Nielsen (SSU), Steven Morgan (BML-UCD) and Jenny Dugan (MSI-UCSB): Baseline Monitoring of Ecosystem and Socioeconomic Indicators for MPAs along the North Central Coast of California: Sandy Beaches Summary

Project Goals & Objectives: Sandy beaches and adjacent surf zones are important foraging areas for shore birds and fishes that feed on intertidal invertebrates. The amount of wrack and plankton cast onto beaches is dynamically linked to adjacent ecosystem features, ocean climate and the growth rates and reproductive output of invertebrates. These links are the critical pathways through which direct and indirect effects of MPA implementation and variation in ocean climate will cascade, making sandy beaches an important target for long-term monitoring to assess ecosystem condition and functioning of the NCC region. Sandy beaches are also used extensively for a variety of recreational activities, including shore-based fishing, bait collection, beachcombing, ATVs, surfing, birding, dog-walking and picnicking. We will 1) provide the first comprehensive, baseline description of the biodiversity of sandy beaches of the NCC region, 2) develop informative ecosystem indicators and a plan for long-term monitoring of the network of MPAs involving citizen scientists (e.g., students, recreational fishers, members of conservation clubs) and collaborations with similar established volunteer groups in the region (e.g., Gulf of the Farallones Beach Watch program), and 3) interpret the important ecological links among the components of the ecosystem, including humans, for use in evaluating the effectiveness of the network of MPAs.

Methodology: We will conduct a comprehensive baseline biodiversity survey and evaluate prospective long-term ecosystem indicators at 12 sandy beaches (6 MPAs and 6 reference sites) characteristic of the large sandy beaches and pocket beaches (< 1 km of shoreline) in the NCC region. Quantitative measurements using standard methods (see appendix) will include 1) species richness and abundance of intertidal macroinvertebrates (once in year 2), 2) biomass and population size structure of key species/taxa (twice annually in years 1 and 2), 3) abundance and species composition of shorebirds and macrophyte wrack (7 times annually in years 1 and 2) and 4) characterization of human activities and physical attributes of the study beaches (7 times annually in years 1 and 2). We also will conduct a pilot version of a citizen-scientist volunteer program that is designed for long-term monitoring of MPAs at 4 sites (2 MPAs and 2 reference sites) in the second year. Volunteers will survey biomass and population size structure of target species, shore birds, macrophyte wrack and human activities. In addition, we will quantify the abundance, diversity and size structure of surfzone fishes using a collaborative fisheries approach, which consists of recruiting volunteer recreational fishers to catch and release fishes using standardized gear and a rigorous sampling design. During the final year, we will work closely with all collaborators on data analysis and interpretation to integrate results across ecosystem features, examine critical linkages in ecosystem functioning and evaluate the network of MPAs in an ecosystem context .

Outcomes & Deliverables: We will provide 1) new baseline data for species richness of macroinvertebrates, abundance and size structure of key species, abundance of shorebirds, wrack and surfzone fishes in the NCC region that will be fully integrated into a shared database including EML metadata; 2) an efficient working model for long-term monitoring of the most critical indicators for sandy shores involving citizen scientist volunteers that will be fully integrated with monitoring of other ecosystem features; and 3) a comprehensive, integrated ecosystem assessment report that clearly indicates how sandy shores contribute to the ecological functioning of the region

Baseline Monitoring of Ecosystem and Socioeconomic Indicators for MPAs along the North Central Coast of California: Sandy Beaches

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Project Goals, Objectives & Rationale

Sandy beaches are among the most intensely used coastal ecosystems for human recreation and are critically important cultural and economic resources to coastal regions. Sandy beaches and adjacent surf zones are also important foraging areas for shorebirds and fishes that feed on intertidal invertebrates. The amount of wrack and plankton cast onto sandy beaches is dynamically linked to adjacent ecosystem features, ocean climate and growth and reproductive output of invertebrates. These links are the critical pathways through which direct and indirect effects of MPA implementation cascade, making sandy beaches an important target for long-term monitoring to assess regional ecosystem condition and functioning. We will conduct a comprehensive baseline biodiversity survey and evaluate prospective long-term ecosystem indicators at 12 sandy beaches (6 MPAs and 6 reference sites), including long and pocket beaches (< 1 km of shoreline), over the first two years. Despite their ecological and cultural importance, sandy beaches are not as well studied as other ecosystem features; this effort will be the first comprehensive survey of sandy beaches in northern California. During year three these data will provide the foundation for: 1) a baseline assessment of this ecosystem feature, and 2) understanding how sandy beaches integrate critical aspects of ecosystem condition and functioning in the North Central Coast (NCC) MPA network.

Project Leaders

Our research team consists of three PIs whose combined knowledge and experience provide a solid foundation to successfully execute all aspects of the work proposed. Jenny Dugan's research focuses on the ecology of sandy beaches and she has an active research program in southern and central California. Karina Nielsen and Steven Morgan both have active research programs in the NCC region and bring combined expertise in community, population and larval ecology, conservation biology and coastal oceanography. We also have prior experience with synthesis and integration in large, interdisciplinary projects (e.g., LTER, PEEIR & PISCO).

Approach to be Used (Plan of Work)

Monitoring Sites

Pocket beaches (< 1 km of shoreline) are more prevalent to the north and long sandy beaches are more prevalent to the south in MPAs within the region; sandy beaches are absent from the Farallon Islands. We will represent both beach types in 6 MPAs spatially paired with 6 reference sites spanning the study region (Fig. 2). We do not include beaches with large freshwater inputs because of their low representation in MPAs and the strong influence of freshwater on species composition and abundance.

Physical Attributes.

Grain size and other physical variables can strongly influence species composition and abundance on sandy beaches, and therefore, we will measure intertidal width as well as the locations of water table outcrop and high tide strand line at each of our study site. Measurements will be taken along 3 vertically oriented transects 7 times per year for two years in conjunction with bird, wrack and people (BWP) surveys (see below; Fig. A1). To estimate beach morphodynamic state, physical parameters including wave height and period, sediment grain size and beach slope at two intertidal levels, swash width and period and beach zone widths will be measured on the three transects at all sites during surveys that target infauna (see below). All sediment samples will be rinsed, dried and analyzed with standard testing sieves.

Mean grain size, sorting, skewness and kurtosis will be calculated for each sample. Dean's parameter will be calculated from the wave and sediment data and used to estimate the mean morphodynamic state of the study beaches.

Biodiversity Survey

Biodiversity (BD) of the intertidal macrofaunal community will be sampled once during daylight on spring low tides at all sites in year two. The intertidal macrofaunal surveys will be temporally overlapped with other sampling at all sites (see below) to maximize comprehensiveness and efficiency. At 4 study sites, BD surveys will also overlap with volunteer (recreational) collaborative fishing program (see Citizen-Scientist Volunteer Monitoring Program [CSVMP] below) allowing us to include surfzone fishes in the survey.

Species richness, abundance, biomass and population characteristics of the invertebrate macrofauna will be estimated using sampling protocols similar to those used in previous studies of California beaches (Dugan et al. 1990, 2003; Engle et al. 1995). Sampling will be done on 12 days during July and August 2011 (constrained to a 30-day period to reduce potential confounding due to seasonal variation) allowing us to capture the peak potential for biodiversity and make comparisons with previous studies on southern California beaches (Dugan et al 2000, Dugan et al 2003). We will use the same three shore-normal transects established on each beach for physical measurements (see above) and macrophyte wrack sampling (see BWP below), which extend from the lower edge of terrestrial vegetation or the bluff to the lowest level exposed by swash of the intertidal at each location. To minimize disturbance of the mobile fauna in the lower beach, spacing between transects will include a minimum buffer zone of 5 m. Each transect will be sampled with 150 cores (10 cm diameter, 20 cm deep) at uniform intervals of 0.25 to 3.0 m depending intertidal width. At each of 15 tidal levels, 10 consecutive cores will be grouped and placed in a mesh bag (1.5 mm aperture) for sieving, retaining macrofauna to be preserved for analysis. This sampling design will yield a total sampling area of 3.5 m^2 and 45 biological samples at each beach (Schlacher et al. 2008). Most species of macrofauna likely to be prey of shorebirds (including eggs of the California Grunion) will be retained on a 1.5 mm sieve. Samples where large amounts of coarse sediments are retained will be elutriated to separate the macrofauna. All macrofauna retained will be placed in labeled ziplock bags, chilled and transported to the lab for processing. Mollusks, crabs and other invertebrates will be processed live whenever possible. All fauna will be identified, enumerated, blotted dry and weighed to the nearest 0.001g. Shell and carapace lengths of mollusks and crabs respectively will be measured with vernier calipers to the nearest mm to determine size frequency distributions. Sticky traps, and standard net sweep samples will also be used to estimate the composition and availability of wrack- associated macroinvertebrates. Flying invertebrates will be collected with standard insect net sweeps along a 1 m wide swath from the upper beach to the swash zone on each transect prior to collection of cores. To collect flying and crawling invertebrates, 2 sticky traps (commercial fly paper strips, Revenge) will be deployed on fresh brown algal wrack located

MILESTONES CHART

	2010	2011	2012
TASKS AND MILESTONES	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D
Biodiversity Survey		XX	
Sand Crab & Wrack Amphipod Surveys	X X	X X	
Birds, Wrack & People Surveys	X XXX X X X	X XXX X X X	
Citizen-Scientist Volunteer Monitoring Program Pilot		X XX	
Develop Protocols, Training Materials & Recruit Volunteers for SCVMP	XXXXXXXXX		
Sample Processing & Data Entry	XXXXXXXXX	XXXXXXXXXXXX	XX
Synthesis & Integration			XXXXXXXXXXX

Figure A1. Project timeline and milestones.

within 1 m of each transect for 15 minutes. After 15 minutes, the strips will be collected and placed in labeled 1 gallon ziplock bags for later analysis.

Long-term Indicators

Comprehensive biodiversity surveys are essential but are labor and time intensive, require a high degree of taxonomic expertise and poor candidates for a long-term monitoring. Long-term monitoring must be sufficiently frequent and efficient to be economically feasible and provide resources managers with clear indicators of ecosystem condition to inform ecosystem based management. Based on evidence from prior research on sandy beaches, and analyses from this effort, we will develop and refine a monitoring protocol for a few key indicators that can be adopted as a citizen-scientist volunteer monitoring program (see below) and used to track ecosystem condition and inform adaptive management. We focus on quantifying 5 indicators that represent critical ecological links within sandy beach ecosystems: wrack, wrack-associated fauna (talitrid amphipods), sand crabs, birds and people (Fig. A2). We will also incorporate 2 additional variables in our analysis of long-term indicators: ocean conditions (existing SST and surfzone chl *a* from regional ocean observing databases [e.g., CeNCOOS]) and surfzone fishes (from our CSVMP described below).

Birds, Wrack & People. Macrophyte wrack that is cast onto the beach is the base of an important food web on sandy beaches, providing sustenance to shorebirds and surfzone fishes in the form of intertidal invertebrates that feed on wrack. In the absence of wrack the biodiversity of sandy beaches declines because this critical trophic link has been broken. Biodiversity is reduced on southern California beaches that are groomed to remove wrack for satisfying a human preference for 'clean' beaches while sunbathing and swimming (Dugan et al 2003). Although beach grooming is not as frequent in the NCC region, people still heavily use sandy beaches for a variety of recreational activities that may be relatively benign, cause some disturbance or be consumptive, such as surfing, off leash dog-walking and shore-based fishing, respectively. To assess the links among the base of the food web, upper trophic levels and human activities, we will conduct bimonthly surveys of birds, wrack and people (BWP) during the first two years.

To describe the distribution, abundance and seasonal occurrence of shorebirds, we will conduct bimonthly, daytime surveys of shorebirds during low tides at all 12 sites. A standard (1 km) transect will be established at each site where feasible, with endpoints recorded and track described using a GPS. On smaller pocket beaches, transect length will be truncated to match the length of the beach. Two teams of 2 observers will survey 2-4 sites/day each, all sites will be surveyed within 3-4 days and scheduled so that the condition of the tide is constrained (0.75 m (2.5 ft) or lower tides spanning the two hours preceding and following low tide). During each survey, all shorebirds, gulls and other birds, including seabirds and terrestrial birds, will be identified and counted using binoculars by a single observer walking the transect. As they are counted, birds will be assigned to intertidal zones (upper intertidal, mid-intertidal, below WTO, swash zone) and their behavior (feeding mode, roosting) noted. Oiled and dead birds and mammals encountered will also be recorded. In addition, the number of people, their activities (e.g., walking, fishing, surfing, sunbathing) and dog use (leashed/unleashed chasing birds, retrieving swimming) and zones of occurrence will be quantified.

Percent cover and composition of macrophyte wrack will be determined at each site using two sampling protocols similar to those used by Dugan et al. (2003). During BWP surveys, we will use a streamlined method to measure percent cover of wrack, while during SCWA surveys (described below) we will use a more detailed approach to gather data on macrophyte composition as well as percent cover of the wrack. Wrack cover will be measured/mapped with a line intercept method on each of the 3 transects used for BD surveys and physical measurements. During BWP surveys, one edge of the track of a distance measuring wheel will be used as the reference line. The extent and presence of each type of macrophyte wrack, driftwood, carrion, and tar will be recorded along the transect using size

categories (1 mm to 5 m) yielding estimates of total wrack cover by type for each site. During the SCWA surveys (see below) wrack cover will be measured/mapped with a line intercept method on the same 3 transects. The extent and presence of each type of wrack (as above) that is 0.5 cm or greater will be recorded along the entire transect. Cover of major macrophytes (e.g., *Nereocystis leutkeana, Phyllospadix spp., Egregia menziesii*) will be calculated for each transect and means will be calculated for each macrophyte type for the study beach. Knowing the composition of the macrophyte wrack will allow us to assess the links among rocky intertidal, rocky subtidal and sandy beach ecosystem features.

Sand Crabs & Wrack-associated Amphipods. To describe the abundance, distribution and size structure of potential prey species/taxa for birds and fishes on sandy beaches, we will conduct quantitative sampling of two target species/taxa: the hippid crab *Emerita analoga* (sand crabs) and talitrid amphipods *Megalorchestia* spp. (wrack-associated amphipods). *Emerita* are widespread, typically dominate the total biomass of macrofauna on sandy beaches, feed on phytoplankton and are prey for surfzone fishes, shorebirds and some seabirds. Talitrid amphipods are also widespread, reflect the total abundance of wrack-associated macrofauna, directly feed on macrophyte wrack and are also prey for shorebirds and fishes. Thus, these two species/taxa are excellent indicators for long-term monitoring. Samples will be collected on low tides at each site, 2 times per year in spring (April/May) and late summer (July/August).

Abundance, biomass and population characteristics of the target species will be estimated using sampling protocols similar to those used in previous California beach studies (Dugan et al. 1990, 2003; Engle et al. 1995). For *Emerita*, an informal spade transect and visual inspections will be used to determine the boundaries of occurrence (Dugan and Hubbard 1994). Quantitative samples will be collected on the same 3 vertical format transects described above. We will collect a series of core samples on the lower part of each transect with the top core, corresponding to the upper edge of *Emerita* distribution, and the lowest core, corresponding to the low swash level. A core (10 cm diameter, 10 cm deep) will be taken at uniform intervals of 0.25 to 1 m depending on width of the distributional boundaries. Cores from each transect will be pooled and placed in a mesh bag (1.5 mm aperture) for sieving. Sieving and elutriation will be conducted as described above. All *Emerita* retained will be placed in labeled ziplock bags, chilled and processed in the laboratory. To sample talitrid amphipods, we will identify the zone of occurrence and collect a series of uniformly spaced cores (10 cm diameter, 20 cm deep), along the 3 transects. Cores will be pooled by transect and sieved as described above. Animals retained will be placed in labeled ziplock bags, chilled and frozen for later processing. All animals sampled will be identified, enumerated, blotted dry and weighed to the nearest 0.001g. Crabs will be processed live whenever possible, and carapace lengths will be measured with vernier calipers to the nearest mm to determine size frequency distributions.

Citizen-Scientist Volunteer Monitoring Program

To develop informative ecosystem indicators and a plan for long-term monitoring of the network of MPAs, we will conduct a pilot version of the citizen-scientist volunteer monitoring program (CSVMP) at 2 MPAs (Montara and Bodega Head) and their respective reference sites during year two. We will develop a training program and conduct a pilot CSVMP using the protocols we develop during year one. An important element of our pilot study will be a cross-validation analysis done by overlapped surveys done by our scientific team and the volunteer citizen-scientist team. This will allow for rigorous evaluation and assessment of data collected by volunteers, providing additional guidance as to which indicators are most suited to a volunteer monitoring effort. We envision using modified versions of the BWP and SCWA methods described above. In addition, we will mount a collaborative recreational fishing survey. Fishers will use standardized gear (decided in consultation) and catch, identify, measure and release fish, within a rigorously designed sampling scheme to assess abundance and size structure of surfzone fishes (primarily surfperch [Embiotocidae] and surf smelt *Hypomesus pretiosus*). Fishing surveys will be conducted over 10 days in July and August 2011. Fishers

will be assigned to fish several standardized segments of beach, randomly assigned, for standardized times. We will recruit volunteers from communities adjacent to MPAs and coordinate with established programs such as the Gulf of the Farallones Marine Sanctuary Association's Beach Watch program when possible to build on established efforts to lay the groundwork for effective development of a long term monitoring program in the future.

Outcomes and Deliverables

We will deliver 1) a description of sandy beaches inside and outside MPAs that is explicitly linked to adjacent ecosystem features through mechanistic processes; 2) comprehensive baseline data of the condition of sandy beaches at MPA implementation and a subset of metrics appropriate for cost-effective and time-efficient long-term tracking of condition and trends (with metadata reporting using the Ecological Metadata Language standard); 3) specific recommendations on how to mount and run a citizen scientist volunteer monitoring program using these metrics that can be run in tandem with similar efforts for other ecosystem features; 4) descriptions of initial changes (if any) in recreational uses including fishing, non-consumptive activities and ecological components on sandy beaches over the first year of MPA implementation; and 5) thorough integration and interpretation of all data from sandy beach surveys into a synthetic ecosystem assessment in collaboration with other components of this effort (Fig. A2).

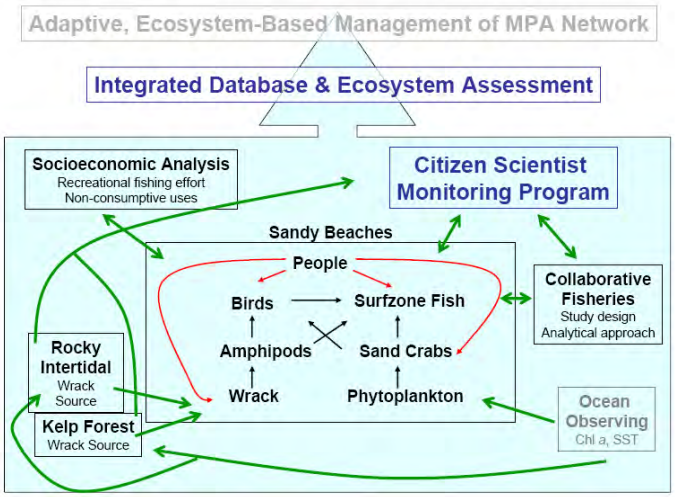

Figure A2. Links among ecosystem features, proposal components, existing datasets and integrated outcomes for sandy beaches. Green arrows show links among proposal components and ecosystem features; black arrows indicate positive effects; red arrows indicate negative effects; black text indicates project module or ecosystem feature; blue text indicates synthetic outcomes; grey text indicates entities or outcomes outside the scope of this proposal.

In addition to the deliverables described above, we are excited by the interesting scientific possibilities provided by the opportunity to collect the first comprehensive data on sandy beaches in northern California. Sandy beaches are poorly represented in the marine ecological literature despite being a nexus for exploring several critical indicators of coastal ecosystem condition. For example, macrophyte wrack data and chlorophyll a from ocean observing stations might be combined with coastal topography to describe and then predict spatial variation in potential productivity of different sites and the likely trophic pathways of that production (Lester et al. 2007, Broitman & Kinlan 2006). Long-term indicator species such as sand crabs, shorebirds and urchins (from adjacent ecosystem features) may track these conditions through processes such as growth or reproductive output. It will also allow us to evaluate the possibility that surfzone fishes respond to invertebrate prey resources on sandy beaches for use in developing metrics of ecosystem condition and health. Our data on human use and surf-fishing will allow us to integrate socioeconomic and cultural components in the baseline evaluation of sandy beaches in the region.

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