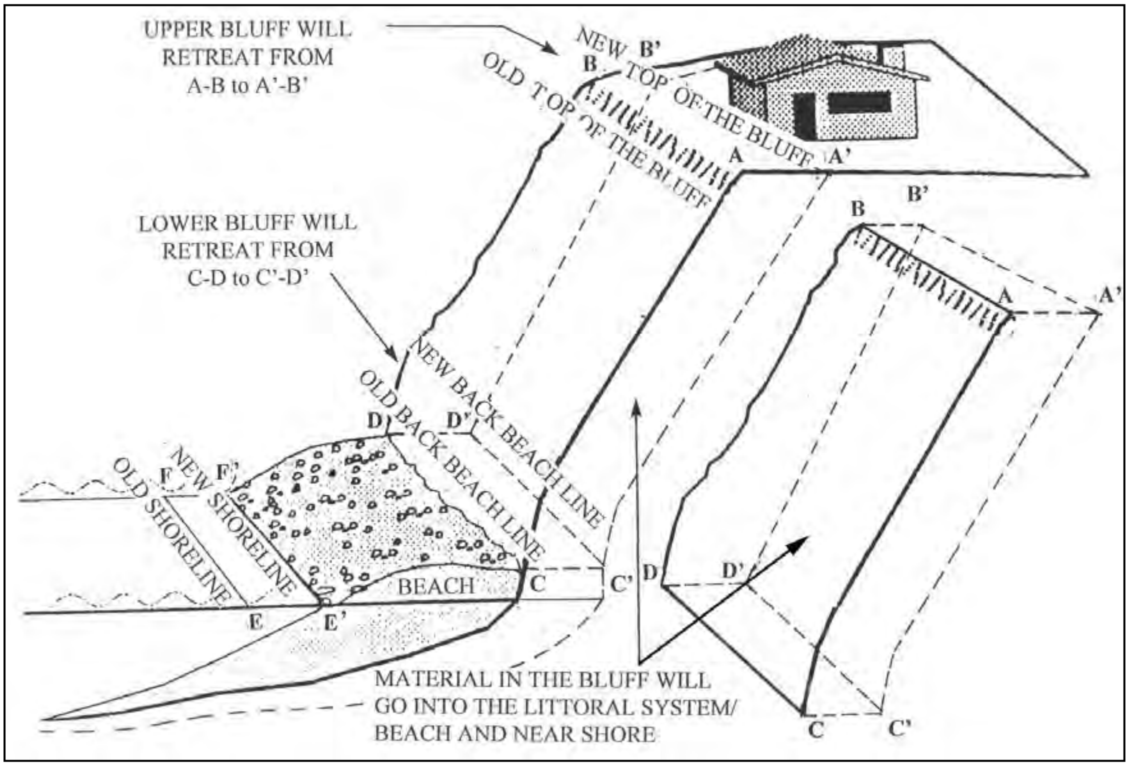


Figure 5

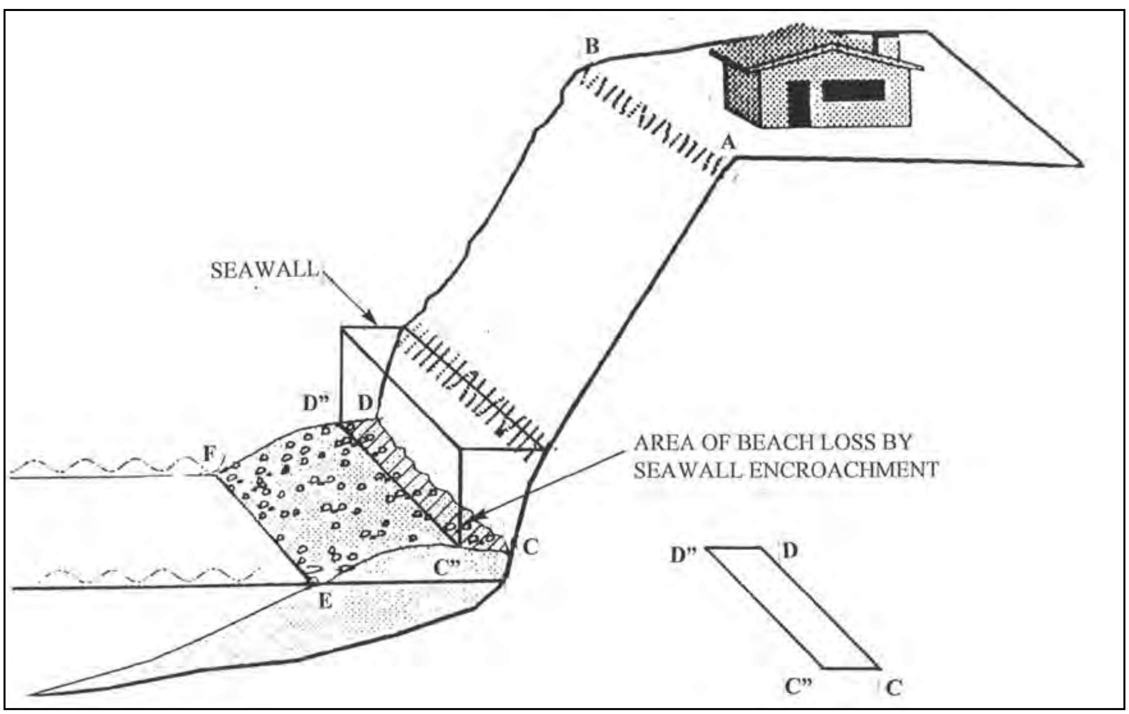


Figure 6

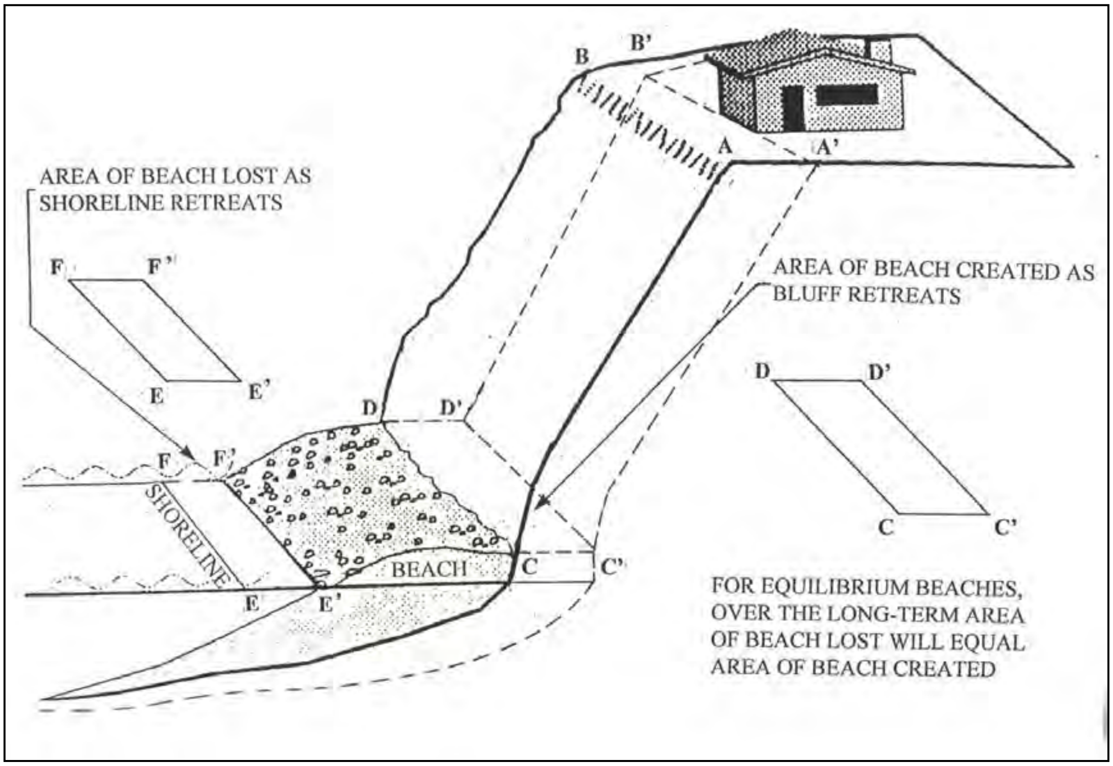

B
B'
A
A'
AREA OF BEACH LOST AS
SHORELINE RETREATS
F
F'
E
E'
AREA OF BEACH CREATED AS
BLUFF RETREATS
D
D'
C
C'
D
D'
F
F'
SHORELINE
BEACH
C
C'
E
E'
FOR EQUILIBRIUM BEACHES,
OVER THE LONG-TERM AREA
OF BEACH LOST WILL EQUAL
AREA OF BEACH CREATED

Figure 7

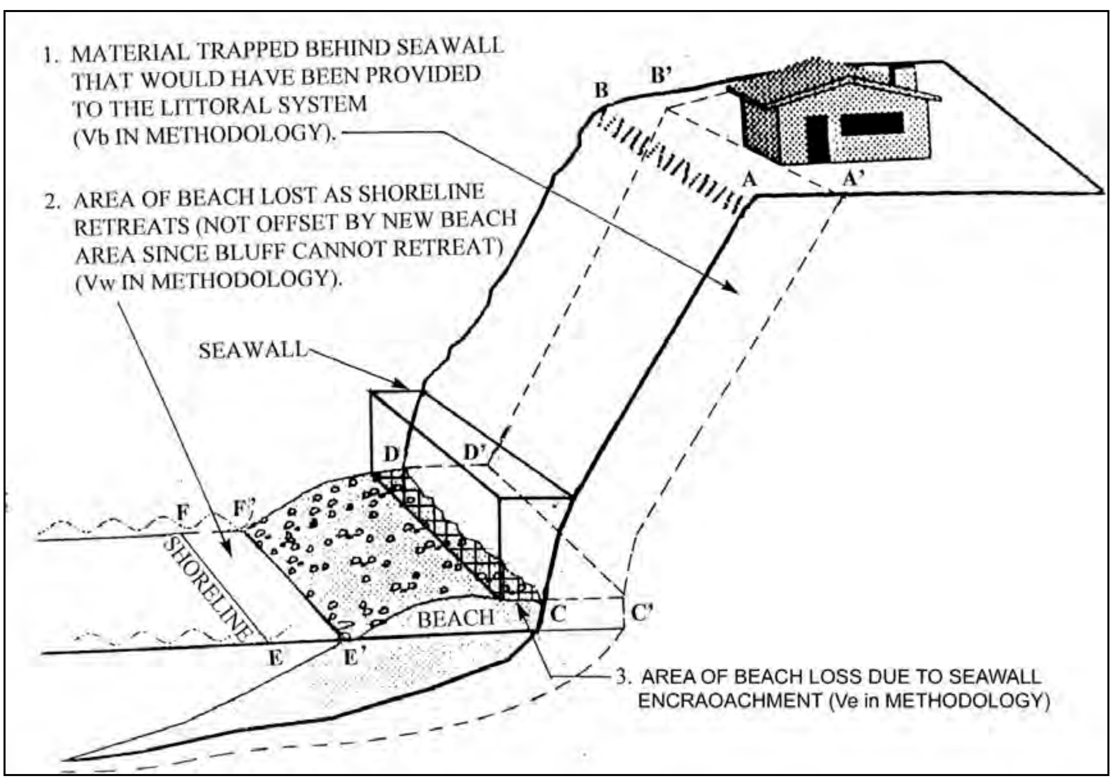

1. MATERIAL TRAPPED BEHIND SEAWALL
THAT WOULD HAVE BEEN PROVIDED
TO THE LITTORAL SYSTEM
(Vb IN METHODOLOGY).
2. AREA OF BEACH LOST AS SHORELINE
RETREATS (NOT OFFSET BY NEW BEACH
AREA SINCE BLUFF CANNOT RETREAT)
(Vw IN METHODOLOGY).
SEAWALL
B
B'
A
A'
D
D'
F
F'
SHORELINE
BEACH
C
C'
E
E'
3. AREA OF BEACH LOSS DUE TO SEAWALL
ENCRAOACHMENT (Ve in METHODOLOGY)

Table 1

Shoreline Protection Impacts Quantified	
Volume of Sediment Trapped by Armoring	Vb = (SxWxL) x[(Rxhs) + (0.5Hu x (Rcw – Rcs)))]/27 [Often this reduces to: Vb = S x W x L x R x h]
Encroachment onto the Beach	Ae = W x E
Passive Erosion	Aw = R x L x W
Mitigation Fee	Sand Volume x Cost of Sand
Lost Beach Area	Encroachment + Passive Erosion
Values Defined	
S	Fraction of beach quality material in the bluff material, based on analysis of bluff material to be provided by the applicant.
W	Width of property to be armored (ft.)
L	The length of time the back beach or bluff will be fixed or the design life of armoring without maintenance (yr.) For repair and maintenance projects, the design life should be an estimate of the additional length of time the proposed maintenance will allow the seawall to remain without further repair or replacement.
R	The retreat rate which must be based on historic erosion, erosion trends, aerial photographs, land surveys, or other accepted techniques and documented by the applicant. The retreat rate should be the same as the predicted retreat rate used to estimate the need for shoreline armoring.
hs	Height of the seawall from the base to the top (ft).

hu	Height of the unprotected upper bluff, from the top of the seawall to the crest of the bluff (ft).
Rcu	Predicted rate of retreat of the crest of the bluff, during the period that the seawall would be in place, assuming no seawall were installed (ft/yr). This value can be assumed to be the same as R unless the applicant provides site specific geotechnical information supporting a different value.
Rcs	Predicted rate of retreat of the crest of the bluff, during the period that the seawall would be in place, assuming the seawall has been installed (ft/yr). This value will be assumed to be zero unless the applicant provides site specific geotechnical information supporting a different value.
E	Encroachment by seawall, measured from the toe of the bluff or back beach to the seaward limit of the protection (ft.)

Attachment C
Linking Recreational and Ecological Beach Characteristics with Physical Characteristics of Beaches Impacted by Shoreline Armoring

There is a broad range of physical characteristics that can be used to categorize sandy beaches in southern California. Below is a list of physical characteristics that have been linked to either ecological or recreational resources of sandy beaches in scientific literature, can be impacted by coastal armoring, and are easily measured or available.

Beach slope:

- Measured slope of the beach face, can be either a snapshot measurement or an average measurement, as beach slope changes throughout the year (ex. The average gradient between the high-water drift line and the low-tide swash zone during spring tides)
- Unit of measure- degrees
- Data sources- physical measurements, scientific literature

Beach width:

- The horizontal dimensions of the beach measured at right angles to the shoreline from the line of extreme low water inland (intersection between dry and wet beach at high tide) to the landward limit of the beach, can be either a snapshot measurement or an average measurement, as beach width changes throughout the year.
- Unit of measure- meters
- Data sources- physical measurements, aerial photographs, scientific literature

Beach area:

- Measured width of the beach multiplied by the measured length of the beach, could be either a snapshot measurement or an average measurement, as beach area changes throughout the year.
- Unit of measure- square meters
- Data sources- physical measurements, maps, scientific literature

Sand grain size:

- Average diameter of individual grains of sediment
- Unit of measure: millimeters or phi units.
- Data sources- physical observation, scientific literature

Wave climate:

- Wave height and period measured at one point in time or observed values over a large time span accounting for seasonal range.
- Unit of measure: wave period in seconds, wave height in meters
- Data sources- physical observations, scientific literature

Tidal range:

- The vertical distance between the high tide and the succeeding low tide.
- Unit of measure- meters
- Data sources: physical measurements, http://tidesandcurrents.noaa.gov/

Macrophyte wrack cover:

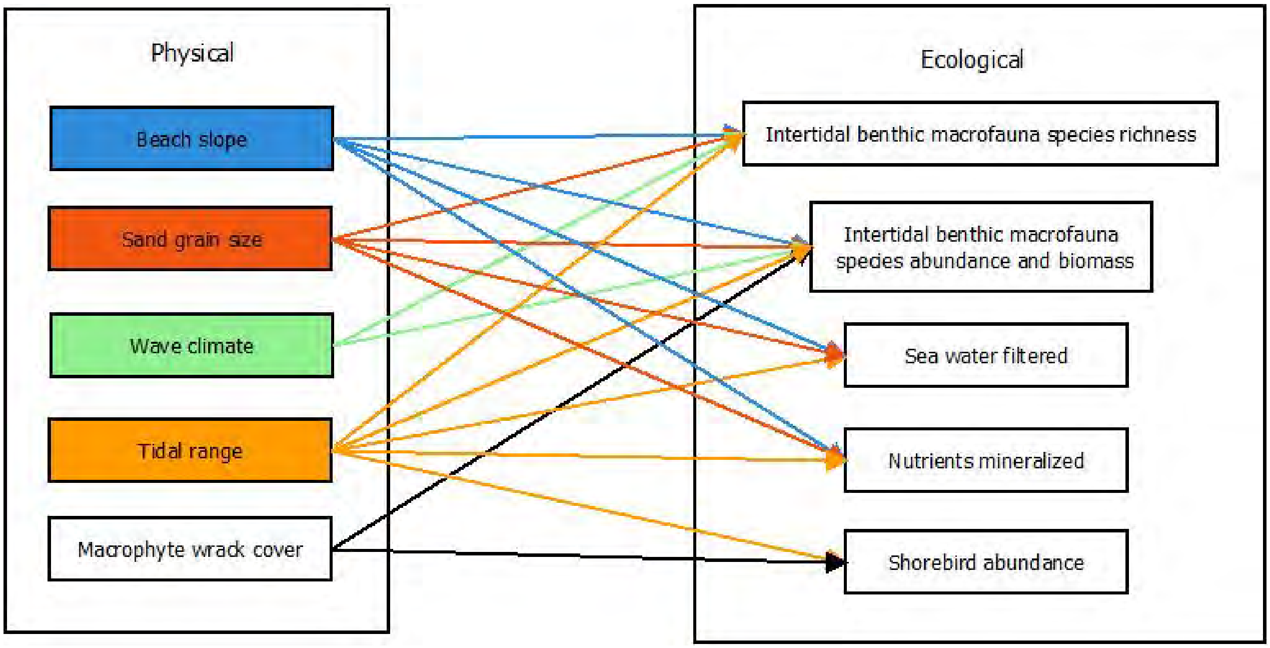
- Amount of wrack cover on a beach
- Unit of measure- square meters of wrack per meter of beach or mean percent cover of wrack estimated by taking total wrack intersected by a transect in meters and divide it by the intertidal width in meters of each transect.
- Data sources- physical measurements, scientific literature

Access (Lateral and Vertical):

- Description of the type/amount of access to a beach
- Unit of measure: detailed description of the access points and availability
- Data sources- physical observation, scientific literature

Physical Characteristics Linked with Ecological Resources

A review of scientific literature revealed studies that link the following physical characteristics of sandy beaches with ecological resources. By understanding the changes coastal armoring can have on these physical characteristics, we may be able to infer changes to the ecological resources.



Detailed information on the links illustrated above:

Physical: Total morphodynamic state of a beach (beach slope, grain size, and wave climate taken together)
Ecological: Intertidal benthic macrofauna species richness
Link to relevant literature: (McLachlan et al. 1993)

Physical: Total morphodynamic state of a beach (beach slope, grain size, and wave climate taken together), surf zone productivity, and wrack inputs.
Ecological: Intertidal benthic macrofauna species abundance and biomass
Link to relevant literature: (McLachlan et al. 1993)

Physical: Beach index which is calculated from: tidal range, beach face slope, and sand particle size
Ecological: Macrobenthic species richness, abundance, and biomass
Link to relevant literature: (McLachlan & Dorvo 2005)

Physical: Tide range, beach slope, and sand particle size
Ecological: Amounts of sea water filtered and inorganic nitrogen regenerated
Link to relevant literature: (McLachlan 1982)

Physical: Tidal height
Ecological: Shorebird abundance
Link to relevant literature: (Hubbard & Dugan 2003)

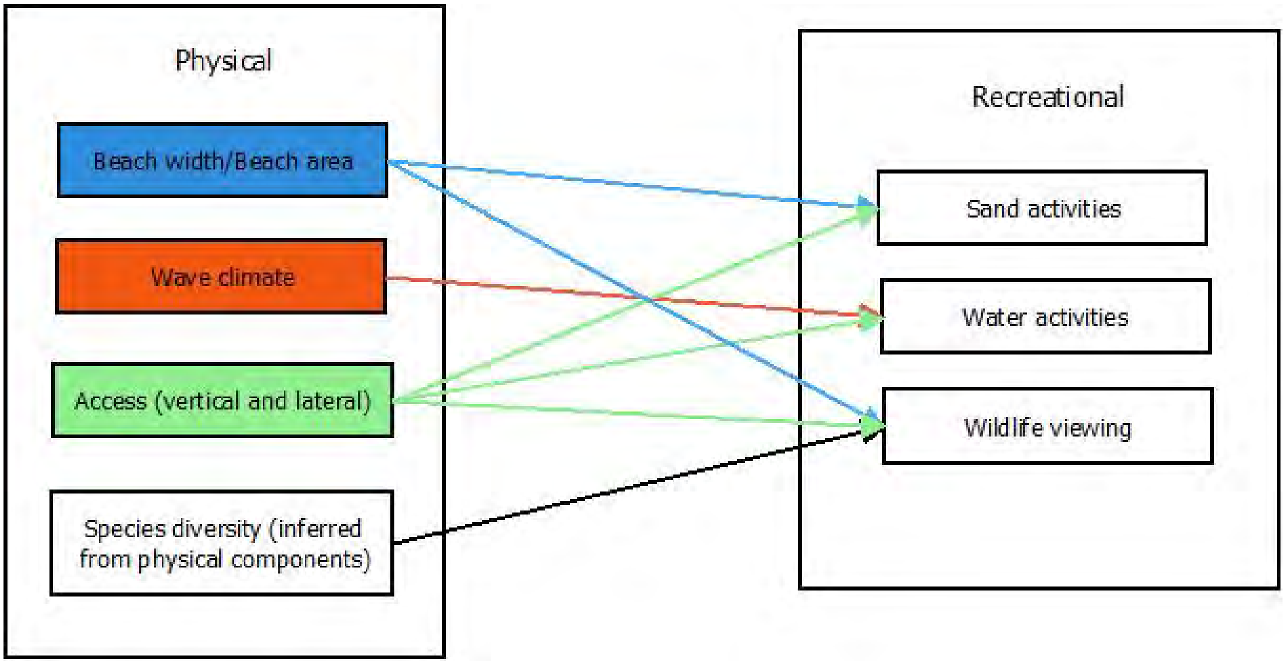
Physical: Macrophyte wrack cover
Ecological: Macrofauna species richness and abundance
Link to relevant literature: (Dugan et al. 2003)

Physical: Macrophyte wrack cover
Ecological: Shorebird abundance
Link to relevant literature: (Dugan et al. 2003)

Physical: Intertidal habitat area
Ecological: Shorebird foraging area (Shorebird abundance)
Link to relevant literature: (Galbraith et al. 2002)

Physical Characteristics Linked with Recreational Resources

A review of scientific literature revealed studies that link the following physical characteristics of sandy beaches with recreational resources. By understanding the changes coastal armoring can have on these physical characteristics, we may be able to infer changes to the recreational resources.



Detailed information on the links illustrated above:

Physical: Beach width
Recreational: Preference for beaches can be related to space availability but varies depending on the type of activity the user plans to engage in.
Link to relevant literature: (Shivlani et al. 2003)

Physical: Beach width
Recreational: Beach preference can be related to beach width only to a certain point and the preference varies based on the activity the user will engage in.
Link to relevant literature: (Pendleton et al. 2011)

Physical: Wave climate (height, period, direction, wavelength in surf area, wave age)
Recreational: Surfing
Link to relevant literature: (Bicudo & Horta 2009)

Physical: Access (Lateral and Vertical)
Recreational: Water, beach, and wildlife viewing activities.
Link to relevant literature: (Caldwell & Segall 2007)

Annotated Bibliography:

Bicudo, P. and Horta, A. (2009) Integrating surfing in the socio-economic and morphology and coastal dynamic impacts of the environmental evaluation of coastal projects. Journal of Coastal Research, 56.

This article provides examples of some of the surf breaks lost in Portugal due to the construction of coastal protection. It recommends wave parameters that should be evaluated when assessing the impact a project may have to the surfing community. It also addresses the potential of using artificial surf reefs to mitigate the loss of surf from projects. * This provides a way to think about how to evaluate loss to surfing and ways to mitigate the loss. *

Caldwell, M. and Segall, C. H. (2007) No day at the beach: sea level ride, ecosystem loss, and public access along the California coast. Ecology Law Quarterly, 34: 534-578.

This law review addresses climate change and sea level rise impacts to the coast, and the need to plan for the future in order to maintain public access and rights. It highlights the compounding loss of public access from sea level rise and coastal armoring. It recommends the use of rolling easement conditions, land purchases, LCP amendments, and limitations of coastal armoring, to maintain the health of the ecosystems and public rights.

Dugan, J. E., Hubbard, D. M., McCrary, M. D., and Pierson, M. O. (2003) The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuarine, Coastal and Shelf Science, 58 (Supplement): 25-40.

This study examined the relationship between macrophyte wrack subsidies and community structure on sandy beaches in southern California. It found that overall species richness and abundance of the macrofauna species studied were positively correlated with the amount of mactophyte wrack cover. The abundance of two shorebird species was also positively correlated with the amount of wrack cover. * Armoring impacts wrack inputs (noted in an article Dugan J.E., Hubbard D.M. (2006) Ecological responses to coastal armoring on exposed sandy beaches. Shore & Beach, 74(1), 10–16…which I was unable to access of the internet) therefore this could be included in the model as it has a significant impact to community structure.*

Galbraith, H., Jones, R., Park, R., Clough, J., Herrod-Julius, S., and Harrington, B., Page, G. (2002) Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. Waterbirds, 25(2): 173-183.

This study attempts to model the loss of intertidal habitat available for shorebird foraging as a result of climate change. It used available bird count data and maps of intertidal habitats from aerial surveys, including intertidal sand habitat. It illustrates the significant loss of shorebird foraging habitat as a result of climate change. * If we want to quantify the value of beaches relative to shorebird foraging habitat, we should have an idea of the habitat that will be lost to climate change. Intertidal habitat used by shorebirds to forage may be more valuable if it becomes rarer throughout the state. *

Hubbard, D. M. and Dugan, J. E. (2003) Shorebird use of an exposed sandy beach in southern California. Estuarine, Coastal and Shelf Science, 58 (Supplement): 41-54.

Shorebird surveys conducted on a southern California beach found that in the fall and winter the abundance of shorebirds was positively correlated with tide height. Alternatively, in the spring, the abundance of shorebirds was negatively correlated with tide height. Researchers also found that overall abundance of shorebirds was depressed during El Nino, when sandy habitat was greatly reduced and intertidal habitat was mostly converted to rocky substrate. * Illustrates how shorebird abundance is influenced by the type of habitat available for foraging which can change throughout seasons and major climatic events.*

McLachlan, A. (1982) A model for the estimation of water filtration and nutrient regeneration by exposed sandy beaches. Marine Environmental Research, 6: 37-47.

This study attempts to use physical beach characteristics to estimate the amount of sea water filtered and inorganic nitrogen regenerated by sandy beaches. Researchers used a regression model to predict the volume of sea water filtered daily by a beach as a function of tide range, beach slope and sand particle size. From this, a method was also derived to estimate the degree of mineralization of organic matter in the filtered sea water based on the distance filtered through the sand and the sand grain size. * If we want to quantify water filtration and nutrient regeneration lost by armoring beaches, this study gives a good introduction to the relationships between the physical and ecological components.*

McLachlan, A. and Dorvlo, A. (2005) Global patterns in sandy beach macrobenthic communities. Journal of Coastal Research, 21(4): 674–687.

This study evaluates the relationships between macrobenthic species richness, abundance, and biomass with physical variables of beaches. A beach index developed in this study based on tide range, beach face slope, and sand particles size was able to explain 56% of the variability found across regions. Researchers found species richness to increase from narrow reflective systems to broad dissipative beaches. The number of species recorded in a transect increases with increasing tide range, finer sand, and flatter slope. * Impacts on armored beaches will be better understood by how the tidal range and slope are impacted (grain size will be important relative to beach nourishment).*

McLachlan, A., Jaramillo, E., Donn, T. E., and Wessels, F. (1993) Sandy beach macrofauna communities and their control by the physical environment: a geographical comparison. Journal of Coastal Research, 15 (Special Issue): 27-38.

This study examined differences in species richness, abundance, and biomass of intertidal benthic macrofauna on beaches ranging from reflective to dissipative extremes, across different geological regions. Researchers found species richness to be greater on dissipative versus reflective beaches. Abundance and biomass were also greater on dissipative beaches but were more variable since this factor is also related to surf zone productivity and wrack inputs. This study concludes that the major contributing factor to the species on a beach is the swash climate. The total morphodynamic state of a beach (produced by beach slope, grain size and wave climate taken together) is a better estimate of species richness than any one factor alone because it directs the swash climate. * If coastal armoring changes beaches from dissipative to reflective then we can use this study to relate that change to a drop in species richness.*

Pendleton, L., Mohn, L.C., Vaughn, R.K., King, P., and Zoulas, J. G. (2011). Size matters: the economic value of beach erosion and nourishment in southern California. Contemporary Economic Policy, 30(2):223-237.

This study examined the welfare benefits of increased beach width by using a model that quantifies recreational benefits as a function of beach width and other beach attributes, using beaches in Los Angeles and Orange County as an example. It reveals that the value of beach width varies for different beach uses and the marginal value of beach width depends on how wide the initial beach was. As an example, beach width was more important for visitors who are seeking space availability. *The most important take away relative to our project would be that the value of increasing beach width to maintain recreational value is dependent on the beach users and uses that are occurring on the beach. *

Shivlani M. P., Letson, D., and Theis, M. (2003) Visitor Preferences for Public Beach Amenities and Beach Restoration in South Florida. Coastal Management, 31(4): 367-385

This study attempts to evaluate a beach user’s willingness to pay for beach nourishment. Results from this study highlight that different users prefer beaches based on the type of activities they participate in (swimming, sunbathing, jet-skiing, fishing, kayaking, walking) due to the presence of features which serve that activity (space availability, cleanliness, amenities, distance, wildlife/vegetation).* We should have an understanding of the major activities occurring on a beach to understand the true recreational impact by loss of beach width.*

Attachment D
Information Commonly Requested from Applicants for Shoreline Armoring Projects

Major plans used for review by Coastal Analysts:

- Site Plan showing the following
  - Mean High Tide Line
  - Elevation contours of the bluff
  - Location of proposed seawall and any other aspects of the project (i.e. upper bluff walls, slope reconstruction, etc.)
  - Location of the existing structure and any other existing improvements at the top of the bluff

- Location of the ‘top of bluff’ and the distance that line is from the primary structure

- Profile sections showing
    - Each segment of the project (seawall, upper bluff wall, slope reconstruction, etc.)

Other information requested:

- Landscape plans
- Sand Mitigation Fee calculation worksheet
- If the seawall is located on a public beach, then they need to tell us the sq. ft. of the wall that will be on the public beach

Geotechnical submittal requirements are listed in detail in a County’s LCP:

<u>Sample of Requirements</u>

A soils report and a geotechnical review or report prepared by a certified engineering geologist certifying that the development will have no adverse affects on bluff stability, or endanger life or property, and will consider:

- Cliff geometry and site topography, extended beyond the site
- Historic, current, and foreseeable cliffs erosion, land surveys and tax assessment records, historic maps and photographs, and possible changes in shore configuration and sand transport.
- Geologic conditions, including soil, sediment, and rock types, and structural features such as bedding, joints, and faults
- Evidence of past or potential landslide conditions and the implications
- Impact of the activity on the stability of the site and adjacent area
- Ground and surface water conditions and variations, including hydrologic changes caused by the development.
- Potential erodibility of site and mitigating measures to be used to ensure minimized erosion problems during and after construction
- Effects of marine erosion on seacliffs and estimated rate of erosion at the base of the bluff fronting the subject site based on current and historical data
- Potential effects of seismic forces resulting from a maximum credible earthquake
- Any other factors that might affect slope stability
- Mitigation measures and alternative solutions for any potential impacts

The geotechnical report shall also address:

- Maximum expected wave height, design wave height, design constraints, and frequency of overtopping
- Normal and maximum tidal ranges
- Estimated erosion rate with and without the proposed preemptive measure
- Percent of beach quality sand within the bluff
- Effect of the proposed structure on adjoining properties
- Potential/effect of scouring at base of proposed structure
- Design life of structure/maintenance provisions
- Alternatives to the project design, including (but not limited to) relocation/removal of threatened portions of or the entire home and beach nourishment
- Construction area and technique of construction
- Certification that the structure is designed to withstand storms comparable to the winter storms of 1982-83.

EXHIBIT B
(Interagency Agreement)

BUDGET DETAIL AND PAYMENT PROVISIONS

1. Invoicing

A. For services satisfactorily rendered and upon receipt and approval of the invoices, the Commission agrees to compensate SFSU for actual expenditures incurred in accordance with the rates specified herein or attached hereto.

B. Invoices shall be submitted in triplicate not more frequently than monthly in arrears to:

California Coastal Commission
Attn: Business Services
45 Fremont Street, Suite 2000
San Francisco, CA 94105-2219

C. Invoices shall contain the following information:
1. Contractor's name and address as shown on this agreement.
2. Date of the invoice.
3. Time period covered by the invoice.
4. Contract number as shown on this agreement.
5. Original signature of the contractor (not required if printed using preprinted letterhead paper).
6. Itemized costs for the billing period in the same or greater level of detail as indicated in this agreement, with supporting documentation. Only those costs and/or cost categories expressly identified in this agreement may be reimbursed.

2. Budget Contingency Clause

A. It is mutually agreed that if the Budget Act of the current year and/or any subsequent years covered under this Agreement does not appropriate sufficient funds for the program, this Agreement shall be of no further force and effect. In this event, the State shall have no liability to pay any funds whatsoever to Contractor or to furnish any other considerations under this Agreement and Contractor shall not be obligated to perform any provisions of this Agreement.

B. If funding for any fiscal year is reduced or deleted by the Budget Act for purposes of this program, the State shall have the option to either cancel this Agreement with no liability occurring to the State, or offer an agreement amendment to Contractor to reflect the reduced amount.

3. **Payment**

A. Costs for this Agreement shall be computed in accordance with State Administrative Manual Sections 8752 and 8752.1.

B. Nothing herein contained shall preclude advance payments pursuant to Article 1, Chapter 3, Part 1, Division 3, Title 2 of the Government Code of the State of California.

EXHIBIT C
(Interagency Agreement)

GENERAL TERMS AND CONDITIONS

PLEASE NOTE: This page will not be included with the final contract. The General Terms and Conditions will be included in the contract by reference to Internet site www.dgs.ca.gov/contracts.

EXHIBIT D
(Interagency Agreement)

SPECIAL TERMS AND CONDITIONS

1. TERMINATION

During the term of this Agreement, either party may terminate this Agreement at will by providing thirty (30) days written notice to the other party. In the event of a termination, SFSU shall take all reasonable measures to prevent further costs attributable to the Commission. The Commission shall then be responsible for any reasonable and non-terminable obligations incurred by SFSU in the performance of this Agreement up to the date of termination, but not to exceed the balance of the total funds which remains unencumbered under this Agreement at the time of termination.

2. CREDITS

The cover or title page of any publication resulting from this Agreement shall include the following credit:

> This publication was prepared with financial assistance from the U.S. Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, under the provisions of the Federal Coastal Zone Management Act of 1972, as amended.

3. DISPUTES

Any dispute concerning a question of fact arising under the terms of this agreement which is not disposed of within a reasonable period of time (ten calendar days) by SFSU and the Commission employees normally responsible for the administration of this contract shall be brought to the attention of the Executive Director (or designated representative) of each organization for joint resolution.

4. FEDERAL GRANT CONDITIONS

This Agreement is funded from a NOAA financial assistance award to the Commission. SFSU shall comply with all conditions and federal administrative requirements of that award relating to third party participation.

5. FEDERAL GRANT EXTENSION

(a) It is mutually understood between the parties that this contract may have been written before ascertaining an extension of the FY 2012 Project of Special Merit NA12NOS4190026 NOAA Grant set to end on December 30, 2013 for the mutual benefit of both parties in order to avoid program and fiscal delays which would occur if the contract were executed after that determination was made.

(b) This contract is subject to any additional restrictions, limitations, or conditions enacted by the Congress or any statute enacted by the Congress which may affect the provisions, terms or funding of this contract in any manner.

Appendix A
Qualifications of Sub-awardees and Curriculum Vitae

Dr. Philip King received his Ph.D. from Cornell in 1987. His specialty is in Applied Microeconomics and Environmental Economies. He is an Associate Professor in Economics at San Francisco State University and was chair from 2002-2005. Over the past 15 years, he has completed over thirty economic studies for various government agencies including the Corps, and State and local governments. These projects analyzed the economic and tax revenue impacts of beach and other coastal projects at the national, State and regional/local levels. His current work involves analyzing the impacts of sea level rise on California's coastal economy and valuing beach ecosystem services.

Dr. Jenny Dugan is an Associate Research Biologist with the Marine Science Institute at the University of California at Santa Barbara. She helps coordinate and serves as an investigator with the Santa Barbara Coastal Long Term Ecological Research program. She has published more than 30 peer-reviewed papers concerning ecological connectivity among nearshore and intertidal habitats, marine conservation and restoration, disturbance responses and recovery, species interactions, and the physical and biological drivers of community structure and function in coastal ecosystems. Much of her research has focused on sandy beach ecosystems, and she has studied numerous aspects of beaches, their food webs and functions ranging from the bottom up effects and ecological function of macroalgal wrack subsidies to exploring the role of shorebirds as ecosystem indicators and key intertidal predators. Presently, she is collaborating with coastal managers to conduct studies to evaluate ecological impacts and implications of widespread human alterations of the coast, including urban development, shoreline armoring, beach grooming, oil spills, intertidal recovery dynamics, and climate change. A goal of this effort is to provide an ecological framework that may be used to inform coastal conservation and management. This project would also contribute to our Project of Special Merit proposal.

David Hubbard is an Assistant Research Specialist at the Marine Science Institute, University of California, Santa Barbara and a founding principal at Coastal Restoration Consultants, Inc. He has investigated the ecology of beaches, wetlands and rocky shorelines in California since 1981 and published 25 peer-reviewed coastal ecology papers on topics ranging from physical dynamics of coastal ecosystems, marine subsidies, nutrient cycling, invertebrates, bird use, coastal strand and dune vegetation, to the effects of beach management actions and shoreline armoring. With Coastal Restoration Consultants, Inc. since 1996, he works on planning, implementing and monitoring wetland and other native habitat restoration projects.

Dr. Karen Martin is Professor of Biology at Pepperdine University and holds the Frank R. Seaver Chair. She is co-creator and Executive Director of the Grunion Greeters program, a statewide network of hundreds of citizen scientist observers. Her research focuses on ecology and physiological adaptations of animals in the sandy and rocky intertidal zones. She has published over 40 peer-reviewed scientific papers and edited two books and two symposium volumes about the biology of the water-land interface.

PHILIP G. KING

Economics Department, San Francisco State University

E-mail: pgking@sfsu.edu

Cell: (530)-867-3935

Education:

July, 87 **Ph.D. in ECONOMICS** **CORNELL UNIVERSITY**
Fields: Applied Microeconomics, Economic Development, International Economics
Dissertation: Bargaining between Multinational Corporations and Less Developed Countries over Mineral Concessions Contracts.

May, 78 **B. A. in PHILOSOPHY & ECONOMICS** **WASHINGTON UNIVERSITY**
Nominated to Omicron Delta Epsilon (Economics Honor Society.)

Work Experience:

1/06-present	**ASSOCIATE PROFESSOR**	**SAN FRANCISCO STATE UNIVERSITY**
9/02-12/05	**CHAIR, ECONOMICS DEPARTMENT**	**SAN FRANCISCO STATE UNIVERSITY**
9/93-present	**ASSOCIATE PROFESSOR**	**SAN FRANCISCO STATE UNIVERSITY**
9/87-9/93	**ASSISTANT PROFESSOR**	**SAN FRANCISCO STATE UNIVERSITY**
9/83-5/85	**ASSISTANT PROFESSOR, ECONOMICS**	**S.U.N.Y. at CORTLAND**

Current Research

- Economics of Sea Level Rise at Ocean Beach, San Francisco (w. SPUR), and in Southern Monterey Bay (w. PWA).
- The Ecological Economics of Beaches (Funded by California Dept. of Boating and Waterways and BEACON), w. J. Dugan (UCSB).

Recent Refereed Papers:

"The Economic Costs of Sea Level Rise to California Beach Communities," w. A. McGregor and J. Whittet, California Resources Agency & Dept. of Boating and Waterways (Refereed through California Ocean Science Trust).

"Who's Counting: An Analysis of Beach Attendance Estimates in Southern California," w. A. McGregor, revise and resubmit at *Ocean and Coastal Management*.

"Size Matters: The Economic Value of Beach Erosion and Nourishment in Southern California', with L. Pendleton, C. Mohn, R. Vaughn, and J. Zoulas., in press, *Contemporary Economic Policy*.

"ESTIMATING THE POTENTIAL ECONOMIC IMPACTS OF CLIMATE CHANGE ON SOUTHERN CALIFORNIA BEACHES," with L. Pendleton, C. Mohn, D. G. Webster, R. Vaughn, and P. Adams, in press, *Climatic Change*.

"Economic Analysis of Reconfiguring the Long Beach Breakwater," w. A. McGregor, *Shore and Beach*, April/May 2011.

"Potential Loss in GNP and GSP from a Failure to Maintain California's Beaches", Fall 2004, with Douglas Symes, *Shore and Beach*.

Books: *International Economics and International Economic Policy*, 5th Edition, McGraw-Hill, 2009.

International Economics and International Economic Policy, 4th Edition, McGraw-Hill, 2004.

International Economics and International Economic Policy, 3rd Edition, McGraw-Hill, 2000.

International Economics and International Economic Policy, 2nd Edition, McGraw-Hill, 1995.

International Economics and International Economic Policy, 1st Edition, McGraw-Hill, 1990.

Policy Papers prepared for Government and Non-Profit Organizations:

Contributed Economics portion of Regional Sediment Master Plan for BEACON (Beach Erosion Authority for Clean Oceans and Nourishment—Santa Barbara and Ventura Counties), February 2009, with Noble Consultants.

ESTIMATING THE POTENTIAL ECONOMIC IMPACTS OF CLIMATE CHANGE ON SOUTHERN CALIFORNIA BEACHES, prepared for the California Energy Commission (Energy Commission) and the California Environmental Protection Agency (Cal/EPA), with Linwood Pendleton, Craig Mohn, D. G. Webster, Ryan K. Vaughn, and Peter Adams.

Prepared for the City of Stockton: Economic Analysis of A Proposed Ordinance to Limit Grocery Sales at Superstores in Stockton, California, May 10, 2007

Contributed Economics Portion of: "The ARC GIS Coastal Sediment Analysis Tool: A GIS Support Tool for Regional Sediment Management Program: White Paper, Draft Technical Report for U.S. Army Corps of Engineers, by Ying Poon (Everest Consultants), Los Angeles District, April 2006.

Contributed Economics Portion of: "Coastal Sediment Analysis Tool (CSBAT) Beta Version--Sediment Management Decision Support Tool for Santa Barbara and Ventura Counties," Draft Technical Report for U.S. Army Corps of Engineers, by Ying Poon (Everest Consultants), Los Angeles District, June 2006.

"The ArcGIS Coastal Sediment Analyst: A Prototype Decision Support Tool for Regional Sediment Management, John Wilson et. al., USC Geography Department, 2004 (contributed economic analysis for paper).

"The Economic of Regional Sediment Management in Ventura and Santa Barbara Counties," prepared for the California State Resources Agency, Final draft (refereed) , Fall 2006, prepared for the Coastal Sediment Management Work group (CSMW).

"The Potential Loss in GNP and GSP from a failure to Maintain California's Beaches," with Douglas Symes, prepared for the California State Resources Agency, 2002, http://userwww.sfsu.edu/~pgking/pubpol.htm.

"The (Economic) Benefits of California's Beaches," prepared for the California State Resources Agency, 2002, http://dbw.ca.gov/beachreport.htm.

"The Economic and Fiscal Impact of Beach Recreation in San Clemente," presented as part of Hearings on Congressional Appropriations for California Coastal Projects, US House of Representatives, April 2002. Also completed similar projects for Cities of Carlsbad, Carpinteria, Encinitas, and Solana Beach.

"Do Beaches Benefit Local Communities?: A Case Study of Two California Beach Towns," Fall 2002, *Proceedings of the Conference on California and the World Oceans.*

San Francisco's Economic Growth 1995-2000: The Fiscal Health of the City and Implications for the Future," prepared for the San Francisco Committee on Jobs Summer 2001. This report was widely cited in the San Francisco press including front page articles by the *Chronicle* and *Examiner*.

"The Demand for Beaches in California," prepared for the California Dept. of Boating and Waterways, Spring 2001.

"Cost Benefit Analysis of Shoreline Protection Projects in California," prepared for the California Dept. of Boating and Waterways, Spring 2000.

"The Fiscal Impact of Beaches in California," prepared for the *Public Research Institute*, San Francisco State University, Fall 1999, available at http://online.sfsu.edu/~pgking/beaches.htm.

"An Economic Analysis of Coastal Resources on the Majuro Atoll," prepared for the *United Nations Development Program* Project MAS 95/001/D01/99 and the *Majuro Atoll Local Government*, September, 1997.

"The Economic Impact of California's Beaches," prepared for the *Public Research Institute*, San Francisco State University, Summer, 1997 (with Michael Potepan.)

"The Revenue Impact of the Proposed Marine Link Pipeline System in Richmond, California," prepared for the *Public Research Institute*, San Francisco State University, Spring, 1997 (with Ted Rust.)

"The Economic Impact of California's Ports and Harbors," prepared for the *Public Research Institute*, San Francisco State University, Spring, 1997 (with Ted Rust).

Public Testimony:

Testified and prepared report to the California Coastal Commission in San Diego on the economic loss due to a proposed seawall at Las Brisas, Solana Beach, California, 2005.

Current SFSU Committees:

Chair, SFSU Foundation Investment Committee and member of SFSU Foundation.

Board Member, SFSU University Corporation and Finance Committee.

Other:

- Present papers at one to three Environmental and Coastal Management Conferences a year.
- Appointed to the City of Davis Budget and Finance Commission.
- Prepared (CEQA) testimony in over forty cases involving Big Box stores in California.

Jenifer Elaine Dugan
Marine Science Institute
University of California
Santa Barbara, CA 93106-6150
(805) 893-2675 office, (805) 893-8062 fax
email: j_dugan@lifesci.ucsb.edu

Education and Professional Preparation

B.A. Aquatic Biology, high honors, University of California, Santa Barbara
Ph.D. Biology, University of California, Santa Barbara
Postdoctoral Fellow, Dept. of Zoology, Univ. Port Elizabeth, Republic of South Africa
Postdoctoral Fellow, Dept. Marine Science, Univ. Otago, Dunedin, New Zealand.

Appointments

2003-	Associate Research Biologist, Marine Science Institute, UC Santa Barbara
2002-	Science Coordinator, Santa Barbara Coastal LTER Program UC Santa Barbara
2000-2007	Deputy Director, Coastal Marine Institute, UC Santa Barbara
1995-2002	Assistant Research Biologist, Marine Science Institute, U.C. Santa Barbara
1995-2002	Lecturer, Ecology, Evolution Marine Biology, Univ. of Calif., Santa Barbara, CA (12 terms).
1991-2004	Lecturer, Environmental Studies, Univ. of Calif, Santa Barbara, CA. (8 terms).
1988-1993	Marine Biologist, Coop. Park Sci. Unit, UC Davis, Channel Islands Nat. Park

Selected Publications

submitted	Jaramillo, E, JE Dugan, DM Hubbard, D Melnick. M Manzano, C Duarte. Ecological legacies of extreme events: footprints of the 2010 earthquake along the Chilean coast. *Proc. Nat. Acad. Sciences*.
submitted	Barnard, PL, DM Hubbard, JE Dugan. Sand dynamics on an alongshore-dominated littoral cell: correlating a 17-year single-point time series with regional patterns, Santa Barbara, California, USA. *Geomorphology*
in press	Dugan, JE, L Airoldi, MG Chapman, S Walker, TA Schlacher. Estuarine and Coastal Structures: Environmental Effects: a focus on shore and nearshore structures. In: Human-induced Problems (Uses and Abuses) in Estuaries and Coasts (eds. M. Kennish, M. Elliot), Treatise on Estuarine and Coastal Science Vol. 8 Chapter 2, Elsevier.
2011	Dugan, JE, DM Hubbard, HM Page, J Schimel. Marine macrophyte wrack inputs and dissolved nutrients in beach sands. *Est. Coasts*. 34(4): 839-850.
2011	Revell DL, JE Dugan, DM Hubbard. Physical and ecological responses of beaches to the 1997-98 El Nino. *J. Coastal Res*.27(4): 718-730..
2011	Dawson, MN, PH Barber, LI Gonzales, RJ Toonen, JE Dugan, RK Grosberg. Phylogeography of *Emerita analoga* (Crustacea, Decapoda, Hippidae), an eastern Pacific Ocean sand crab with long-lived pelagic larvae. *J.Biogeog*. 38(8): 1600-1612. DOI: 10.1111/j.1365-2699.2011.02499.x
2010	Dugan, JE, O Defeo, E Jaramillo, AR Jones, M Lastra, R Nel, CH Peterson, F Scapini, T Schlacher, DS Schoeman. Give beach ecosystems their day in the sun. *Science*, 329: 1146.
2010	Dugan, JE, DM Hubbard. Loss of coastal strand habitat in southern California: the role of beach grooming. *Est. Coasts*. 33(1): 67-77.
2009	Guerrini, A, JE Dugan. Coastal Dynamics: Toward informing ecological restoration in a coastal context. Pp 131-142 In: Restoration and History: The Search for a Usable Environmetal Past (ed. M. Hall) Routledge, Oxford.
2009	Defeo O, A McLachlan, D Schoeman, T Schlacher, J Dugan, A Jones, M Lastra, F Scapini. Threats to sandy beach ecosystems: a review. *Est. Coastl Shelf Sci.* 81: 1-12
2008	Dugan J.E., D.M. Hubbard, I.F. Rodil, D. Revell. Ecological effects of coastal armoring on sandy beaches. *Mar. Ecol*. 29: 160-170.

2008 Schlacher TA, DS Schoeman, J Dugan, M. Lastra, A Jones, F Scapini, A McLachlan. Sandy beach ecosystems: key features, management challenges, climate change impacts, and sampling issues. *Mar. Ecol*. 29: 70-90.

2008 Page HM, DC Reed, MA Brzezinski, JM Melack, JE Dugan. Assessing the importance of land and marine sources of organic matter to kelp forest food webs. *Mar. Ecol. Prog. Ser*. 360: 47-62.

2008 Lastra M, HM Page, JE Dugan, DM Hubbard, IF Rodil. Processing of allochthonous macrophyte subsidies by sandy beach consumers: estimates of feeding rates and impacts on food resources. *Mar. Biol*. 154: 163-174.

2008 Page HM, C Culver, J Dugan, B Mardian Oceanographic gradients and patterns in invertebrate assemblages on offshore oil platforms. *ICES J Mar. Sci*.

2007 Schlacher TA, JE Dugan, DS Schoeman, M Lastra, A Jones, F Scapini, A McLachlan, O Defeo. Sandy beaches at the brink. *Div. Dist*. 13(5): 556-560.

2007 Page HM, JE Dugan, DM Schroeder, MM Nishimoto, MS Love, JC Hoesterery. Trophic links and condition of a temperate reef fish: comparisons among offshore oil platform and natural reef habitats. *Mar. Ecol. Prog. Ser*. 344: 245-256.

2006 Page HM, JE Dugan, CC Culver, J Hoesterey. Exotic invertebrate species on offshore oil platforms. *Mar. Ecol Prog. Ser*. 325: 101-107.

2006 Dugan JE, DM Hubbard. Ecological responses to coastal armoring on exposed sandy beaches. *Shore & Beach*. 74(1): 10-16.

2005 Bram JB, HM Page, JE Dugan. Spatial and temporal variability in early successional patterns of an invertebrate assemblage at an offshore oil platform. *J. Exp. Mar. Biol. Ecol*. 317(2): 223-237.

2004 Bomkamp R, HM Page, JE Dugan. Role of food subsidies and habitat structure in influencing benthic communities of shell mounds at sites of existing and former offshore oil platforms. *Mar. Biol*. 1432-1793

2004 Dugan JE, DM Hubbard, E Jaramillo, H Contreras, C Duarte. Competitive interactions in macroinfaunal animals of exposed sandy beaches. *Oecologia*. 139 (4): 630-640

2003 Dugan JE, DM Hubbard, M McCrary, M Pierson. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. *Est Coastl. Shelf Sci*. 58S: 133-148.

2003 Hubbard DM, JE Dugan. Shorebird use of an exposed sandy beach in southern California. *Est. Coastl. Shelf Sci*. 58S: 169-182.

2003 Roberts C, S Andelman, G Branch, R Bustamante, J Carlos-Castilla, J Dugan, B Halpern, H Leslie, K Lafferty, J Lubchenco, D McArdle, H Possingham, M Ruckleshaus, R Warner. Ecological criteria for evaluating candidate sites for marine reserves *Ecol. Appl*. 13(1 Suppl S):S199-S214

2003 Airame S, JE Dugan, , KD Lafferty, HM Leslie, D McArdle, RR Warner. Applying ecological criteria to the design of marine reserves: a case study from the California Channel Islands. *Ecol. Appl*. 13(1 Suppl S):S170-S184.

2000 Dugan JE, DM Hubbard, M Lastra. Burrowing abilities and swash behavior of three crabs, *Emerita analoga* Stimpson, *Blepharipoda occidentalis* Randall and *Lepidopa californica* Efford (Anomura, Hippoidea), of exposed sandy beaches. *J. Exp. Mar. Biol. Ecol*. 255(2): 229-245.

1999 Dugan JE, A McLachlan. An assessment of longshore movement in *Donax serra*: Röding (Bivalvia: Donacidae) on an exposed sandy beach. *J. Exp. Mar. Biol. Ecol***.** 234 (1): 111-124.

1995 McLachlan A, E Jaramillo, O Defeo, J Dugan, A de Ruyck, P Coetzee. Adaptations of bivalves to different beach types. *J. Exp. Mar. Biol. Ecol.* 187: 147-160.

1996 McLachlan A, J Dugan, O Defeo, A Ansell, D Hubbard, E Jaramillo, P Penchaszadeh. Beach clam fisheries. *Ocean. Mar. Biol. Ann. Rev*. 34: 163-232.

1994 Dugan JE., DM Hubbard, AM Wenner. Geographic variation in life history in populations of the sand crab, *Emerita analoga* Stimpson, on the California coast: relationships to environmental variables. *J. Exp. Mar. Biol. Ecol*. 181: 255-278.

David M. Hubbard

Coastal Restoration Consultants, Inc.
6896 Sabado Tarde Road
Isla Vista, CA 93117
telephone: 805-698-1119
email: dave@crcsb.com

David founded Coastal Restoration Consultants, Inc. with Matthew James in 2005. He has studied the natural resources of the California coast since 1981, and has been planning, implementing and monitoring wetland and other native habitat restoration projects since 1996.

EDUCATION:

1980 – B.A. Studio Art with high honors, UCSB, 1984 – 2nd major Biology, UCSB

RECENT EMPLOYMENT AND EXPERIENCE:

Principal, Coastal Restoration Consultants, Inc., 2005 to present. Responsibilities include designing, implementing, monitoring and reporting on native habitat restoration projects: data analysis and presentation, writing plans and reports; coordinating with project managers, agency staff and contractors; hiring, training and supervising staff, and presenting results at meetings and conferences.

Assistant Research Specialist, UCSB Marine Science Institute, 2005 to present. Investigating ecology of sandy beaches: physical factors, marine wrack subsidies, invertebrates and bird surveys. Responsibilities include: field work, literature reviews, data analysis and presentation, writing reports and manuscripts.

Museum Scientist, UCSB Museum of Systematics and Ecology, Department of Ecology, Evolution and Marine Biology. Natural Areas manager and coordinator for restoration ecology program and restoration ecology seminars, designed and implemented restoration projects, 1999-2005.

Staff Research Associate, UCSB Marine Science Institute. 1995-1999. Investigated ecology of sandy and rocky shores: field work, data analysis and report preparation.

Project Biologist, Ecometrics, Carlsbad, CA. 1996. Developed protocols and conducted field studies of potential impacts of oil spill on sandy beach invertebrates at Guadalupe, CA.

SELECTED PEER-REVIEWED PUBLICATIONS ON BEACHES AND BEACH ECOLOGY:

Submitted. Barnard P.L, D. M. Hubbard and J. E. Dugan. Sand dynamics on an alongshore-dominated littoral cell: correlating a 17-year single-point time series with regional patterns, Santa Barbara, California, USA. Geomorphology.

2011. Revell, D. L., J. E. Dugan and D. M. Hubbard. Physical and ecological responses of sandy beaches to the 1997-98 El Nino. Journal of Coastal Research 27(4): 718-730.
http://www.pwa-ltd.com/about/news/revelletal_lidarecology_jcr072011.pdf

2011. Dugan, J.E., D. M. Hubbard, H. M. Page and J. P. Schimel. Marine macrophyte wrack inputs and dissolved nutrients in beach sands. Estuaries and Coasts 34(4): 839-850.
http://www.springerlink.com/content/u034q2l0p0j98286/

2010. Dugan, J. E. and D. M. Hubbard. Loss of coastal strand habitat in southern California: the role of beach grooming. Estuaries and Coasts 33(1): 67-77.
http://www.springerlink.com/content/8781487k27513h22/

2008. Lastra, M., H. M. Page, J. E. Dugan, D. M. Hubbard and I. F. Rodil. Processing of allochthonous macrophyte subsidies by sandy beach consumers: estimates of feeding rates and impacts on food resources. Marine Biology 154 (1): 163- 174.
http://www.springerlink.com/content/g82k076506411j47/

2008. Dugan, J. E., D. M. Hubbard, I. F. Rodil, D. Revell and S. Schroeter. Ecological effects of coastal armoring on sandy beaches. Marine Ecology Progress Series, 29: 160-170.
http://www.mendeley.com/research/ecological-effects-of-coastal-armoring-on-sandy-beaches/

2006 Dugan, J. E., and D. M. Hubbard. Ecological responses to coastal armoring on exposed sandy beaches. Shore and Beach. 74(1): 10-16.
http://md1.csa.com/partners/viewrecord.php?requester=gs&collection=ENV&recid=6787916&q=Ecological+responses+to+coastal+armoring+on+exposed+sandy+beaches&uid=790982803

2004 Dugan, J. E., Jaramillo, E. , D. M. Hubbard, H. Contreras and C. Duarte. Competitive interactions in macroinfauna of exposed sandy beaches. Oecologia 139: 630-640
http://www.springerlink.com/content/xamr3bry474nu845/

2003 Dugan, J. E., D. M. Hubbard, M. McCrary and M. Pierson. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuar. Coastl. Shelf Sci. 58S: 133-148.
http://www.bren.ucsb.edu/academics/courses/254/Readings/Dugan_et_al_2003.pdf

2003 Hubbard, D. M. and J. E. Dugan. Shorebird use of an exposed sandy beach in southern California. Estuar. Coastl. Shelf Sci. 58S: 169-182.
http://www.sciencedirect.com/science/article/pii/S0272771403000489

2000 Dugan, J. E., Hubbard, D. M., Engle, J. M., Martin, D. L., Richards, D. M., Davis, G. E., Lafferty, K. D., Ambrose, R. F. Macrofauna communities of exposed sandy beaches on the Southern California mainland and Channel Islands. Fifth California Islands Symposium, OCS Study, MMS 99-0038: 339-346.

Karen L. M. Martin, Ph.D.
Frank R. Seaver Professor of Biology, Department of Biology, Natural Science Division, Pepperdine University, 24255 Pacific Coast Highway, Malibu, CA 90263-4321
Email: karen.martin@pepperdine.edu; Phone: (310) 506-4808; Fax: (310) 506-4785.
Research Associate, Scripps Institution of Oceanography
Executive Director, Grunion Greeters: www.Grunion.Org
Board of Directors, Beach Ecology Coalition

Professional Preparation

University of Oklahoma	Zoology	BS	1975
University of Oklahoma	Zoology	MS	1979
University of California, Los Angeles	Biology	PhD	1990
University of Washington	Friday Harbor Postdoctoral Fellow		1990-91

Professional Experience

1991-present Professor of Biology, Pepperdine University, Malibu, Calif., Frank R. Seaver Chair in Natural Science since 2000.
2009-present: Section Editor, peer-reviewed journal COPEIA, for Physiological Ecology
1998-99 Adjunct Research Professor, Calif. State Univ., Fullerton, Sabbatical.
1990 Lecturer, University of California, Los Angeles (UCLA).

Publications: *Ten most closely related to project*

1. Martin K. L., K. Bailey, C. Moravek and K. Carlson. 2011. Taking the plunge: California Grunion embryos emerge rapidly with environmentally cued hatching (ECH). Integrative and Comparative Biology 51:1-12. doi:10.1093/icb/icr037
2. Moravek C. L. and K. L. Martin. 2011. Life goes on: Delayed hatching, extended incubation and heterokairy in development of embryonic California Grunion *Leuresthes tenuis*. Copeia 2011(2): 308-314. DOI 10.1643/CG-10-164
3. Martin K. L. M., C. L. Moravek and A. J. Walker. 2011. Waiting for a sign: Extended incubation postpones larval stage in the beach spawning California Grunion *Leuresthes tenuis* (Ayres). Environmental Biology of Fishes 91:63-70. doi:/10.1007/s10641-010-9760
4. Johnson, P. B., K. L. Martin, T. L. Vandergon, R. L. Honeycutt, R. S. Burton, and A. Fry. 2009. Microsatellite and mitochondrial genetic comparisons between northern and southern populations of California Grunion *Leuresthes tenuis*. Copeia 2009: 467-476.
5. Martin, K. L. M., C. L. Moravek, and J. A. Flannery. 2009. Embryonic staging series for the beach spawning, terrestrially incubating California grunion *Leuresthes tenuis* (Ayres 1860) with comparisons to other Atherinomorpha. J. Fish Biology 75: 17-38.
6. Matsumoto, J. K., and K. L. M. Martin. 2008. Lethal and sublethal effects of altered sand salinity on embryos of beach-spawning California Grunion. Copeia 2008: 483-490.
7. Martin, K., T. Speer-Blank, R. Pommerening, J. Flannery, and K. Carpenter. 2006. Does beach grooming harm grunion eggs? Shore & Beach 74: 17-22.
8. Martin, K. L. M., R. C. Van Winkle, J. E. Drais, and H. Lakisic. 2004. Beach spawning fishes, terrestrial eggs, and air breathing. Physiological and Biochemical Zoology 77: 750-759.
9. Martin, K., A. Staines, M. Studer, C. Stivers, C. Moravek, P. Johnson, and J. Flannery. 2007. Grunion Greeters in California: Beach Spawning Fish, Coastal Stewardship, Beach Management and Ecotourism. Pp. 73-86 *in* Lück, M.; Gräupl, A.; Auyong, J.; Miller, M.L. & M.B. Orams (eds.): *Proceedings of the 5th International Coastal & Marine Tourism Congress: Balancing Marine Tourism, Development and Sustainability*. Auckland, New Zealand: New Zealand Tourism Research Institute.

10. Roberts, D., R. N. Lea, and K. L. M. Martin. 2007. First record of the occurrence of the California Grunion, *Leuresthes tenuis*, in Tomales Bay, California; a northern extension of the species. California Fish & Game 93:107-110.

Educational Media

"*Surf, Sand, and Silversides: The California Grunion*," 2011, an educational video produced at Pepperdine University in collaboration with Michael Murrie and many students, funded by National Geographic Society, California Coastal Commission, and National Marine Fisheries Service. Screenings at several film festivals and aquariums.

Honors and Awards

Conservation Achievement Award, American Fisheries Society, Western Division, 2011.

First Place for Short Documentary, Los Angeles City Cinema Festival, "*Surf, Sand, and Silversides: The California Grunion*," 2011. This video received an Award of Merit, Best Shorts 2011, and was an Official Selection at several film festivals.

Environmental Partnership Award, American Shore and Beach Preservation Association, 2006.

Fellow, American Institute of Fishery Research Biologists, since 2004.

Synergistic activities:

1) Executive Director, Grunion Greeters, 2002-present.
2) Workshops for Grunion Greeters every year since 2002; in 2009, at Santa Monica Pier Aquarium in Los Angeles, Muth Interpretive Center in Newport Beach, Pepperdine University in Malibu, Buena Vista Audubon Society in Oceanside, Birch Aquarium at Scripps Institution of Oceanography in La Jolla, Aquarium of the Pacific in Long Beach, Marine Science Institute at UC Santa Barbara in Goleta, Tijuana Estuarine Research Reserve in Imperial Beach, Pacific Grove Museum in Monterey, California. Web site for grunion monitoring by citizen scientist Grunion Greeters, 2002 – present, See www.Grunion.Org.
3) Outreach (selected recent examples): Girls in Ocean Science, San Diego Science Festival, "Wildlife Watch Week" for National Wildlife Federation, National Geographic television program, "*Caught Bare-Handed*," "Animal Planet" Discovery Channel television: *Most Extreme: Swarms*, workshop for middle school teachers, Marina Del Rey Marine Science Academy; public programs at aquariums and state parks.
4) Board of Directors and Co-Founder, Beach Ecology Coalition, 2004- present.
5) Meetings for Beach Ecology Coalition semiannually since 2004, working with beach managers, park rangers, coastal scientists, environmental groups, and regulatory agencies to develop best practices for ecologically sensitive beach management.

Research Grants Received from:

National Science Foundation, Society for Integrative and Comparative Biology, Ocean Associates, Coastal America Foundation, National Marine Fisheries Service- Southwest Region, Habitat Conservation Division, National Park Service and U. S. Geological Survey, California Sea Grant College, Malibu City Council, National Geographic Society, Committee for Research and Exploration, National Fish and Wildlife Foundation**.**

Appendix B. Scope of Work for Academic Assistance

EXHIBIT A
(Interagency Agreement)

STATEMENT OF WORK

1. The California Coastal Commission ("the Commission") hereby contracts with San Francisco State University (SFSU) to provide services in accordance with the specifications stated in the Scope of Work, pursuant to the Project of Special Merit Grant Award from National Oceanic and Atmospheric Administration's Office of Ocean and Coastal Resource Management (NOAA-OCRM). The federal award documents for NOAA grant #NA12NOS4190026 are incorporated herein by this reference.

2. The term of this agreement will be for a period of eighteen (18) months from July 1, 2013 to December 31, 2014. There is an amendment option to extend the term of the agreement for an additional six (6) month time period under the same terms and conditions.

3. The project representatives during the term of this agreement will be:

Requesting Agency: California Coastal Commission	Providing Agency: San Francisco State University, Office of Research & Sponsored Programs
Name: Michelle Jesperson, Federal Programs Manager	Name: Janet Framiglio, ORSP Contract Coordinator
Address: 45 Fremont Street, Suite 2000 San Francisco, CA 94105	Address: 1600 Holloway Avenue, ADM 471 San Francisco, CA 94132
Phone: (415) 904-5297	Phone: (415) 405-0739
Fax: (415) 904-5400	Fax: (415) 338-2493

Direct all inquiries to:

Requesting Agency: California Coastal Commission	Providing Agency: San Francisco State University
Section/Unit: Federal Programs	Section/Unit: Office of Research & Sponsored Programs
Attention: Michelle Jesperson	Attention: Susan Pelton, Manager
Address: 45 Fremont St., Suite 2000 San Francisco, CA 94105	Address: 1600 Holloway Avenue, ADM 471 San Francisco, CA 94132
Phone: (415) 904-5297	Phone: (415) 338-7090
Fax: (415) 904-5400	Fax: (415) 338-2493

4. Scope of Work

SCOPE OF WORK

Improved Valuation of Impacts to Recreation, Public Access, and Beach Ecology from Shoreline Armoring in California

I. Introduction

The purpose of this work is to build upon ongoing efforts by the California Coastal Commission to mitigate proportionally and appropriately for the impacts to recreation, public access, and beach ecology, resulting from changes to shoreline sand supply and coastal processes, caused by shoreline armoring. For this project, Commission staff will work with beach ecologists and economists to assess California beach resources and develop valuation methods that will better account for the impacts of permitting shoreline armoring projects. The Commission's Senior Coastal Engineer will provide technical expertise on coastal processes and shoreline changes to assist the beach ecologists and economists with their analyses. This information will then be used to develop a set of mitigation options to appropriately offset any losses caused by such projects.

II. Background

An issue of major concern facing California today is the loss of beaches due to natural processes and anthropogenic factors. Since much of the coast is developed, beach loss puts development at risk from erosion and inundation. Now and into the future, accelerated sea level rise and extreme storm events are anticipated outcomes of climate change that will further increase beach losses, risks to development, and the resulting demand for both hard and soft protective options, such as shoreline armoring (seawalls and rip rap) and beach replenishment. These protective options often have unintended recreational, public access, and ecological consequences that need to be better understood, evaluated, avoided, and/or appropriately mitigated for when necessary.

The mission of the Coastal Commission is to "*Protect, conserve, restore, and enhance environmental and human-based resources of the California coast and ocean for environmentally sustainable and prudent use by current and future generations*." The Coastal Commission, or local government as appropriate, is charged with reviewing applications for coastal development permits to ensure proposed projects are consistent with the California Coastal Act policies or relevant Local Coastal Program where applicable. Detailed information on Coastal Act policies related to shoreline armoring can be found in **Attachment A.**

Coastal Act Section 30235 states:

> *"Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fishkills should be phased out or upgraded where feasible."*

Accordingly, Section 30235 only requires the Commission to authorize the construction of shoreline protective structures when the structures are required to serve coastal dependent uses or protect existing structures or public beaches in danger from erosion. The Coastal Act provides these limitations because shoreline armoring can have a variety of impacts on coastal resources, including effects on sand supply, public access and recreation, coastal views, natural landforms, marine resources, and overall shoreline beach dynamics on and off site. While the Coastal Act allows for shoreline armoring as outlined above, it is the Commission's policy to consider all options that will avoid impacts to coastal resources to the maximum extent possible and only to mitigate for any unavoidable impacts.

Over the years, the Commission has applied methods to quantify some of the typical impacts to sand supply and coastal processes caused by shoreline armoring including:

(1) The physical encroachment onto the beach from constructing the structure.
(2) The future loss of beach that will occur when the nearshore beach continues to erode and the back beach remains fixed.
(3) The future loss of beach sand that would have been contributed to the littoral cell from back shore erosion.

The first two of these factors represent physical losses of beach area which have significant consequences to recreation, public access, and beach ecology. The third factor has direct effects on the available sand supply and the ability of beaches to form and expand. Once the impacts to beach area and sand supply are quantified, those quantities are then used to establish mitigation requirements. The loss of sand supply and recreational opportunities is typically assigned a monetary value; however, there may also be other appropriate mitigation options to offset the losses. In-kind mitigation is the Commission's preferred alternative but is often not possible. **Attachment B** provides detail on the Coastal Commission's current valuation methods, as well as mitigation requirements that have been used to offset impacts quantified by these methods.

While the Commission's review of shoreline armoring has generally focused on those impacts that can be quantified and directly attributed to armoring, the Commission is aware that hard structures can have many other impacts on the coast. Hard structures can increase beach scour, cause end effects, and change the visual and community character of the beach, to list a few. These changes may be temporary or long-term. Some impacts, such as scour, may have cumulative impacts, with small amounts of sand being pulled offshore during each scour event. These impacts do not easily fit into any quantitative metrics; however, they are important changes to the beach that should not be overlooked in any evaluation of the overall impacts and resulting consequences from shoreline armoring. If and when quantitative metrics are developed for assessing such changes, the Commission will evaluate the benefit of adding them to the existing methods used to determine shoreline armoring impacts.

The Commission's current valuation methods, as applied to shoreline armoring projects, have only been used to address impacts to recreation and public access. The methods have not been used to address any of the impacts to the beach ecosystem (e.g. loss of ecosystem services, adverse impacts to beach organisms). In addition, the Commission has considered mitigation in the form of beach replenishment to offset losses to recreation; but the Commission has not consistently accounted for the potential adverse impacts beach replenishment may have on beach ecology.

To better evaluate the impacts of shoreline armoring and help establish mitigation alternatives for the impacts to recreation, public access, and beach ecology, the Commission is looking to develop more comprehensive valuation methods. Any new valuation methods should meet the following criteria to be useful to the Commission:

- Must be linked to beach resources that are impacted by shoreline armoring (**Attachment C** provides some examples found in the scientific literature).
- Must be applicable to a variety of California beaches that vary in size (wide, narrow, pocket) and material (sandy, cobble, boulder) as the methods will be utilized throughout California.
- Data required for the methods must be readily available in the peer-reviewed literature, government reports, and/or easily collected with limited resources (**Attachment D** details site specific information commonly requested from applicants for shoreline armoring projects).
- Must be relatively straightforward as it will be employed by coastal analysts and managers who will be under tight deadlines.
- Results from the methods must be in the form of a quantifiable currency (e.g. USD, number of acres, amount of larvae, biomass) so that they may logically lead to appropriate, site specific mitigation options.

With improved and more comprehensive valuation methods the immediate, future, and cumulative impacts of shoreline armoring can be reduced and better mitigated.

III. Scope

Goal: This work will produce valuation methods that can be used to assess the impacts and appropriate mitigation options for shoreline armoring projects throughout California, and assist Commission staff in better protecting the recreation, public access, and ecological values of California beaches.

The *objectives* we seek to meet in achieving this goal are to:

1. Develop a method to estimate the value of ecological beach resources that can be used to assess ecological losses that may result from shoreline armoring.

2. Develop a method to estimate the value of recreation and public access beach resources that can be used to assess recreation and access losses that may result from shoreline armoring.

3. Apply the recreation and public access valuation method (and the ecological valuation method depending on its state of development) to one or more real world case studies to evaluate its effectiveness for various beach conditions.

IV. Tasks and Schedule

Task 1: Kick Off Meeting
Timeline: 1 month, July 2013

1. **Conduct an in person kick off meeting** with all consultants and Commission staff involved in the project to discuss project objectives, deliverables, schedule, and the expectations of the consultants.

Task 2: Development of Ecological Valuation Method
Timeline: 15 months, August 2013-October 2014

Percent of Project Funding: 40%

2.1 Conduct a review of:

a) The ecological components and features of beaches and the existing information on qualitative and quantitative responses (losses) of these ecological resources to impacts imposed by shoreline armoring.

Consultants Responsible: Karen Martin, Dave Hubbard, and Jenny Dugan.

Deliverable (a): A report that identifies the ecological resources and features of beaches that respond to shoreline armoring and qualitatively describes the state of existing knowledge on impacts to (losses of) these ecological resources that occur when a shoreline is armored, identifying information gaps and needs.

b) The tools/models/methods that have been or could be applied in the valuation of beach ecological resources (identified in 2.1 (a)) to account for the quantitative and qualitative impacts to (losses of) these resources that can result from shoreline armoring (identified in 2.1 (a)). The tools, models, and methods could include (but are not limited to) Natural Capital Project InVEST models, Habitat Equivalency Analysis, Standard Assessment Methodology, Compensatory Mitigation Value-Transfer, Hedonic Analysis, and Spatial Analysis.

Consultants responsible: Phil King and Chad Nelson in consultation with Karen Martin, Dave Hubbard, and Jenny Dugan.

Deliverable (b): A report that describes the various tools, models, and methods that could be applied in the valuation of the beach ecological resources and the impacts to (losses of) these resources from shoreline armoring. For each method detail the analytical steps, an assessment of the data needs and feasibility of obtaining that data, describe the parameters that must be measured for use in the analysis, and describe the output that results from the method.

Deadline for Task 2.1: March 2014

2.2 Meeting/Consultation: Present to/consult with Commission staff on the outcomes of 2.1 (a) and (b) and the conclusions regarding the best approach to pursue for a beach ecological valuation method. Get direction from Commission staff on the feasibility and utility of the chosen approach.

Consultants Responsible: Phil King, Chad Nelson, Karen Martin, Dave Hubbard, and Jenny Dugan.

Deadline for Task 2.2: May 2014

2.3 Ecological Valuation Method: Based on the outcomes of 2.1 & 2.2, initiate development of an ecological valuation method to estimate the ecological value of California beaches that can be used to assess the ecological impacts/losses (as a quantifiable currency; e.g. USD, number of acres, amount of larvae, biomass) associated with specified changes to the beach resulting from shoreline armoring. Armoring changes could include direct loss of the beach from encroachment, loss of new sand to the beach and littoral cell from preventing inland erosion, or progressive loss of the beach due to sea level rise against a fixed back beach. Document the rationale supporting the chosen approach including the feasibility and utility of the proposed approach for economically valuing beach ecology. Depending on the state of the ecological method development, show application of the method through one or more case studies that are not active Coastal Commission projects.

Consultants Responsible: Phil King, Chad Nelson, Karen Martin, Dave Hubbard, and Jenny Dugan.

Deliverable: A report of the ecological valuation method and rationale for the method, including the analytical steps, the parameters that must be measured for use in the analysis, how to obtain the necessary measurements, and the outputs that will result from the method. If feasible based on the state of the ecological method development, include a write-up of one or more case studies demonstrating application of the method to specific situations.

Consultation: Meet with Commission staff to review the final method and gather feedback.

Deadline for Task 2.3: October 2014

<u>Task 3: Development of Recreation and Access Valuation Method</u>
Timeline: 15 months, August 2013-October 2014
Percent of Project Funding: 40%

3.1 Conduct a review of the tools/models/methods that have been applied in the valuation of recreation and public access resources provided by beaches (on the beach and within nearshore waters) and the quantitative and qualitative changes to these resources that can result when shoreline armoring occurs. The purpose of the review is to provide background for the economic valuation tool developed in this project.

Consultants Responsible: Phil King and Chad Nelson.

Deliverable: A report that describes these tools, models, and methods. For each method detail the analytical steps, describe the parameters that must be measured for use in the analysis, and describe the outputs that will result from the method.

Deadline for Task 3.1: March 2014

3.2 Meeting/Consultation: Meet with relevant Coastal Commission staff to discuss the following:

a. The format/usability of a recreation/public access method for coastal managers.
b. What data should be required by the applicant (or where applicant does not provide the data, what assumptions should be made).
c. What, if any, data inputs Coastal Commission staff could/should supply.
d. Format/features of the user manual for the user-friendly method.
e. Discuss specific case studies to be used in the project.

Consultants Responsible: Phil King and Chad Nelson.

Deadline for Task 3.2: May 2014

3.3 Develop a recreation and public access valuation method, based on the results of 3.1 and 3.2, to estimate the value of recreation and public access resources provided by California beaches that can be used to assess the public access and recreation losses associated with specified changes to the beach resulting from armoring projects. Armoring changes could include direct loss of the beach from encroachment, a loss of new sand to the beach and littoral cell from preventing inland erosion, or progressive loss of the beach due to sea level rise against a fixed back beach. Show application of the method through one or more case studies that are not active Coastal Commission projects. (Phil and Chad)

Consultants Responsible: Phil King and Chad Nelson.

Deliverable: (a)A user-friendly method which values recreation and public access based on key inputs/parameters (e.g., attendance, beach width over time, amenities, access) approved by Coastal Commission staff. The method may also allow staff to choose from a taxonomy of beach types (e.g., heavily used southern California beach with full amenities and access, narrow northern California beach with few amenities, etc.). (b) A short (~ 15-20 page) user manual along with a technical appendix or paper explaining the method in more detail and write-up of one or more case studies demonstrating application of the method to specific situations.

Consultation (in person): Meet with Commission staff to review final methodology and gather feedback.

Deadline for Task 3.3: October 2014

Task 4 Write Up Final Report
Timeline: 3 months, October 2014-December 2014
Percent of Project Funding: 20%

The team will write up a final report incorporating memos and research discussed above. The report will be thorough enough to cover clearly all issues and information required by this Scope of Work. It is anticipated that the earlier deliverables will be sections of the final report and that the full report will be approximately 50 pages. CCC staff will have 6 weeks to review.

Consultants Responsible: Phil King, Chad Nelson, Karen Martin, Dave Hubbard, and Jenny Dugan.

Deadline for Task 4: December 2014

V. Project Budget

The total amount allocated for this agreement is $117,100. The project budget has been allocated as a percentage for each task.

Consultant Responsible	Percent Time on Task	Budget Allocation	Overhead Rate	Overhead Cost	Total Cost
Task 2: Development of Ecological Valuation Method (40%)					
Karen Martin	10%	10,000	15%	1,500	11,500
Dave Hubbard	10%	10,000	15%	1,500	11,500
Jenny Dugan	10%	10,000	30%	3,000	13,000
Phil King	5%	5,000	15%	750	5,750
Chad Nelsen	5%	5,000	15%	750	5,750
Task 3: Development of Recreation and Access Valuation Method (40%)					
Phil King	20%	20,000	15%	3,000	23,000
Chad Nelsen	20%	20,000	15%	3,000	23,000
Task 4: Write Up Final Report (40%)					
Karen Martin	4%	4,000	15%	600	4,600
Dave Hubbard	4%	4,000	15%	600	4,600
Jenny Dugan	4%	4,000	30%	1,200	5,200
Phil King	4%	4,000	15%	600	4,600
Chad Nelsen	4%	4,000	15%	600	4,600
Total Cost		100,000		17,100	**117,100**

VI. Progress/Compliance

Periodic consultations have been scheduled and linked to individual deliverables to ensure the outcomes of the project will be relevant, realistic, and useful for the Commission staff's project review process. Other communication can be arranged as needed by the project work. The primary points of contact within the Commission will be Jonna Engel and Lesley Ewing. Consultations will be scheduled by the primary points of contact and can be in person or by phone call, depending on discussion topics and consultant availability. A Steering Committee made up of Commission staff members and one out of state coastal manager will periodically review the products being produced and provide feedback to the primary points of contact to be relayed to the consultants. Other Commission staff may assist with scheduling and project management as appropriate. Below is a table summarizing the tasks, deliverables, consultations, and deadlines.

Task #	Description	Deliverable	Consultation	Deadline
Task 1	**Kick Off Meeting**			
1.	Conduct an in person meeting with all consultants and Commission staff to discuss the project and expectations of the consulting team.			July 2013
Task 2	**Development of Ecological Valuation Method**			
2.1	Review of beach ecological resources and tools/models/methods	Report on resources and tools/models/methods		March 2014
2.2	Present to/consult with Commission staff on the outcomes of 2.1			May 2014

Task #	Description	Deliverable	Consultation	Deadline
2.3	Initiate development of an ecological beach resource valuation method	Method and method rationale	In person meeting with Commission Staff	October 2014
Task 3	**Development of Recreation and Access Valuation Method**			
3.1	Review of public access and recreation resources and tools/models/methods	Report on tools/models/methods		March 2014
3.2	Meet with Commission staff to discuss format and features of method and user manual.			May 2014
3.3	Develop a recreation and public access valuation method	Method and Manual	In person meeting with Commission Staff	October 2014
Task 4	**Final Report**			
4.1	Write-up a final report	Final Report		December 2014

VII. End Product Delivery

All mid-project deliverables, including references, should be delivered to the primary points of contact via email in word or pdf format by the designated scheduled deadline.

VIII. Attachments

Attachment A: Select Coastal Act Policies Specifically Applicable to Shoreline Protection Projects

Attachment B: Methods Used by the California Coastal Commission to Evaluate and Mitigate for Beach Recreation and Access Impacts

Attachment C: Linking Recreational and Ecological Beach Characteristics with Physical Characteristics of Beaches Impacted by Shoreline Armoring

Attachment D: Information Commonly Requested from Applicants for Shoreline Armoring Projects

Attachment A
Select Coastal Act Policies Specifically Applicable to Shoreline Protection Projects

Construction altering natural shoreline

Coastal Act Section 30235 addresses the use of shoreline protective devices:

> ***30235.*** *Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fish kills should be phased out or upgraded where feasible.*

Minimization of adverse impacts

Coastal Act Section 30253 addresses the need to ensure long-term structural integrity, minimize future risk, and to avoid landform altering protective measures in the future. Section 30253 provides, in applicable part:

> ***Section 30253.*** *New development shall do all of the following:*
>
> *(1) Minimize risks to life and property in areas of high geologic, flood, and fire hazard.*
>
> *(2) Assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs.*

Public access and recreation

Coastal Act Sections 30210 through 30214 and 30220 through 30224 specifically protect public access and recreation. In particular:

> ***30210.*** *In carrying out the requirement of Section 4 of Article X of the California Constitution, maximum access, which shall be conspicuously posted, and recreational opportunities shall be provided for all the people consistent with public safety needs and the need to protect public rights, rights of private property owners, and natural resource areas from overuse.*
>
> ***30211.*** *Development shall not interfere with the public's right of access to the sea where acquired through use or legislative authorization, including, but not limited to, the use of dry sand and rocky coastal beaches to the first line of terrestrial vegetation.*
>
> ***30213.*** *Lower cost visitor and recreational facilities shall be protected, encouraged, and, where feasible, provided. Developments providing public recreational opportunities are preferred. …*
>
> ***30221.*** *Oceanfront land suitable for recreational use shall be protected for recreational use and development unless present and foreseeable future demand for public or commercial recreational activities that could be accommodated on the property is already adequately provided for in the area.*
>
> ***30223.*** *Upland areas necessary to support coastal recreational uses shall be reserved for such uses, where feasible.*

Coastal Act Section 30240(b) also protects parks and recreation areas, such as the adjacent beach area. Section 30240(b) states:

> ***30240(b).*** *Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas.*

Visual resources

Coastal Act Section 30251 states:

> ***Section 30251.*** *The scenic and visual qualities of coastal areas shall be considered and protected as a resource of public importance. Permitted development shall be sited and designed to protect views to and along the ocean and scenic coastal areas, to minimize the alteration of natural land forms, to be visually compatible with the character of surrounding areas, and, where feasible, to restore and enhance visual quality in visually degraded areas. New development in highly scenic areas such as those designated in the California Coastline Preservation and Recreation Plan prepared by the Department of Parks and Recreation and by local government shall be subordinate to the character of its setting.*

Coastal Act Section 30240(b), previously cited, also protects the aesthetics of beach recreation areas Section 30240(b) states:

> ***Section 30240(b):*** *Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas.*

Marine resources

Coastal Act Sections 30230 and 30231 provide:

> ***Section 30230.*** *Marine resources shall be maintained, enhanced, and where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.*

> ***Section 30231.*** *The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of ground water supplies and substantial interference with surface water flow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of natural streams.*

Attachment B
Methods Used by the California Coastal Commission to Evaluate and Mitigate for Beach Recreation and Access Impacts

Overview

The protection and enhancement of beach access and public recreational uses of the coast are fundamental tenets of the California Coastal Act. Throughout the years, the Commission has acted to improve beach conditions through access dedications, offers to dedicate access and open space, through certification of Local Coastal Programs and through project review and permit conditions that avoid or minimize physical impacts to beach areas. The installation or expansion of seawalls, revetments and other back shore protection structures is one of the main actions that can have an adverse impact on beaches as well as on the various opportunities for using the beach. This paper will provide a short summary of the recent Commission approaches to beach and recreation use protection and the Coastal Act basis for these efforts.

Impacts from Armoring and Mitigation Required by the Coastal Act

In the mid-1990's, Commission staff noticed several disturbing trends in shore protection – the first were applications for larger and more massive seawalls to protect coastal bluffs (Figure 1), and the second was the proliferation of shore protection being placed on lands that could be considered public beach, either due to the ambulatory nature of the Mean High Tide Line, to an offer to dedicate access, or to a prior determination of state interest. Adverse impacts to beach areas and beach access has long been a concern for coastal managers and the California Coastal Act addresses those concerns through general requirements to avoid adverse impacts to coastal resources whenever possible, to minimize unavoidable impacts and then to mitigate for unavoidable impacts if possible – especially impacts to local sand supply. The basis for this comes from Section 30235 of the California Coastal Act that states, "Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Existing marine structures causing water stagnation contributing to pollution problems and fishkills should be phased out or upgraded where feasible."

Figure 1: Large soldier pile seawall.

The tests for shoreline protection are that

1. there is a coastal dependent use, existing structure or public beach;
2. that the coastal dependent use, existing structure or public beach is in danger from erosion,
3. that the structure avoid or minimize impacts on coastal resources and
4. that the structure eliminate or mitigate adverse impacts on local shoreline sand supply.

This leads to an analysis of the need for the project, identification of alternatives that would avoid the need for shoreline armoring, and then designs that minimize the impacts from shoreline armoring that is found to be needed. In order to minimize impacts from unavoidable shore protection, the Commission discouraged massive engineered seawalls and revetments in favor of seawalls that were more in line with the profile of the bluff and that could be colored and texturized to mimic natural bluff features (Figure 2).

Figure 2: Photo of Seawall at Pleasure Point. Designed and built to blend with natural bluff conditions.

The Commission also developed and implemented a method for quantifying many of the impacts to beach areas from the installation of shore protection structures. The Commission worked through the process of quantifying impacts with the thought that it might be easier to develop mitigation for quantifiable impacts. Seawall impacts are not limited to those that can be easily quantified – there are also temporary but recurring impacts due to scour, longer term impacts due to end effects, and visual impacts, which can result in permanent changes to the character of the coast. In addition, if a seasonal eroded beach condition occurs with greater frequency due to the placement of a shoreline protective device, then the subject beach would also accrete at a slower rate. Morever, if the seawall is subject to wave action on a frequent basis, then beach scour during the winter season will be accelerated because there is less beach area to dissipate the wave's energy. And, even if these beach changes are reversible or short-lived, the beach disturbances may result in changes to the ecosystems function that last long after physical recovery. However, the three aspects of the impacts of shore protection that have been regularly quantified are:

1. the physical encroachment from placing the structure on the beach;
2. the long-term denial of new beach area due to fixing the back location of the beach on an eroding shoreline, often termed passive erosion; and
3. the denial of sediment to the littoral cell from halting bluff erosion.

Figures 3-7 show these aspects of seawall impacts and the general equations for calculating these impacts are shown in **Table 1**. This method provided a means to quantify both a volume of sand lost to the littoral cell and an area of beach that would be lost for public access and recreation.

Over the years, the Commission had taken various steps to require that new seawall projects mitigate for unavoidable impacts. As noted in the 1997 Report on In-Lieu Fee Beach Sand Mitigation Program: San Diego County:

> "The California Environmental Quality Act (CEQA) guidelines provide a definition of mitigation for purposes of CEQA. Section 15370 of the CEQA guidelines define mitigation as:
>
> > 1) Avoiding the impact altogether by not taking a certain action or parts of an action.
> >
> > 2) Minimizing impact by limiting the degree or magnitude of the action and its implementation.
> >
> > 3) Rectifying the impact by repairing, rehabilitating, or restoring the impacted environment.
> >
> > 4) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
> >
> > 5) Compensating for the impact by replacing or providing substitute resources or environments.
>
> This definition provides several alternative forms of mitigation. In mitigation by avoidance, adverse impacts are avoided altogether through alteration of project location, design, or other related aspects. Commission staff typically recommends mitigation by avoidance, if feasible, since it is the best way to prevent direct adverse impacts to public access and sand supply in association with a shoreline protective device. However, if the Commission is required to approve a shoreline altering device to protect an existing structure in danger from erosion, minimizing, rectifying or reducing project impacts are forms of mitigation that diminish the severity of the project related impacts and are required under Section 30235. Although these forms of mitigation can result in alterations to the project design, the overall integrity of the project can be preserved."[1]

Options for Mitigation of Seawall Impacts

Options for mitigation are evolving; there has not been one universal mitigation option that covers all parts of the state or all impact situations. And, since the best mitigation is something that provides immediate and lasting benefits to the coastal region that is being affected, in-situ mitigation, while difficult to develop, is normally encouraged. When actual site improvements are not possible, the commission has considered some off-site improvements, and as a final option has considered in-lieu mitigation. Over the years, the Commission has generally used four different mitigation approaches. These approaches have connected the in-lieu mitigation to either the land value (as either the cost to

[1] Sarb, Sherilyn and Lesley Ewing (1997) Report on In-Lieu Fee Beach Sand Mitigation Program: San Diego County, http://www.coastal.ca.gov/pgd/sand1.html, last revised 25April 2012.

undertake nourishment that would create an area of beach equivalent to the area lost or the value of bluff or back beach land equivalent to the lost beach area) or to the user value (either the reduced quality of the beach experience as the available beach narrows or the lost opportunity to visit the beach).

LAND VALUE METHODS

In-Lieu Beach Sand Mitigation Program: The first In-Lieu Beach Sand Mitigation Program was developed for San Diego County, where much of the beach seaward of the coastal bluffs was already public beach. Installation of a seawall would encroach onto public beach, prevent the formation of new public beach that would occur through landward movement of the shoreline, and prevent the addition of coastal bluff sands to the littoral cell. The In-Lieu Beach Sand Mitigation Program mitigated for all three of these impacts through a sand replenishment fund. The volume of sand denied to the littoral cell was quantified directly as a volume of sand. The area losses were quantified for a specified length of erosion (normally 20 to 25 years) and the area of beach lost was converted to a volume of sand, based on the amount of sand that would be needed to build an equivalent area of beach through beach nourishment. The fee was then determined by obtaining three estimates for providing this volume of beach compatible sand to the beach adjacent to the project site. This method is shown in Table 1. In San Diego County, over $1.2 million has been provided to the Beach Sand Mitigation Program as of the end of 2011 and much of those funds have come from the In-Lieu Beach Sand Mitigation Fee.

Assessor Values

Recent projects with impacts to coastal recreation have attempted to determine the cost for purchasing an area of beach equivalent to the area lost. Since beach land is rarely for sale, the equivalent area of unimproved beachfront (or blufftop) land has been used as a close substitute for the value of beach land. Information on land costs has been developed from web sites such as Zillow and from local appraisals (see for example, CDP #6-07-133 (Li), or 6-09-033 (Garber et al.)).

USER VALUE METHODS

Recreation and Visitor Value Losses: A second in-lieu effort has been to look at the recreational and visitor value that is associated with the lost beach area. The Commission first undertook this type of analysis in Monterey County, for a large condominium project known as Ocean Harbor House where there is a high rate of erosion and waves were likely to be breaking on the shore protection within a few decades. The beach that then fronted the development was expected to become an intertidal beach. The quantified impacts to the beach were the encroachment, denial of formation of new beach from fixing the back beach location and denial of bluff sand to the littoral cell – the same three elements that are quantified in the In-Lieu Beach Sand Mitigation Program. But, unlike in San Diego, Monterey had no on-going program for beach nourishment; thus, the Commission sought to acquire other beach property within the area to replace the loss or mitigation for the beach area losses attributable to the project. Staff provided the Commission with three options for determining appropriate value for beach land:

1. the dollar amount assuming the In-Lieu Beach Sand Mitigation Program could be implemented in the area,
2. a real estate assessment of the value of beach area, and
3. a beach valuation approach that identified what monetary value a beach user would place of the beach, based upon a travel-cost model.

The Commission used the third option, and this was subsequently upheld in a court ruling related to the Commission's right to implement such mitigation (CDP 3-02-024 and Superior Court of California, County of Monterey, Case No. M73109).

Recreational Losses Associated with Gradual Beach Loss: After the Ocean Harbor House project, the Commission began to include recreation and access mitigation for shoreline armoring projects elsewhere in the state. The Commission continued to require mitigation for the lost littoral sand based on the dollar cost to replace an equivalent volume of sand. For recreation, the Commission used a modified travel-cost method to determine the value of a trip to the beach and then quantified the recreational losses based on the reduction in recreational beach area that could be attributed to the shore protection (Las Brisas; CDP # 6-04-156). This method, however, required too much input data and, at that time, it was not easily transferred to other shoreline protection projects.

Figure 3

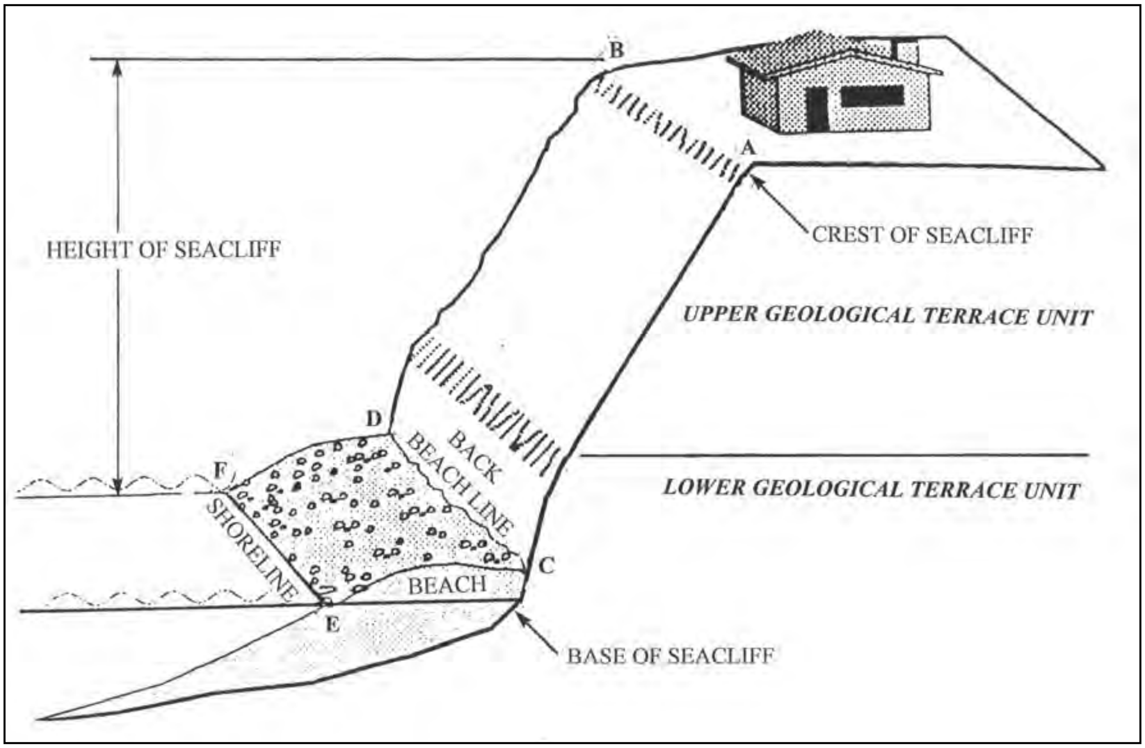


Figure 4

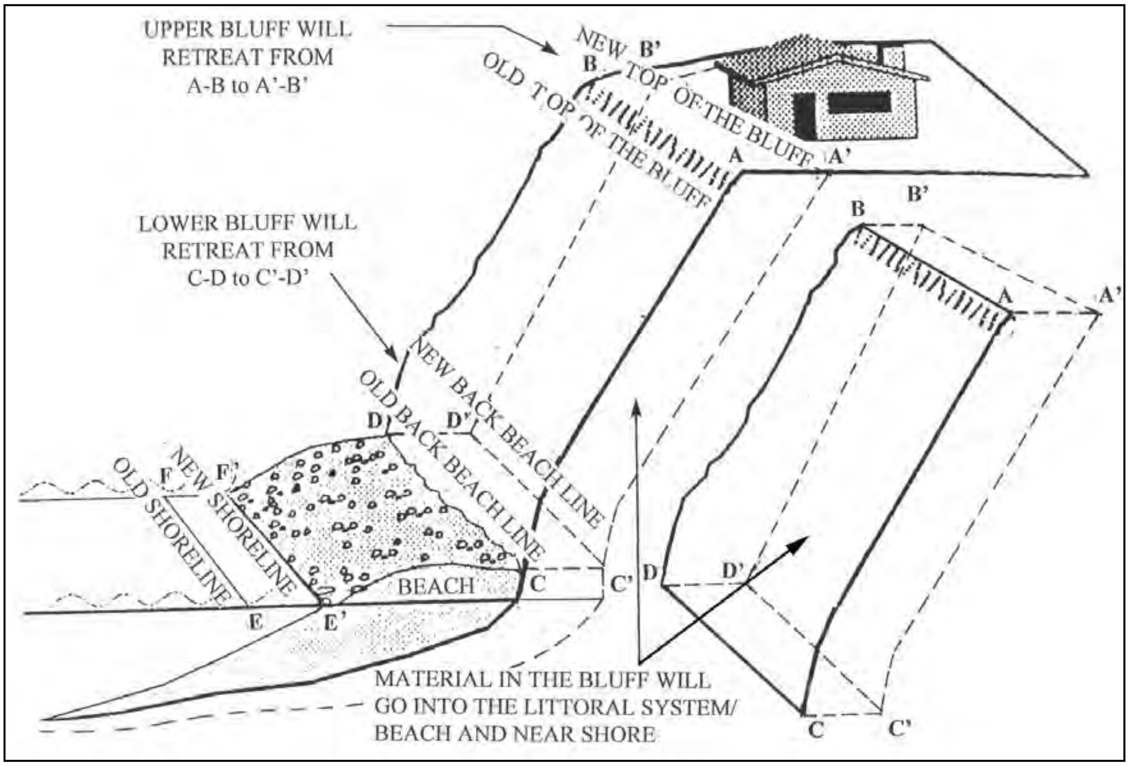


Figure 5

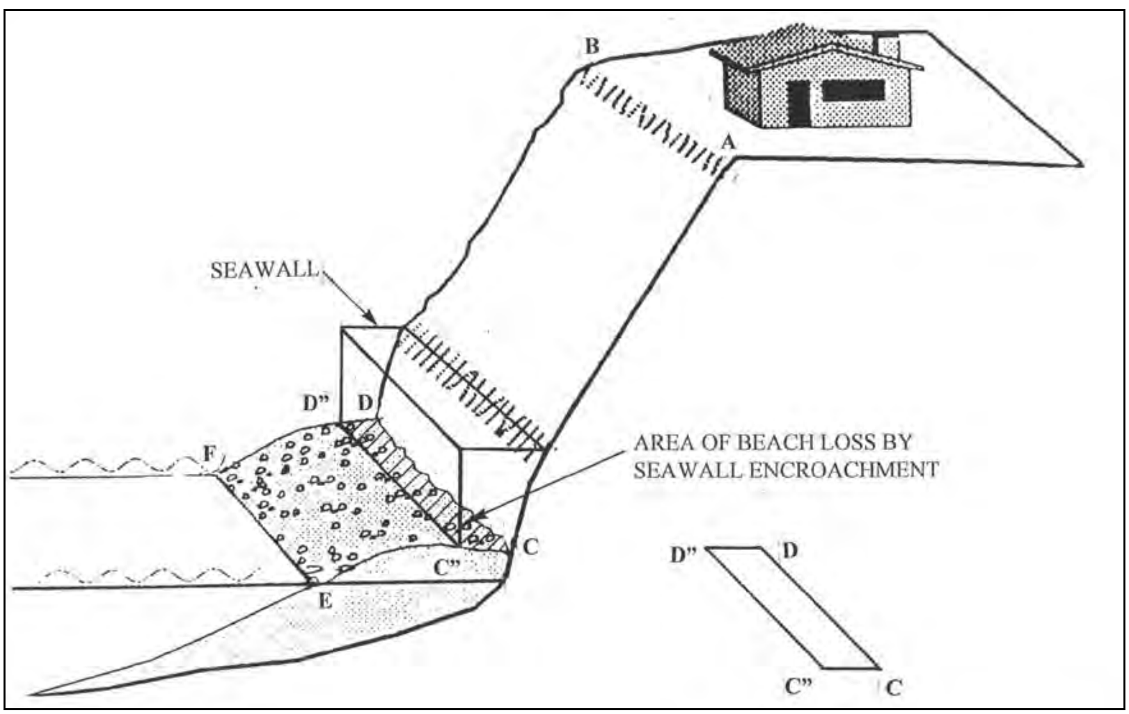


Figure 6

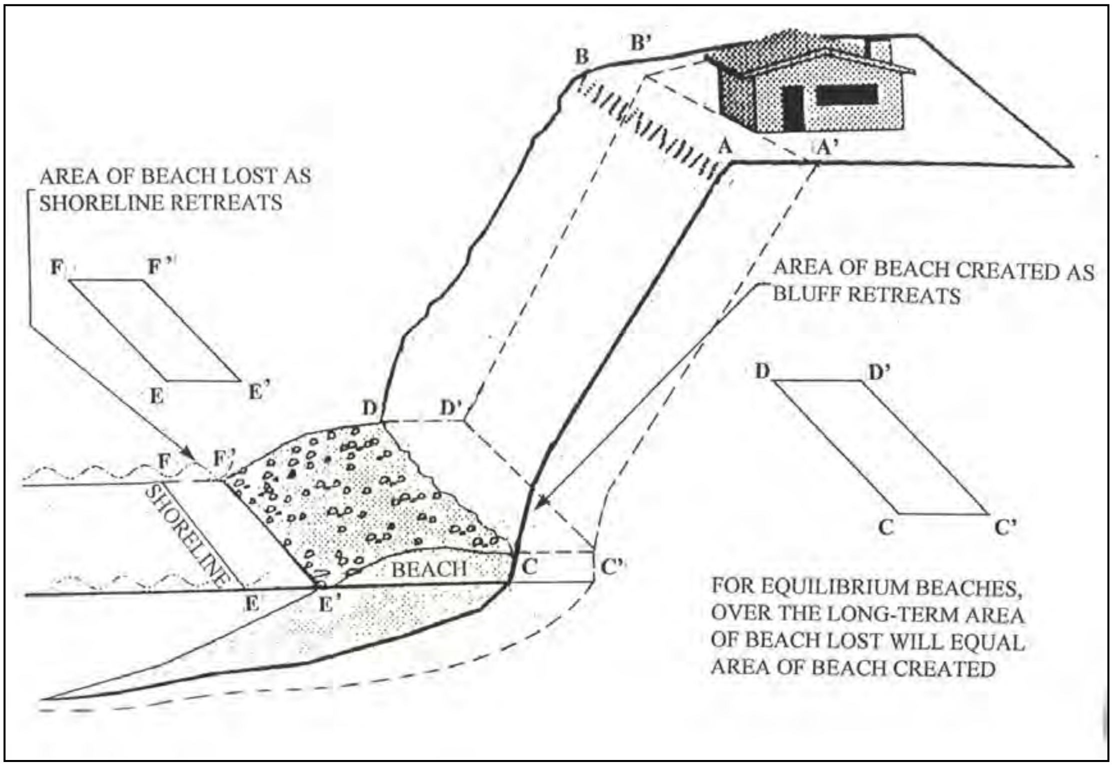

B
B'
A
A'
AREA OF BEACH LOST AS
SHORELINE RETREATS
F
F'
E
E'
AREA OF BEACH CREATED AS
BLUFF RETREATS
D
D'
C
C'
D
D'
F
F'
SHORELINE
BEACH
C
C'
E
E'
FOR EQUILIBRIUM BEACHES,
OVER THE LONG-TERM AREA
OF BEACH LOST WILL EQUAL
AREA OF BEACH CREATED

Figure 7

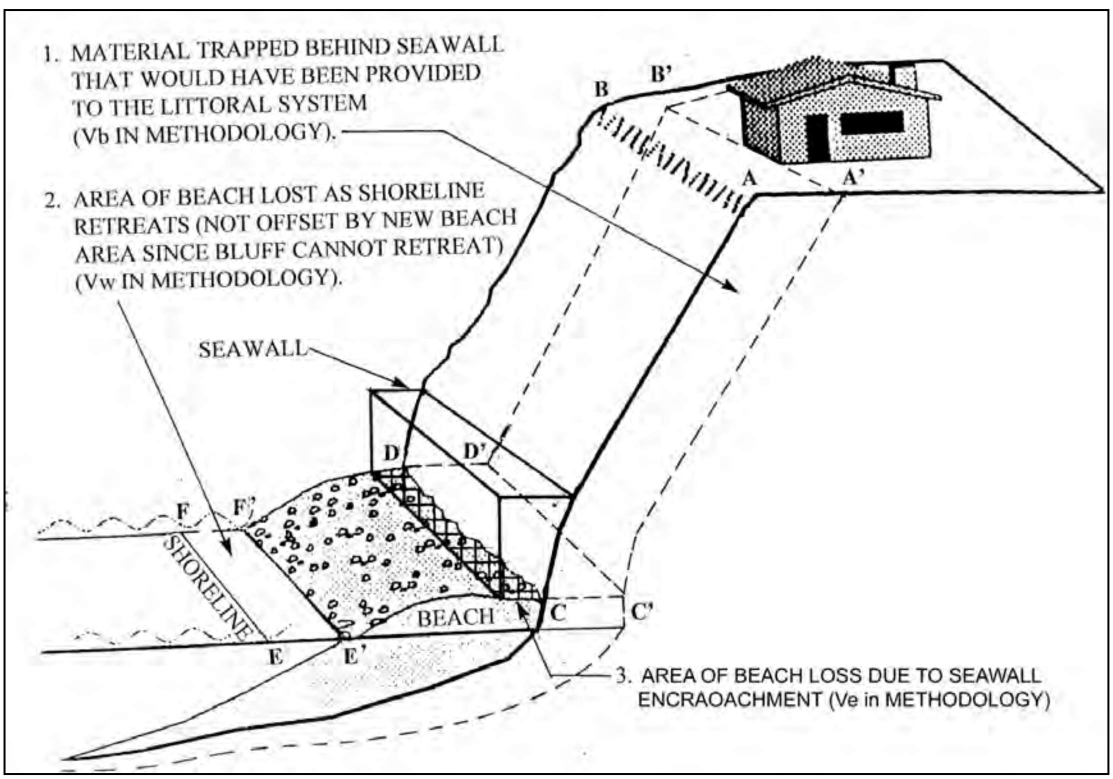

1. MATERIAL TRAPPED BEHIND SEAWALL
THAT WOULD HAVE BEEN PROVIDED
TO THE LITTORAL SYSTEM
(Vb IN METHODOLOGY).
B
B'
A
A'
2. AREA OF BEACH LOST AS SHORELINE
RETREATS (NOT OFFSET BY NEW BEACH
AREA SINCE BLUFF CANNOT RETREAT)
(Vw IN METHODOLOGY).
SEAWALL
D
D'
F
F'
SHORELINE
BEACH
C
C'
E
E'
3. AREA OF BEACH LOSS DUE TO SEAWALL
ENCRAOACHMENT (Ve in METHODOLOGY)

Table 1

Shoreline Protection Impacts Quantified	
Volume of Sediment Trapped by Armoring	Vb = (SxWxL) x[(Rxhs) + (0.5Hu x (Rcw – Rcs)))]/27 [Often this reduces to: Vb = S x W x L x R x h]
Encroachment onto the Beach	Ae = W x E
Passive Erosion	Aw = R x L x W
Mitigation Fee	Sand Volume x Cost of Sand
Lost Beach Area	Encroachment + Passive Erosion
Values Defined	
S	Fraction of beach quality material in the bluff material, based on analysis of bluff material to be provided by the applicant.
W	Width of property to be armored (ft.)
L	The length of time the back beach or bluff will be fixed or the design life of armoring without maintenance (yr.) For repair and maintenance projects, the design life should be an estimate of the additional length of time the proposed maintenance will allow the seawall to remain without further repair or replacement.
R	The retreat rate which must be based on historic erosion, erosion trends, aerial photographs, land surveys, or other accepted techniques and documented by the applicant. The retreat rate should be the same as the predicted retreat rate used to estimate the need for shoreline armoring.
hs	Height of the seawall from the base to the top (ft).

hu	Height of the unprotected upper bluff, from the top of the seawall to the crest of the bluff (ft).
Rcu	Predicted rate of retreat of the crest of the bluff, during the period that the seawall would be in place, assuming no seawall were installed (ft/yr). This value can be assumed to be the same as R unless the applicant provides site specific geotechnical information supporting a different value.
Rcs	Predicted rate of retreat of the crest of the bluff, during the period that the seawall would be in place, assuming the seawall has been installed (ft/yr). This value will be assumed to be zero unless the applicant provides site specific geotechnical information supporting a different value.
E	Encroachment by seawall, measured from the toe of the bluff or back beach to the seaward limit of the protection (ft.)

Attachment C
Linking Recreational and Ecological Beach Characteristics with Physical Characteristics of Beaches Impacted by Shoreline Armoring

There is a broad range of physical characteristics that can be used to categorize sandy beaches in southern California. Below is a list of physical characteristics that have been linked to either ecological or recreational resources of sandy beaches in scientific literature, can be impacted by coastal armoring, and are easily measured or available.

Beach slope:

- Measured slope of the beach face, can be either a snapshot measurement or an average measurement, as beach slope changes throughout the year (ex. The average gradient between the high-water drift line and the low-tide swash zone during spring tides)
- Unit of measure- degrees
- Data sources- physical measurements, scientific literature

Beach width:

- The horizontal dimensions of the beach measured at right angles to the shoreline from the line of extreme low water inland (intersection between dry and wet beach at high tide) to the landward limit of the beach, can be either a snapshot measurement or an average measurement, as beach width changes throughout the year.
- Unit of measure- meters
- Data sources- physical measurements, aerial photographs, scientific literature

Beach area:

- Measured width of the beach multiplied by the measured length of the beach, could be either a snapshot measurement or an average measurement, as beach area changes throughout the year.
- Unit of measure- square meters
- Data sources- physical measurements, maps, scientific literature

Sand grain size:
- Average diameter of individual grains of sediment
- Unit of measure: millimeters or phi units.
- Data sources- physical observation, scientific literature

Wave climate:
- Wave height and period measured at one point in time or observed values over a large time span accounting for seasonal range.
- Unit of measure: wave period in seconds, wave height in meters
- Data sources- physical observations, scientific literature

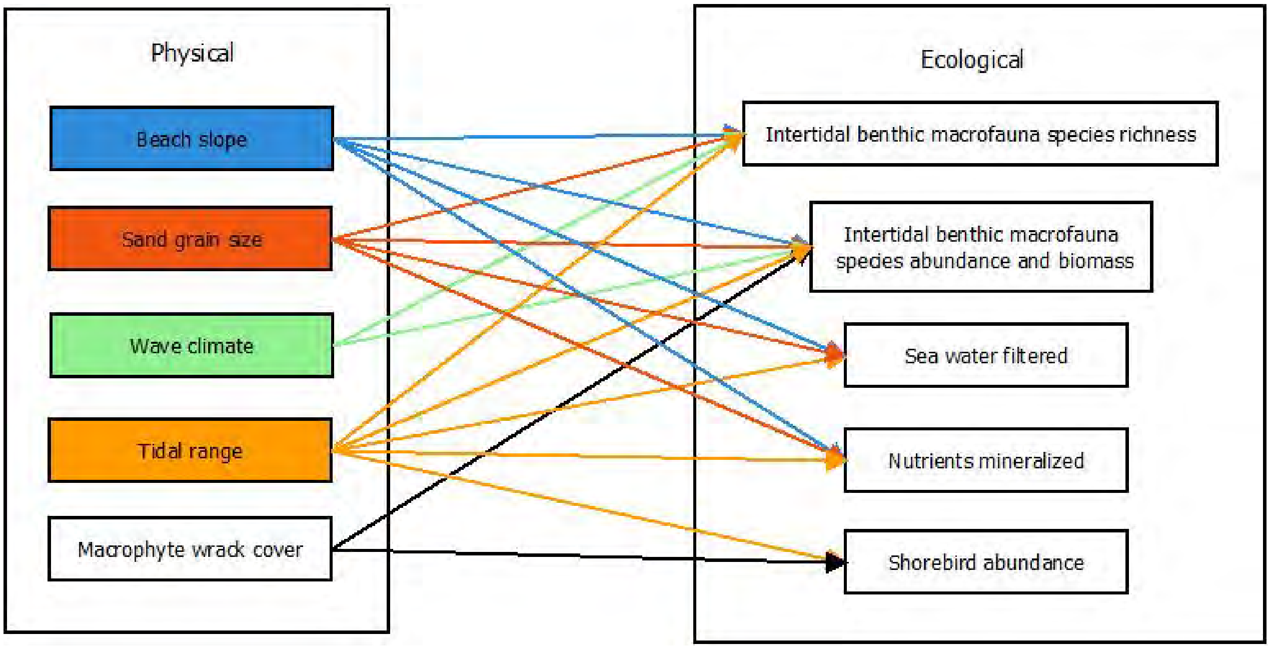
Tidal range:
- The vertical distance between the high tide and the succeeding low tide.
- Unit of measure- meters
- Data sources: physical measurements, http://tidesandcurrents.noaa.gov/

Macrophyte wrack cover:
- Amount of wrack cover on a beach
- Unit of measure- square meters of wrack per meter of beach or mean percent cover of wrack estimated by taking total wrack intersected by a transect in meters and divide it by the intertidal width in meters of each transect.
- Data sources- physical measurements, scientific literature

Access (Lateral and Vertical):
- Description of the type/amount of access to a beach
- Unit of measure: detailed description of the access points and availability
- Data sources- physical observation, scientific literature

Physical Characteristics Linked with Ecological Resources

A review of scientific literature revealed studies that link the following physical characteristics of sandy beaches with ecological resources. By understanding the changes coastal armoring can have on these physical characteristics, we may be able to infer changes to the ecological resources.



Detailed information on the links illustrated above:

Physical: Total morphodynamic state of a beach (beach slope, grain size, and wave climate taken together)
Ecological: Intertidal benthic macrofauna species richness
Link to relevant literature: (McLachlan et al. 1993)

Physical: Total morphodynamic state of a beach (beach slope, grain size, and wave climate taken together), surf zone productivity, and wrack inputs.
Ecological: Intertidal benthic macrofauna species abundance and biomass
Link to relevant literature: (McLachlan et al. 1993)

Physical: Beach index which is calculated from: tidal range, beach face slope, and sand particle size
Ecological: Macrobenthic species richness, abundance, and biomass
Link to relevant literature: (McLachlan & Dorvo 2005)

Physical: Tide range, beach slope, and sand particle size
Ecological: Amounts of sea water filtered and inorganic nitrogen regenerated
Link to relevant literature: (McLachlan 1982)

Physical: Tidal height
Ecological: Shorebird abundance
Link to relevant literature: (Hubbard & Dugan 2003)

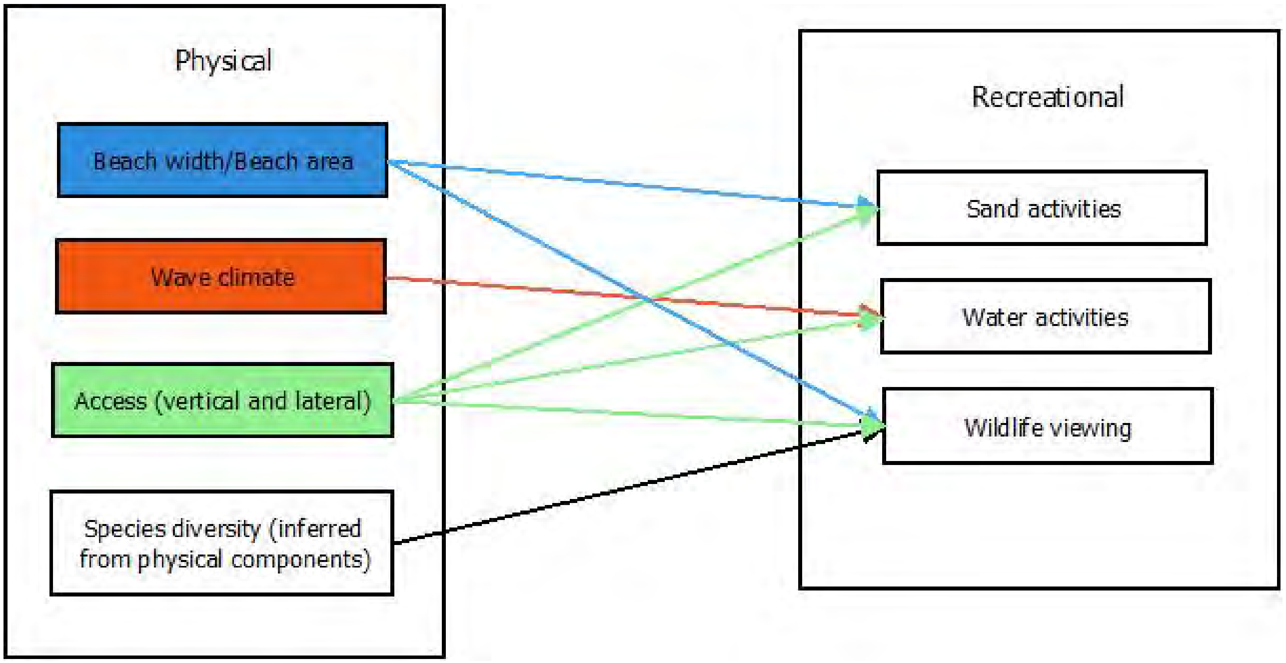
Physical: Macrophyte wrack cover
Ecological: Macrofauna species richness and abundance
Link to relevant literature: (Dugan et al. 2003)

Physical: Macrophyte wrack cover
Ecological: Shorebird abundance
Link to relevant literature: (Dugan et al. 2003)

Physical: Intertidal habitat area
Ecological: Shorebird foraging area (Shorebird abundance)
Link to relevant literature: (Galbraith et al. 2002)

Physical Characteristics Linked with Recreational Resources

A review of scientific literature revealed studies that link the following physical characteristics of sandy beaches with recreational resources. By understanding the changes coastal armoring can have on these physical characteristics, we may be able to infer changes to the recreational resources.



Detailed information on the links illustrated above:

Physical: Beach width
Recreational: Preference for beaches can be related to space availability but varies depending on the type of activity the user plans to engage in.
Link to relevant literature: (Shivlani et al. 2003)

Physical: Beach width
Recreational: Beach preference can be related to beach width only to a certain point and the preference varies based on the activity the user will engage in.
Link to relevant literature: (Pendleton et al. 2011)

Physical: Wave climate (height, period, direction, wavelength in surf area, wave age)
Recreational: Surfing
Link to relevant literature: (Bicudo & Horta 2009)

Physical: Access (Lateral and Vertical)
Recreational: Water, beach, and wildlife viewing activities.
Link to relevant literature: (Caldwell & Segall 2007)

Annotated Bibliography:

Bicudo, P. and Horta, A. (2009) Integrating surfing in the socio-economic and morphology and coastal dynamic impacts of the environmental evaluation of coastal projects. Journal of Coastal Research, 56.

This article provides examples of some of the surf breaks lost in Portugal due to the construction of coastal protection. It recommends wave parameters that should be evaluated when assessing the impact a project may have to the surfing community. It also addresses the potential of using artificial surf reefs to mitigate the loss of surf from projects. * This provides a way to think about how to evaluate loss to surfing and ways to mitigate the loss. *

Caldwell, M. and Segall, C. H. (2007) No day at the beach: sea level ride, ecosystem loss, and public access along the California coast. Ecology Law Quarterly, 34: 534-578.

This law review addresses climate change and sea level rise impacts to the coast, and the need to plan for the future in order to maintain public access and rights. It highlights the compounding loss of public access from sea level rise and coastal armoring. It recommends the use of rolling easement conditions, land purchases, LCP amendments, and limitations of coastal armoring, to maintain the health of the ecosystems and public rights.

Dugan, J. E., Hubbard, D. M., McCrary, M. D., and Pierson, M. O. (2003) The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuarine, Coastal and Shelf Science, 58 (Supplement): 25-40.

This study examined the relationship between macrophyte wrack subsidies and community structure on sandy beaches in southern California. It found that overall species richness and abundance of the macrofauna species studied were positively correlated with the amount of mactophyte wrack cover. The abundance of two shorebird species was also positively correlated with the amount of wrack cover. * Armoring impacts wrack inputs (noted in an article Dugan J.E., Hubbard D.M. (2006) Ecological responses to coastal armoring on exposed sandy beaches. Shore & Beach, 74(1), 10–16…which I was unable to access of the internet) therefore this could be included in the model as it has a significant impact to community structure.*

Galbraith, H., Jones, R., Park, R., Clough, J., Herrod-Julius, S., and Harrington, B., Page, G. (2002) Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. Waterbirds, 25(2): 173-183.

This study attempts to model the loss of intertidal habitat available for shorebird foraging as a result of climate change. It used available bird count data and maps of intertidal habitats from aerial surveys, including intertidal sand habitat. It illustrates the significant loss of shorebird foraging habitat as a result of climate change. * If we want to quantify the value of beaches relative to shorebird foraging habitat, we should have an idea of the habitat that will be lost to climate change. Intertidal habitat used by shorebirds to forage may be more valuable if it becomes rarer throughout the state. *

Hubbard, D. M. and Dugan, J. E. (2003) Shorebird use of an exposed sandy beach in southern California. Estuarine, Coastal and Shelf Science, 58 (Supplement): 41-54.

Shorebird surveys conducted on a southern California beach found that in the fall and winter the abundance of shorebirds was positively correlated with tide height. Alternatively, in the spring, the abundance of shorebirds was negatively correlated with tide height. Researchers also found that overall abundance of shorebirds was depressed during El Nino, when sandy habitat was greatly reduced and intertidal habitat was mostly converted to rocky substrate. * Illustrates how shorebird abundance is influenced by the type of habitat available for foraging which can change throughout seasons and major climatic events.*

McLachlan, A. (1982) A model for the estimation of water filtration and nutrient regeneration by exposed sandy beaches. Marine Environmental Research, 6: 37-47.

This study attempts to use physical beach characteristics to estimate the amount of sea water filtered and inorganic nitrogen regenerated by sandy beaches. Researchers used a regression model to predict the volume of sea water filtered daily by a beach as a function of tide range, beach slope and sand particle size. From this, a method was also derived to estimate the degree of mineralization of organic matter in the filtered sea water based on the distance filtered through the sand and the sand grain size. * If we want to quantify water filtration and nutrient regeneration lost by armoring beaches, this study gives a good introduction to the relationships between the physical and ecological components.*

McLachlan, A. and Dorvlo, A. (2005) Global patterns in sandy beach macrobenthic communities. Journal of Coastal Research, 21(4): 674–687.

This study evaluates the relationships between macrobenthic species richness, abundance, and biomass with physical variables of beaches. A beach index developed in this study based on tide range, beach face slope, and sand particles size was able to explain 56% of the variability found across regions. Researchers found species richness to increase from narrow reflective systems to broad dissipative beaches. The number of species recorded in a transect increases with increasing tide range, finer sand, and flatter slope. * Impacts on armored beaches will be better understood by how the tidal range and slope are impacted (grain size will be important relative to beach nourishment).*

McLachlan, A., Jaramillo, E., Donn, T. E., and Wessels, F. (1993) Sandy beach macrofauna communities and their control by the physical environment: a geographical comparison. Journal of Coastal Research, 15 (Special Issue): 27-38.

This study examined differences in species richness, abundance, and biomass of intertidal benthic macrofauna on beaches ranging from reflective to dissipative extremes, across different geological regions. Researchers found species richness to be greater on dissipative versus reflective beaches. Abundance and biomass were also greater on dissipative beaches but were more variable since this factor is also related to surf zone productivity and wrack inputs. This study concludes that the major contributing factor to the species on a beach is the swash climate. The total morphodynamic state of a beach (produced by beach slope, grain size and wave climate taken together) is a better estimate of species richness than any one factor alone because it directs the swash climate. * If coastal armoring changes beaches from dissipative to reflective then we can use this study to relate that change to a drop in species richness.*

Pendleton, L., Mohn, L.C., Vaughn, R.K., King, P., and Zoulas, J. G. (2011). Size matters: the economic value of beach erosion and nourishment in southern California. Contemporary Economic Policy, 30(2):223-237.

This study examined the welfare benefits of increased beach width by using a model that quantifies recreational benefits as a function of beach width and other beach attributes, using beaches in Los Angeles and Orange County as an example. It reveals that the value of beach width varies for different beach uses and the marginal value of beach width depends on how wide the initial beach was. As an example, beach width was more important for visitors who are seeking space availability. *The most important take away relative to our project would be that the value of increasing beach width to maintain recreational value is dependent on the beach users and uses that are occurring on the beach. *

Shivlani M. P., Letson, D., and Theis, M. (2003) Visitor Preferences for Public Beach Amenities and Beach Restoration in South Florida. Coastal Management, 31(4): 367-385

This study attempts to evaluate a beach user's willingness to pay for beach nourishment. Results from this study highlight that different users prefer beaches based on the type of activities they participate in (swimming, sunbathing, jet-skiing, fishing, kayaking, walking) due to the presence of features which serve that activity (space availability, cleanliness, amenities, distance, wildlife/vegetation).* We should have an understanding of the major activities occurring on a beach to understand the true recreational impact by loss of beach width.*

Attachment D
Information Commonly Requested from Applicants for Shoreline Armoring Projects

Major plans used for review by Coastal Analysts:

- Site Plan showing the following
  - Mean High Tide Line
  - Elevation contours of the bluff
  - Location of proposed seawall and any other aspects of the project (i.e. upper bluff walls, slope reconstruction, etc.)
  - Location of the existing structure and any other existing improvements at the top of the bluff

- Location of the ‘top of bluff’ and the distance that line is from the primary structure

- Profile sections showing
    - Each segment of the project (seawall, upper bluff wall, slope reconstruction, etc.)

Other information requested:

- Landscape plans
- Sand Mitigation Fee calculation worksheet
- If the seawall is located on a public beach, then they need to tell us the sq. ft. of the wall that will be on the public beach

Geotechnical submittal requirements are listed in detail in a County’s LCP:

Sample of Requirements

A soils report and a geotechnical review or report prepared by a certified engineering geologist certifying that the development will have no adverse affects on bluff stability, or endanger life or property, and will consider:

- Cliff geometry and site topography, extended beyond the site
- Historic, current, and foreseeable cliffs erosion, land surveys and tax assessment records, historic maps and photographs, and possible changes in shore configuration and sand transport.
- Geologic conditions, including soil, sediment, and rock types, and structural features such as bedding, joints, and faults
- Evidence of past or potential landslide conditions and the implications
- Impact of the activity on the stability of the site and adjacent area
- Ground and surface water conditions and variations, including hydrologic changes caused by the development.
- Potential erodibility of site and mitigating measures to be used to ensure minimized erosion problems during and after construction
- Effects of marine erosion on seacliffs and estimated rate of erosion at the base of the bluff fronting the subject site based on current and historical data
- Potential effects of seismic forces resulting from a maximum credible earthquake
- Any other factors that might affect slope stability
- Mitigation measures and alternative solutions for any potential impacts

The geotechnical report shall also address:

- Maximum expected wave height, design wave height, design constraints, and frequency of overtopping
- Normal and maximum tidal ranges
- Estimated erosion rate with and without the proposed preemptive measure
- Percent of beach quality sand within the bluff
- Effect of the proposed structure on adjoining properties
- Potential/effect of scouring at base of proposed structure
- Design life of structure/maintenance provisions
- Alternatives to the project design, including (but not limited to) relocation/removal of threatened portions of or the entire home and beach nourishment
- Construction area and technique of construction
- Certification that the structure is designed to withstand storms comparable to the winter storms of 1982-83.

EXHIBIT B
(Interagency Agreement)

BUDGET DETAIL AND PAYMENT PROVISIONS

1. Invoicing

A. For services satisfactorily rendered and upon receipt and approval of the invoices, the Commission agrees to compensate SFSU for actual expenditures incurred in accordance with the rates specified herein or attached hereto.

B. Invoices shall be submitted in triplicate not more frequently than monthly in arrears to:

California Coastal Commission
Attn: Business Services
45 Fremont Street, Suite 2000
San Francisco, CA 94105-2219

C. Invoices shall contain the following information:
1. Contractor's name and address as shown on this agreement.
2. Date of the invoice.
3. Time period covered by the invoice.
4. Contract number as shown on this agreement.
5. Original signature of the contractor (not required if printed using preprinted letterhead paper).
6. Itemized costs for the billing period in the same or greater level of detail as indicated in this agreement, with supporting documentation. Only those costs and/or cost categories expressly identified in this agreement may be reimbursed.

2. Budget Contingency Clause

A. It is mutually agreed that if the Budget Act of the current year and/or any subsequent years covered under this Agreement does not appropriate sufficient funds for the program, this Agreement shall be of no further force and effect. In this event, the State shall have no liability to pay any funds whatsoever to Contractor or to furnish any other considerations under this Agreement and Contractor shall not be obligated to perform any provisions of this Agreement.

B. If funding for any fiscal year is reduced or deleted by the Budget Act for purposes of this program, the State shall have the option to either cancel this Agreement with no liability occurring to the State, or offer an agreement amendment to Contractor to reflect the reduced amount.

3. Payment

A. Costs for this Agreement shall be computed in accordance with State Administrative Manual Sections 8752 and 8752.1.

B. Nothing herein contained shall preclude advance payments pursuant to Article 1, Chapter 3, Part 1, Division 3, Title 2 of the Government Code of the State of California.

EXHIBIT C
(Interagency Agreement)

GENERAL TERMS AND CONDITIONS

PLEASE NOTE: This page will not be included with the final contract. The General Terms and Conditions will be included in the contract by reference to Internet site www.dgs.ca.gov/contracts.

EXHIBIT D
(Interagency Agreement)

SPECIAL TERMS AND CONDITIONS

1. TERMINATION

During the term of this Agreement, either party may terminate this Agreement at will by providing thirty (30) days written notice to the other party. In the event of a termination, SFSU shall take all reasonable measures to prevent further costs attributable to the Commission. The Commission shall then be responsible for any reasonable and non-terminable obligations incurred by SFSU in the performance of this Agreement up to the date of termination, but not to exceed the balance of the total funds which remains unencumbered under this Agreement at the time of termination.

2. CREDITS

The cover or title page of any publication resulting from this Agreement shall include the following credit:

> This publication was prepared with financial assistance from the U.S. Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, under the provisions of the Federal Coastal Zone Management Act of 1972, as amended.

3. DISPUTES

Any dispute concerning a question of fact arising under the terms of this agreement which is not disposed of within a reasonable period of time (ten calendar days) by SFSU and the Commission employees normally responsible for the administration of this contract shall be brought to the attention of the Executive Director (or designated representative) of each organization for joint resolution.

4. FEDERAL GRANT CONDITIONS

This Agreement is funded from a NOAA financial assistance award to the Commission. SFSU shall comply with all conditions and federal administrative requirements of that award relating to third party participation.

5. FEDERAL GRANT EXTENSION

(a) It is mutually understood between the parties that this contract may have been written before ascertaining an extension of the FY 2012 Project of Special Merit NA12NOS4190026 NOAA Grant set to end on December 30, 2013 for the mutual benefit of both parties in order to avoid program and fiscal delays which would occur if the contract were executed after that determination was made.

(b) This contract is subject to any additional restrictions, limitations, or conditions enacted by the Congress or any statute enacted by the Congress which may affect the provisions, terms or funding of this contract in any manner.

Appendix A
Qualifications of Sub-awardees and Curriculum Vitae

Dr. Philip King received his Ph.D. from Cornell in 1987. His specialty is in Applied Microeconomics and Environmental Economies. He is an Associate Professor in Economics at San Francisco State University and was chair from 2002-2005. Over the past 15 years, he has completed over thirty economic studies for various government agencies including the Corps, and State and local governments. These projects analyzed the economic and tax revenue impacts of beach and other coastal projects at the national, State and regional/local levels. His current work involves analyzing the impacts of sea level rise on California's coastal economy and valuing beach ecosystem services.

Dr. Jenny Dugan is an Associate Research Biologist with the Marine Science Institute at the University of California at Santa Barbara. She helps coordinate and serves as an investigator with the Santa Barbara Coastal Long Term Ecological Research program. She has published more than 30 peer-reviewed papers concerning ecological connectivity among nearshore and intertidal habitats, marine conservation and restoration, disturbance responses and recovery, species interactions, and the physical and biological drivers of community structure and function in coastal ecosystems. Much of her research has focused on sandy beach ecosystems, and she has studied numerous aspects of beaches, their food webs and functions ranging from the bottom up effects and ecological function of macroalgal wrack subsidies to exploring the role of shorebirds as ecosystem indicators and key intertidal predators. Presently, she is collaborating with coastal managers to conduct studies to evaluate ecological impacts and implications of widespread human alterations of the coast, including urban development, shoreline armoring, beach grooming, oil spills, intertidal recovery dynamics, and climate change. A goal of this effort is to provide an ecological framework that may be used to inform coastal conservation and management. This project would also contribute to our Project of Special Merit proposal.

David Hubbard is an Assistant Research Specialist at the Marine Science Institute, University of California, Santa Barbara and a founding principal at Coastal Restoration Consultants, Inc. He has investigated the ecology of beaches, wetlands and rocky shorelines in California since 1981 and published 25 peer-reviewed coastal ecology papers on topics ranging from physical dynamics of coastal ecosystems, marine subsidies, nutrient cycling, invertebrates, bird use, coastal strand and dune vegetation, to the effects of beach management actions and shoreline armoring. With Coastal Restoration Consultants, Inc. since 1996, he works on planning, implementing and monitoring wetland and other native habitat restoration projects.

Dr. Karen Martin is Professor of Biology at Pepperdine University and holds the Frank R. Seaver Chair. She is co-creator and Executive Director of the Grunion Greeters program, a statewide network of hundreds of citizen scientist observers. Her research focuses on ecology and physiological adaptations of animals in the sandy and rocky intertidal zones. She has published over 40 peer-reviewed scientific papers and edited two books and two symposium volumes about the biology of the water-land interface.

PHILIP G. KING

Economics Department, San Francisco State University

E-mail: pgking@sfsu.edu

Cell: (530)-867-3935

Education:

July, 87 **Ph.D. in ECONOMICS** **CORNELL UNIVERSITY**
Fields: Applied Microeconomics, Economic Development, International Economics
Dissertation: Bargaining between Multinational Corporations and Less Developed Countries over Mineral Concessions Contracts.

May, 78 **B. A. in PHILOSOPHY & ECONOMICS** **WASHINGTON UNIVERSITY**
Nominated to Omicron Delta Epsilon (Economics Honor Society.)

Work Experience:

1/06-present	**ASSOCIATE PROFESSOR**	**SAN FRANCISCO STATE UNIVERSITY**
9/02-12/05	**CHAIR, ECONOMICS DEPARTMENT**	**SAN FRANCISCO STATE UNIVERSITY**
9/93-present	**ASSOCIATE PROFESSOR**	**SAN FRANCISCO STATE UNIVERSITY**
9/87-9/93	**ASSISTANT PROFESSOR**	**SAN FRANCISCO STATE UNIVERSITY**
9/83-5/85	**ASSISTANT PROFESSOR, ECONOMICS**	**S.U.N.Y. at CORTLAND**

Current Research

- Economics of Sea Level Rise at Ocean Beach, San Francisco (w. SPUR), and in Southern Monterey Bay (w. PWA).
- The Ecological Economics of Beaches (Funded by California Dept. of Boating and Waterways and BEACON), w. J. Dugan (UCSB).

Recent Refereed Papers:

"The Economic Costs of Sea Level Rise to California Beach Communities," w. A. McGregor and J. Whittet, California Resources Agency & Dept. of Boating and Waterways (Refereed through California Ocean Science Trust).

"Who's Counting: An Analysis of Beach Attendance Estimates in Southern California," w. A. McGregor, revise and resubmit at *Ocean and Coastal Management*.

"Size Matters: The Economic Value of Beach Erosion and Nourishment in Southern California', with L. Pendleton, C. Mohn, R. Vaughn, and J. Zoulas., in press, *Contemporary Economic Policy*.

"ESTIMATING THE POTENTIAL ECONOMIC IMPACTS OF CLIMATE CHANGE ON SOUTHERN CALIFORNIA BEACHES," with L. Pendleton, C. Mohn, D. G. Webster, R. Vaughn, and P. Adams, in press, *Climatic Change*.

"Economic Analysis of Reconfiguring the Long Beach Breakwater," w. A. McGregor, *Shore and Beach*, April/May 2011.

"Potential Loss in GNP and GSP from a Failure to Maintain California's Beaches", Fall 2004, with Douglas Symes, *Shore and Beach*.

Books: *International Economics and International Economic Policy*, 5th Edition, McGraw-Hill, 2009.

International Economics and International Economic Policy, 4th Edition, McGraw-Hill, 2004.

International Economics and International Economic Policy, 3rd Edition, McGraw-Hill, 2000.

International Economics and International Economic Policy, 2nd Edition, McGraw-Hill, 1995.

International Economics and International Economic Policy, 1st Edition, McGraw-Hill, 1990.

Policy Papers prepared for Government and Non-Profit Organizations:

Contributed Economics portion of Regional Sediment Master Plan for BEACON (Beach Erosion Authority for Clean Oceans and Nourishment—Santa Barbara and Ventura Counties), February 2009, with Noble Consultants.

ESTIMATING THE POTENTIAL ECONOMIC IMPACTS OF CLIMATE CHANGE ON SOUTHERN CALIFORNIA BEACHES, prepared for the California Energy Commission (Energy Commission) and the California Environmental Protection Agency (Cal/EPA), with Linwood Pendleton, Craig Mohn, D. G. Webster, Ryan K. Vaughn, and Peter Adams.

Prepared for the City of Stockton: Economic Analysis of A Proposed Ordinance to Limit Grocery Sales at Superstores in Stockton, California, May 10, 2007

Contributed Economics Portion of: "The ARC GIS Coastal Sediment Analysis Tool: A GIS Support Tool for Regional Sediment Management Program: White Paper, Draft Technical Report for U.S. Army Corps of Engineers, by Ying Poon (Everest Consultants), Los Angeles District, April 2006.

Contributed Economics Portion of: "Coastal Sediment Analysis Tool (CSBAT) Beta Version--Sediment Management Decision Support Tool for Santa Barbara and Ventura Counties," Draft Technical Report for U.S. Army Corps of Engineers, by Ying Poon (Everest Consultants), Los Angeles District, June 2006.

"The ArcGIS Coastal Sediment Analyst: A Prototype Decision Support Tool for Regional Sediment Management, John Wilson et. al., USC Geography Department, 2004 (contributed economic analysis for paper).

"The Economic of Regional Sediment Management in Ventura and Santa Barbara Counties," prepared for the California State Resources Agency, Final draft (refereed) , Fall 2006, prepared for the Coastal Sediment Management Work group (CSMW).

"The Potential Loss in GNP and GSP from a failure to Maintain California's Beaches," with Douglas Symes, prepared for the California State Resources Agency, 2002, http://userwww.sfsu.edu/~pgking/pubpol.htm.

"The (Economic) Benefits of California's Beaches," prepared for the California State Resources Agency, 2002, http://dbw.ca.gov/beachreport.htm.

"The Economic and Fiscal Impact of Beach Recreation in San Clemente," presented as part of Hearings on Congressional Appropriations for California Coastal Projects, US House of Representatives, April 2002. Also completed similar projects for Cities of Carlsbad, Carpinteria, Encinitas, and Solana Beach.

"Do Beaches Benefit Local Communities?: A Case Study of Two California Beach Towns," Fall 2002, *Proceedings of the Conference on California and the World Oceans.*

San Francisco's Economic Growth 1995-2000: The Fiscal Health of the City and Implications for the Future," prepared for the San Francisco Committee on Jobs Summer 2001. This report was widely cited in the San Francisco press including front page articles by the *Chronicle* and *Examiner*.

"The Demand for Beaches in California," prepared for the California Dept. of Boating and Waterways, Spring 2001.

"Cost Benefit Analysis of Shoreline Protection Projects in California," prepared for the California Dept. of Boating and Waterways, Spring 2000.

"The Fiscal Impact of Beaches in California," prepared for the *Public Research Institute*, San Francisco State University, Fall 1999, available at http://online.sfsu.edu/~pgking/beaches.htm.

"An Economic Analysis of Coastal Resources on the Majuro Atoll," prepared for the *United Nations Development Program* Project MAS 95/001/D01/99 and the *Majuro Atoll Local Government*, September, 1997.

"The Economic Impact of California's Beaches," prepared for the *Public Research Institute*, San Francisco State University, Summer, 1997 (with Michael Potepan.)

"The Revenue Impact of the Proposed Marine Link Pipeline System in Richmond, California," prepared for the *Public Research Institute*, San Francisco State University, Spring, 1997 (with Ted Rust.)

"The Economic Impact of California's Ports and Harbors," prepared for the *Public Research Institute*, San Francisco State University, Spring, 1997 (with Ted Rust).

Public Testimony:

Testified and prepared report to the California Coastal Commission in San Diego on the economic loss due to a proposed seawall at Las Brisas, Solana Beach, California, 2005.

Current SFSU Committees:

Chair, SFSU Foundation Investment Committee and member of SFSU Foundation.

Board Member, SFSU University Corporation and Finance Committee.

Other:

- Present papers at one to three Environmental and Coastal Management Conferences a year.
- Appointed to the City of Davis Budget and Finance Commission.
- Prepared (CEQA) testimony in over forty cases involving Big Box stores in California.

Jenifer Elaine Dugan
Marine Science Institute
University of California
Santa Barbara, CA 93106-6150
(805) 893-2675 office, (805) 893-8062 fax
email: j_dugan@lifesci.ucsb.edu

Education and Professional Preparation

B.A. Aquatic Biology, high honors, University of California, Santa Barbara
Ph.D. Biology, University of California, Santa Barbara
Postdoctoral Fellow, Dept. of Zoology, Univ. Port Elizabeth, Republic of South Africa
Postdoctoral Fellow, Dept. Marine Science, Univ. Otago, Dunedin, New Zealand.

Appointments

2003-	Associate Research Biologist, Marine Science Institute, UC Santa Barbara
2002-	Science Coordinator, Santa Barbara Coastal LTER Program UC Santa Barbara
2000-2007	Deputy Director, Coastal Marine Institute, UC Santa Barbara
1995-2002	Assistant Research Biologist, Marine Science Institute, U.C. Santa Barbara
1995-2002	Lecturer, Ecology, Evolution Marine Biology, Univ. of Calif., Santa Barbara, CA (12 terms).
1991-2004	Lecturer, Environmental Studies, Univ. of Calif, Santa Barbara, CA. (8 terms).
1988-1993	Marine Biologist, Coop. Park Sci. Unit, UC Davis, Channel Islands Nat. Park

Selected Publications

submitted	Jaramillo, E, JE Dugan, DM Hubbard, D Melnick. M Manzano, C Duarte. Ecological legacies of extreme events: footprints of the 2010 earthquake along the Chilean coast. *Proc. Nat. Acad. Sciences*.
submitted	Barnard, PL, DM Hubbard, JE Dugan. Sand dynamics on an alongshore-dominated littoral cell: correlating a 17-year single-point time series with regional patterns, Santa Barbara, California, USA. *Geomorphology*
in press	Dugan, JE, L Airoldi, MG Chapman, S Walker, TA Schlacher. Estuarine and Coastal Structures: Environmental Effects: a focus on shore and nearshore structures. In: Human-induced Problems (Uses and Abuses) in Estuaries and Coasts (eds. M. Kennish, M. Elliot), Treatise on Estuarine and Coastal Science Vol. 8 Chapter 2, Elsevier.
2011	Dugan, JE, DM Hubbard, HM Page, J Schimel. Marine macrophyte wrack inputs and dissolved nutrients in beach sands. *Est. Coasts*. 34(4): 839-850.
2011	Revell DL, JE Dugan, DM Hubbard. Physical and ecological responses of beaches to the 1997-98 El Nino. *J. Coastal Res*.27(4): 718-730..
2011	Dawson, MN, PH Barber, LI Gonzales, RJ Toonen, JE Dugan, RK Grosberg. Phylogeography of *Emerita analoga* (Crustacea, Decapoda, Hippidae), an eastern Pacific Ocean sand crab with long-lived pelagic larvae. *J.Biogeog*. 38(8): 1600-1612. DOI: 10.1111/j.1365-2699.2011.02499.x
2010	Dugan, JE, O Defeo, E Jaramillo, AR Jones, M Lastra, R Nel, CH Peterson, F Scapini, T Schlacher, DS Schoeman. Give beach ecosystems their day in the sun. *Science*, 329: 1146.
2010	Dugan, JE, DM Hubbard. Loss of coastal strand habitat in southern California: the role of beach grooming. *Est. Coasts*. 33(1): 67-77.
2009	Guerrini, A, JE Dugan. Coastal Dynamics: Toward informing ecological restoration in a coastal context. Pp 131-142 In: Restoration and History: The Search for a Usable Environmetal Past (ed. M. Hall) Routledge, Oxford.
2009	Defeo O, A McLachlan, D Schoeman, T Schlacher, J Dugan, A Jones, M Lastra, F Scapini. Threats to sandy beach ecosystems: a review. *Est. Coastl Shelf Sci.* 81: 1-12
2008	Dugan J.E., D.M. Hubbard, I.F. Rodil, D. Revell. Ecological effects of coastal armoring on sandy beaches. *Mar. Ecol*. 29: 160-170.

2008	Schlacher TA, DS Schoeman, J Dugan, M. Lastra, A Jones, F Scapini, A McLachlan. Sandy beach ecosystems: key features, management challenges, climate change impacts, and sampling issues. *Mar. Ecol*. 29: 70-90.
2008	Page HM, DC Reed, MA Brzezinski, JM Melack, JE Dugan. Assessing the importance of land and marine sources of organic matter to kelp forest food webs. *Mar. Ecol. Prog. Ser*. 360: 47-62.
2008	Lastra M, HM Page, JE Dugan, DM Hubbard, IF Rodil. Processing of allochthonous macrophyte subsidies by sandy beach consumers: estimates of feeding rates and impacts on food resources. *Mar. Biol*. 154: 163-174.
2008	Page HM, C Culver, J Dugan, B Mardian Oceanographic gradients and patterns in invertebrate assemblages on offshore oil platforms. *ICES J Mar. Sci*.
2007	Schlacher TA, JE Dugan, DS Schoeman, M Lastra, A Jones, F Scapini, A McLachlan, O Defeo. Sandy beaches at the brink. *Div. Dist*. 13(5): 556-560.
2007	Page HM, JE Dugan, DM Schroeder, MM Nishimoto, MS Love, JC Hoesterery. Trophic links and condition of a temperate reef fish: comparisons among offshore oil platform and natural reef habitats. *Mar. Ecol. Prog. Ser*. 344: 245-256.
2006	Page HM, JE Dugan, CC Culver, J Hoesterey. Exotic invertebrate species on offshore oil platforms. *Mar. Ecol Prog. Ser*. 325: 101-107.
2006	Dugan JE, DM Hubbard. Ecological responses to coastal armoring on exposed sandy beaches. *Shore & Beach*. 74(1): 10-16.
2005	Bram JB, HM Page, JE Dugan. Spatial and temporal variability in early successional patterns of an invertebrate assemblage at an offshore oil platform. *J. Exp. Mar. Biol. Ecol*. 317(2): 223-237.
2004	Bomkamp R, HM Page, JE Dugan. Role of food subsidies and habitat structure in influencing benthic communities of shell mounds at sites of existing and former offshore oil platforms. *Mar. Biol*. 1432-1793
2004	Dugan JE, DM Hubbard, E Jaramillo, H Contreras, C Duarte. Competitive interactions in macroinfaunal animals of exposed sandy beaches. *Oecologia*. 139 (4): 630-640
2003	Dugan JE, DM Hubbard, M McCrary, M Pierson. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. *Est Coastl. Shelf Sci*. 58S: 133-148.
2003	Hubbard DM, JE Dugan. Shorebird use of an exposed sandy beach in southern California. *Est. Coastl. Shelf Sci*. 58S: 169-182.
2003	Roberts C, S Andelman, G Branch, R Bustamante, J Carlos-Castilla, J Dugan, B Halpern, H Leslie, K Lafferty, J Lubchenco, D McArdle, H Possingham, M Ruckleshaus, R Warner. Ecological criteria for evaluating candidate sites for marine reserves *Ecol. Appl*. 13(1 Suppl S):S199-S214
2003	Airame S, JE Dugan, , KD Lafferty, HM Leslie, D McArdle, RR Warner. Applying ecological criteria to the design of marine reserves: a case study from the California Channel Islands. *Ecol. Appl*. 13(1 Suppl S):S170-S184.
2000	Dugan JE, DM Hubbard, M Lastra. Burrowing abilities and swash behavior of three crabs, *Emerita analoga* Stimpson, *Blepharipoda occidentalis* Randall and *Lepidopa californica* Efford (Anomura, Hippoidea), of exposed sandy beaches. *J. Exp. Mar. Biol. Ecol*. 255(2): 229-245.
1999	Dugan JE, A McLachlan. An assessment of longshore movement in *Donax serra*: Röding (Bivalvia: Donacidae) on an exposed sandy beach. *J. Exp. Mar. Biol. Ecol.* 234 (1): 111-124.
1995	McLachlan A, E Jaramillo, O Defeo, J Dugan, A de Ruyck, P Coetzee. Adaptations of bivalves to different beach types. *J. Exp. Mar. Biol. Ecol.* 187: 147-160.
1996	McLachlan A, J Dugan, O Defeo, A Ansell, D Hubbard, E Jaramillo, P Penchaszadeh. Beach clam fisheries. *Ocean. Mar. Biol. Ann. Rev*. 34: 163-232.
1994	Dugan JE., DM Hubbard, AM Wenner. Geographic variation in life history in populations of the sand crab, *Emerita analoga* Stimpson, on the California coast: relationships to environmental variables. *J. Exp. Mar. Biol. Ecol*. 181: 255-278.

David M. Hubbard

Coastal Restoration Consultants, Inc.
6896 Sabado Tarde Road
Isla Vista, CA 93117
telephone: 805-698-1119
email: dave@crcsb.com

David founded Coastal Restoration Consultants, Inc. with Matthew James in 2005. He has studied the natural resources of the California coast since 1981, and has been planning, implementing and monitoring wetland and other native habitat restoration projects since 1996.

EDUCATION:

1980 – B.A. Studio Art with high honors, UCSB, 1984 – 2nd major Biology, UCSB

RECENT EMPLOYMENT AND EXPERIENCE:

Principal, Coastal Restoration Consultants, Inc., 2005 to present. Responsibilities include designing, implementing, monitoring and reporting on native habitat restoration projects: data analysis and presentation, writing plans and reports; coordinating with project managers, agency staff and contractors; hiring, training and supervising staff, and presenting results at meetings and conferences.

Assistant Research Specialist, UCSB Marine Science Institute, 2005 to present. Investigating ecology of sandy beaches: physical factors, marine wrack subsidies, invertebrates and bird surveys. Responsibilities include: field work, literature reviews, data analysis and presentation, writing reports and manuscripts.

Museum Scientist, UCSB Museum of Systematics and Ecology, Department of Ecology, Evolution and Marine Biology. Natural Areas manager and coordinator for restoration ecology program and restoration ecology seminars, designed and implemented restoration projects, 1999-2005.

Staff Research Associate, UCSB Marine Science Institute. 1995-1999. Investigated ecology of sandy and rocky shores: field work, data analysis and report preparation.

Project Biologist, Ecometrics, Carlsbad, CA. 1996. Developed protocols and conducted field studies of potential impacts of oil spill on sandy beach invertebrates at Guadalupe, CA.

SELECTED PEER-REVIEWED PUBLICATIONS ON BEACHES AND BEACH ECOLOGY:

Submitted. Barnard P.L, D. M. Hubbard and J. E. Dugan. Sand dynamics on an alongshore-dominated littoral cell: correlating a 17-year single-point time series with regional patterns, Santa Barbara, California, USA. Geomorphology.

2011. Revell, D. L., J. E. Dugan and D. M. Hubbard. Physical and ecological responses of sandy beaches to the 1997-98 El Nino. Journal of Coastal Research 27(4): 718-730.
http://www.pwa-ltd.com/about/news/revelletal_lidarecology_jcr072011.pdf

2011. Dugan, J.E., D. M. Hubbard, H. M. Page and J. P. Schimel. Marine macrophyte wrack inputs and dissolved nutrients in beach sands. Estuaries and Coasts 34(4): 839-850.
http://www.springerlink.com/content/u034q2l0p0j98286/

2010. Dugan, J. E. and D. M. Hubbard. Loss of coastal strand habitat in southern California: the role of beach grooming. Estuaries and Coasts 33(1): 67-77.
http://www.springerlink.com/content/8781487k27513h22/

2008. Lastra, M., H. M. Page, J. E. Dugan, D. M. Hubbard and I. F. Rodil. Processing of allochthonous macrophyte subsidies by sandy beach consumers: estimates of feeding rates and impacts on food resources. Marine Biology 154 (1): 163- 174.
http://www.springerlink.com/content/g82k076506411j47/

2008. Dugan, J. E., D. M. Hubbard, I. F. Rodil, D. Revell and S. Schroeter. Ecological effects of coastal armoring on sandy beaches. Marine Ecology Progress Series, 29: 160-170.
http://www.mendeley.com/research/ecological-effects-of-coastal-armoring-on-sandy-beaches/

2006 Dugan, J. E., and D. M. Hubbard. Ecological responses to coastal armoring on exposed sandy beaches. Shore and Beach. 74(1): 10-16.
http://md1.csa.com/partners/viewrecord.php?requester=gs&collection=ENV&recid=6787916&q=Ecological+responses+to+coastal+armoring+on+exposed+sandy+beaches&uid=790982803

2004 Dugan, J. E., Jaramillo, E. , D. M. Hubbard, H. Contreras and C. Duarte. Competitive interactions in macroinfauna of exposed sandy beaches. Oecologia 139: 630-640
http://www.springerlink.com/content/xamr3bry474nu845/

2003 Dugan, J. E., D. M. Hubbard, M. McCrary and M. Pierson. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuar. Coastl. Shelf Sci. 58S: 133-148.
http://www.bren.ucsb.edu/academics/courses/254/Readings/Dugan_et_al_2003.pdf

2003 Hubbard, D. M. and J. E. Dugan. Shorebird use of an exposed sandy beach in southern California. Estuar. Coastl. Shelf Sci. 58S: 169-182.
http://www.sciencedirect.com/science/article/pii/S0272771403000489

2000 Dugan, J. E., Hubbard, D. M., Engle, J. M., Martin, D. L., Richards, D. M., Davis, G. E., Lafferty, K. D., Ambrose, R. F. Macrofauna communities of exposed sandy beaches on the Southern California mainland and Channel Islands. Fifth California Islands Symposium, OCS Study, MMS 99-0038: 339-346.

Karen L. M. Martin, Ph.D.
Frank R. Seaver Professor of Biology, Department of Biology, Natural Science Division, Pepperdine University, 24255 Pacific Coast Highway, Malibu, CA 90263-4321
Email: karen.martin@pepperdine.edu; Phone: (310) 506-4808; Fax: (310) 506-4785.
Research Associate, Scripps Institution of Oceanography
Executive Director, Grunion Greeters: www.Grunion.Org
Board of Directors, Beach Ecology Coalition

Professional Preparation

University of Oklahoma	Zoology	BS	1975
University of Oklahoma	Zoology	MS	1979
University of California, Los Angeles	Biology	PhD	1990
University of Washington	Friday Harbor Postdoctoral Fellow		1990-91

Professional Experience

1991-present Professor of Biology, Pepperdine University, Malibu, Calif., Frank R. Seaver Chair in Natural Science since 2000.
2009-present: Section Editor, peer-reviewed journal COPEIA, for Physiological Ecology
1998-99 Adjunct Research Professor, Calif. State Univ., Fullerton, Sabbatical.
1990 Lecturer, University of California, Los Angeles (UCLA).

Publications: *Ten most closely related to project*

1. Martin K. L., K. Bailey, C. Moravek and K. Carlson. 2011. Taking the plunge: California Grunion embryos emerge rapidly with environmentally cued hatching (ECH). Integrative and Comparative Biology 51:1-12. doi:10.1093/icb/icr037
2. Moravek C. L. and K. L. Martin. 2011. Life goes on: Delayed hatching, extended incubation and heterokairy in development of embryonic California Grunion *Leuresthes tenuis*. Copeia 2011(2): 308-314. DOI 10.1643/CG-10-164
3. Martin K. L. M., C. L. Moravek and A. J. Walker. 2011. Waiting for a sign: Extended incubation postpones larval stage in the beach spawning California Grunion *Leuresthes tenuis* (Ayres). Environmental Biology of Fishes 91:63-70. doi:/10.1007/s10641-010-9760
4. Johnson, P. B., K. L. Martin, T. L. Vandergon, R. L. Honeycutt, R. S. Burton, and A. Fry. 2009. Microsatellite and mitochondrial genetic comparisons between northern and southern populations of California Grunion *Leuresthes tenuis*. Copeia 2009: 467-476.
5. Martin, K. L. M., C. L. Moravek, and J. A. Flannery. 2009. Embryonic staging series for the beach spawning, terrestrially incubating California grunion *Leuresthes tenuis* (Ayres 1860) with comparisons to other Atherinomorpha. J. Fish Biology 75: 17-38.
6. Matsumoto, J. K., and K. L. M. Martin. 2008. Lethal and sublethal effects of altered sand salinity on embryos of beach-spawning California Grunion. Copeia 2008: 483-490.
7. Martin, K., T. Speer-Blank, R. Pommerening, J. Flannery, and K. Carpenter. 2006. Does beach grooming harm grunion eggs? Shore & Beach 74: 17-22.
8. Martin, K. L. M., R. C. Van Winkle, J. E. Drais, and H. Lakisic. 2004. Beach spawning fishes, terrestrial eggs, and air breathing. Physiological and Biochemical Zoology 77: 750-759.
9. Martin, K., A. Staines, M. Studer, C. Stivers, C. Moravek, P. Johnson, and J. Flannery. 2007. Grunion Greeters in California: Beach Spawning Fish, Coastal Stewardship, Beach Management and Ecotourism. Pp. 73-86 *in* Lück, M.; Gräupl, A.; Auyong, J.; Miller, M.L. & M.B. Orams (eds.): *Proceedings of the 5th International Coastal & Marine Tourism Congress: Balancing Marine Tourism, Development and Sustainability*. Auckland, New Zealand: New Zealand Tourism Research Institute.

10. Roberts, D., R. N. Lea, and K. L. M. Martin. 2007. First record of the occurrence of the California Grunion, *Leuresthes tenuis*, in Tomales Bay, California; a northern extension of the species. California Fish & Game 93:107-110.

Educational Media

"*Surf, Sand, and Silversides: The California Grunion*," 2011, an educational video produced at Pepperdine University in collaboration with Michael Murrie and many students, funded by National Geographic Society, California Coastal Commission, and National Marine Fisheries Service. Screenings at several film festivals and aquariums.

Honors and Awards

Conservation Achievement Award, American Fisheries Society, Western Division, 2011.
First Place for Short Documentary, Los Angeles City Cinema Festival, "*Surf, Sand, and Silversides: The California Grunion*," 2011. This video received an Award of Merit, Best Shorts 2011, and was an Official Selection at several film festivals.
Environmental Partnership Award, American Shore and Beach Preservation Association, 2006.
Fellow, American Institute of Fishery Research Biologists, since 2004.

Synergistic activities:

1) Executive Director, Grunion Greeters, 2002-present.
2) Workshops for Grunion Greeters every year since 2002; in 2009, at Santa Monica Pier Aquarium in Los Angeles, Muth Interpretive Center in Newport Beach, Pepperdine University in Malibu, Buena Vista Audubon Society in Oceanside, Birch Aquarium at Scripps Institution of Oceanography in La Jolla, Aquarium of the Pacific in Long Beach, Marine Science Institute at UC Santa Barbara in Goleta, Tijuana Estuarine Research Reserve in Imperial Beach, Pacific Grove Museum in Monterey, California. Web site for grunion monitoring by citizen scientist Grunion Greeters, 2002 – present, See www.Grunion.Org.
3) Outreach (selected recent examples): Girls in Ocean Science, San Diego Science Festival, "Wildlife Watch Week" for National Wildlife Federation, National Geographic television program, "*Caught Bare-Handed*," "Animal Planet" Discovery Channel television: *Most Extreme: Swarms*, workshop for middle school teachers, Marina Del Rey Marine Science Academy; public programs at aquariums and state parks.
4) Board of Directors and Co-Founder, Beach Ecology Coalition, 2004- present.
5) Meetings for Beach Ecology Coalition semiannually since 2004, working with beach managers, park rangers, coastal scientists, environmental groups, and regulatory agencies to develop best practices for ecologically sensitive beach management.

Research Grants Received from:

National Science Foundation, Society for Integrative and Comparative Biology, Ocean Associates, Coastal America Foundation, National Marine Fisheries Service- Southwest Region, Habitat Conservation Division, National Park Service and U. S. Geological Survey, California Sea Grant College, Malibu City Council, National Geographic Society, Committee for Research and Exploration, National Fish and Wildlife Foundation.