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The Center for Santa Monica Bay Studies

a program of the Seaver College of Science and Engineering at Loyola Marymount University and the Santa Monica Bay Restoration Foundation

Benthic Invertebrate Sampling in the Ballona Wetlands

PHOTO: SMBRF

Urban Coast

The Journal of the Center for Santa Monica Bay Studies

Urban Greening | Funding Challenges | Low Impact Development | High Marsh Restoration | Urban Stream Restoration
Marine Debris | Climate Change Adaptation | Giant Kelp Restoration | Freshwater Treatment Wetlands

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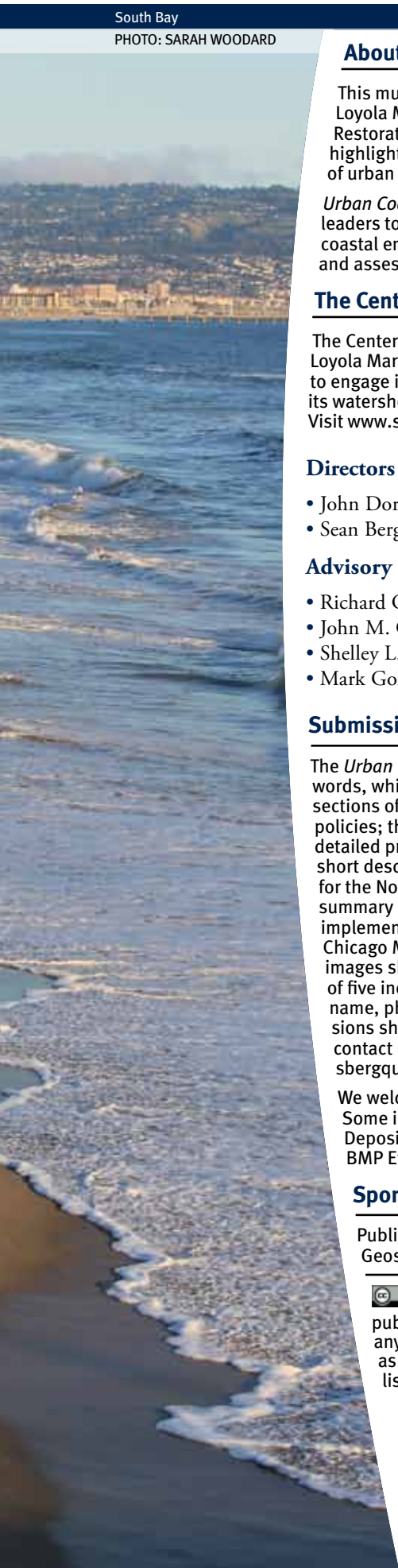

South Bay
PHOTO: SARAH WOODARD

About Urban Coast

This multidisciplinary journal is a product of the Center for Santa Monica Bay Studies, a partnership of Loyola Marymount University's Seaver College of Science and Engineering and the Santa Monica Bay Restoration Foundation. *Urban Coast* fulfills the Center's goal of providing a much-needed forum to highlight research that informs the most pressing issues of our day and policies that affect the condition of urban coastal resources.

Urban Coast is the ideal forum for researchers, agencies, advocacy groups, and other science and policy leaders to engage in constructive discussion and information exchange on issues that are pertinent to our coastal environments. In this way, we can find common ground and highlight the robust science, analysis, and assessment needed to catalyze good policy, good design, and good management measures.

The Center for Santa Monica Bay Studies

The Center for Santa Monica Bay Studies is a program of the Seaver College of Science and Engineering at Loyola Marymount University and the Santa Monica Bay Restoration Foundation. The mission of the Center is to engage in multidisciplinary research on environmental and social issues affecting Santa Monica Bay and its watershed, and to contribute to policies and actions that improve the environmental condition of the Bay. Visit www.santamonicabay.org.

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Submissions

The *Urban Coast* is a peer-reviewed publication. Feature articles are generally between 4,000 and 6,000 words, while short submissions are between 1,000 and 3,000. Submissions are accepted for all four sections of the journal, including Perspectives with essays and editorials that review current conditions or policies; the Research & Policy section features articles on scientific or policy studies; Case Studies are detailed project reports with implications for the urban coastal environment; and Notes & Abstracts are short descriptions of research, policy, and events relevant to our urban coastal environment. Submissions for the Notes & Abstracts section are between 250 and 500 words, and should be an abstract or a short summary about your innovative environmental research, technical study, restoration project, BMP or LID implementation, or other projects. All submissions should be written according to the standards of the Chicago Manual of Style, 15th Edition. References should be placed at the end of the document. Tables and images should be separated from the text. Images should be provided in .tif format, not exceeding a width of five inches and a resolution of 600 dpi (a width of 3,000 pixels). Include the article's title; the author's name, phone number, and email address; and a two-sentence biographical statement. Article submissions should include a 250-word abstract. Submissions will be accepted on a rolling basis. Feel free to contact us by email to discuss your ideas. Please send manuscripts as .doc attachments via email to: sbergquist@santamonicabay.org and swoodard@waterboards.ca.gov.

We welcome submissions for science and policy topics pertinent to the urban coastal environment. Some initial topics for consideration include: Stream Restoration Science, Stormwater Permit, Aerial Deposition, Water Conservation/Independence, Carbon Sequestration – wetlands, Rapid Indicators, BMP Effectiveness, Emerging Contaminants, and Aquatic Invasive Species – impacts, control measures.

Sponsors

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Great Blue Herons on the Ballona Wetlands

PHOTO: SARAH WOODARD

Letter from the Director

Oil Spill—When Tragedy Strikes, Healthy Wetlands Are Our Best Protection

PHOTO: LORNA APPER

We all watched with sickening despair as oil washed ashore this summer in Louisiana, Mississippi, Alabama, and Florida, and as even more oil swirled in giant, toxic, underwater pools, likely killing millions of tiny organisms that bigger fish eat as well as the fish, turtles, and dolphins that swim through it. The oil spill was a tragedy of monumental proportions that has brought continuing hardship to thousands of people, killed millions of animals, and crippled one of the most productive ocean ecosystems in the world.

This tragedy illuminates for us the stark truth that, once a large spill occurs, there is little we can do to protect precious wetlands and other natural resources. Containing large amounts of oil, on the sea's surface and especially underwater, is extremely difficult, and all the technology in the world doesn't guarantee a quick and painless clean-up. Walling off our wetlands from the ocean's life-giving tides, as was proposed in Louisiana and bitterly opposed by local scientists and environmental groups, is simply irrational because it would prevent those same areas from functioning naturally and providing the habitat and biodiversity that should be their hallmarks.

Instead, we need to ensure that the ecosystems we treasure and rely upon for our livelihoods are healthy and robust. Intact ecosystems—wetlands, estuaries, and kelp forests—are the best protection we can offer. Healthy systems can absorb some damage, while large robust systems buffer against changes in conditions, in part because many important functions are duplicated—where there are many different species thriving, one can become scarce for a time because there are other similar species to take its place, at least for a while, allowing the harmed species to make a comeback.

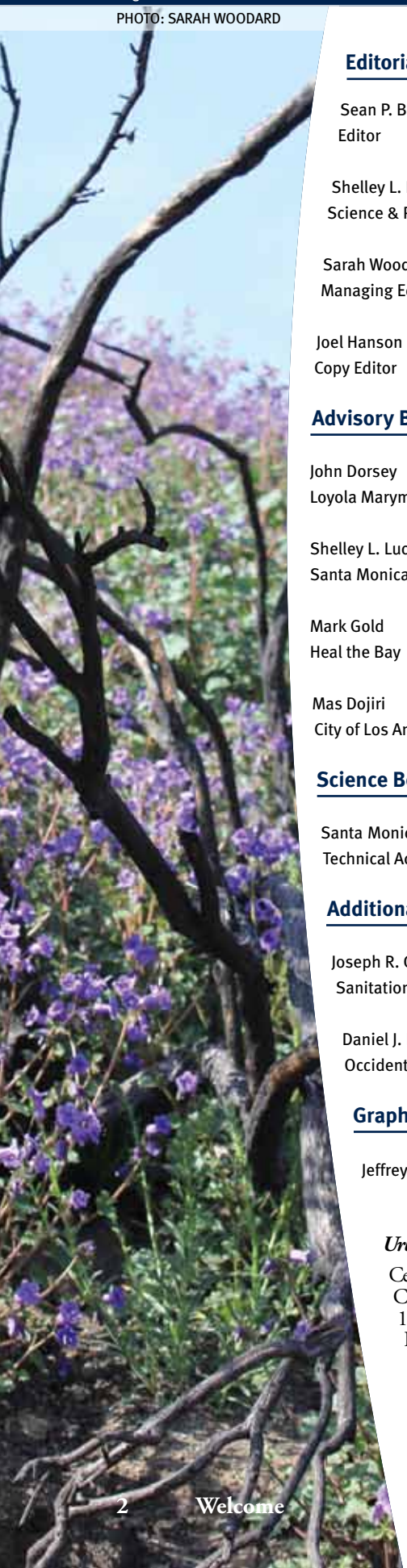
Healthy ecosystems also have a greater ability to recover from changed conditions. In a degraded wetland that has been filled in, paved over, and dried out by blocking tidal flows, invasive plants that find their way in can quickly spread, choking out the few patches of native plants that are hanging on. However, in a diverse wetland where native species thrive, exotic plants may try to invade but are less likely to gain a foothold because there are many different plants to compete with the interlopers and the native species are in good enough condition to hold their own.

This healthy ecosystem model will protect against other things too, including the predicted—and the unpredictable—impacts of a changing climate. In a warming world, some things will be irrevocably lost. The best hope we have of maintaining some level of biodiversity and a livable planet is to ensure that our ecosystems are healthy and robust now, before disaster strikes.

There is no doubt that we need better protection against oil spills. Safety precautions and spill response plans need to be much more rigorous, and actually enforced. Governments and individuals need to support alternative energy development and move away from fossil fuels altogether. We need to recognize that as long as we are drilling for oil, we are at risk of the next, bigger-than-ever spill. In the meantime, restoring healthy, functioning tidal wetlands and marine systems is the best protection our coastlines have.

Shelley L. Luce, Executive Director
Santa Monica Bay Restoration Foundation

Welcome



Regrowth after a Wildfire
PHOTO: SARAH WOODARD

Urban Coast

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Urban Coast Volume 2, Number 1

Letter from the Editor

PHOTO: LORNA APPER

In this issue of *Urban Coast*, we continue to highlight urban coastal issues and the various restorative actions that planning and policy communities undertake to address these environmental problems. Let us take inspiration from an exclusive interview with Majora Carter, who is bringing the green economy to urban communities. Next, we move to the topic of runoff, with Mark Gold discussing the needs, options, and obstacles in obtaining steady funding to address the impacts of urban runoff. One way to reduce urban runoff is with low impact development (LID), and in this issue, local stormwater management leaders discuss regional approaches to LID and how various municipalities are implementing these principles. On the restoration front, experts discuss project implementation and the leading science of urban stream, coastal wetland, and near shore marine restorations. To add some international perspective, one of the regions most threatened by climate change, the low lying coastal city of Rotterdam, Netherlands, provides details of local planning efforts to address future impacts. Next, Heal the Bay examines international and U.S.-based models for marine debris policies and suggests recommendations for effective reduction and prevention policies. Finally, we learn about the challenges and successes of creating a treatment wetland in conjunction with the Playa Vista development.

We continue to receive informative and exciting articles about the many approaches to improving the environmental conditions of our urban coast and the progress and successes already achieved. Please contact our offices if you would like to discuss topics for submission or help support the continued publication of *Urban Coast*.

Sean P. Bergquist, Editor
Santa Monica Bay Restoration Foundation

Majora Carter in Concrete Plant Park

PHOTO: MAJORA CARTER GROUP

Urban Greening with Majora Carter

Profile and Interview

COMPILED AND EDITED BY MARC BEYELER

GREEN ECONOMIC INNOVATOR, Majora Carter, came to Los Angeles in January to speak at the Santa Monica Bay Restoration Commission's State of the Bay Conference. Carter spoke to a packed luncheon audience about the challenges and potential of "urban greening," forcefully and passionately articulating its power to transform our cities and create sustainable, livable communities. Her story and message inspired and challenged the audience to broaden its environmental consciousness to encompass urban issues and costly environmental equality gaps.

Through her work, Carter, a MacArthur Foundation "genius" fellow, has become a national spokesperson for green solutions to our urban environmental and public health problems. She has been described as "the green power broker" by the *New York Times*, and as a visionary in sustainable urban renewal, based on her work in the South Bronx, and across the United States.

From 2001 to 2008, Carter was the executive director of Sustainable South Bronx (SSBx), a non-profit project incubator, dedicated to environmental justice solutions in an economically depressed neighborhood of New York City.

After moving back to her South Bronx neighborhood, Carter happened upon an abandoned public street end at the edge of the Bronx River. Decades of illegal dumping and other activities had kept families away. Against the odds, Carter, and a diverse coalition of corporate neighbors and community members, reclaimed the 2.5-acre riverfront site for events and programs. From that spark, the South Bronx Greenway Master Plan was developed, envisioning the eleven miles of shoreline paths, parks, and green spaces that are now being built. Within five years, a $3.2 million public park with an award-winning landscape design, a floating dock and boat launch, kiddie fountains, and an amphitheatre were completed on the former illegal dump. New parks along the river have also been completed or are underway.

Carter also spearheaded South Bronx community interest into transforming plans for another noxious waste facility into an equitable solid waste management plan for the entire city. For the past decade, she has led other efforts to remake private and public spaces with green infrastructure, while pioneering green-collar job training. A big part of her success has been her ability to link environmental improvement to economic renewal, and to help communities develop sustainable new businesses that employ local people and make the world a better place.

Carter recently formed an economic consulting firm to develop new, green economic and infrastructure projects in cities across the nation, including New Orleans and Detroit. After telling her story to a lunchtime audience at the State of the Bay Conference, Carter took the time to talk more with *Urban Coast*.

Majora Carter

PHOTO: MAJORA CARTER GROUP

Q. Why come all the way to Los Angeles to talk about your work in the South Bronx?

A. *Many of the same urban problems, and many of the same green solutions, exist and can be realized in Los Angeles and other U.S. cities. While every community is different and unique, many elements of the new green economy can be important foundations of future urban and community sustainability. I work across the nation, and on a range of targeted projects such as our American City Farms. This is a national brand of locally grown, clean food that we are launching in 2010.*

Q. A great deal of your attention is directed to community empowerment through "ownership," as well as community employment and economic development. Why are these important?

A. *Without community ownership, management, and stewardship there will be fewer community benefits and little buy-in. In the South Bronx, we created green job training and placement systems to promote local economic and environmental development efforts that included riverbank and estuary stabilization, urban forestry, brownfield remediation, and green roof installation. We are very serious about the need to address living-wage, community employment. Without support for the valuable environmental services these projects provide, these efforts can't provide long-lasting community economic turn-around.*

Q. What are the goals of the B.E.S.T. program and the SmartRoofs business?

A. *The Bronx Environmental Stewardship Training (B.E.S.T.) program is focused on adult employment, in climate change-driven sectors as one of the nation's first urban green-collar training and placement systems. A major focus involved managing urban forestry systems, and maintaining the South Bronx Greenway improvements. Similarly, SSBx's SmartRoofs installation business provides new green infrastructure, as well as community employment. Since B.E.S.T. began in 2003, 80% of its graduates have been placed in permanent jobs and 10% have gone on to enroll in college. When we engage our communities based on their needs, linking green employment and environmental inequality is a logical and fulfilling path.*

Q. Can you tell us more about your American City Farms project?

A. *We are exploring a pilot launch of this new business venture in Detroit, Flint, and/or New York City. It's a new model for urban micro-agribusiness that disrupts the conventional food distribution system with healthy small businesses throughout cities across America. It's pesticide- and herbicide-free, and meant to form a trusted, dependable name in local produce everywhere.*

Q. In 2008, you formed a consulting firm. What are your goals for this effort?

A. *I wanted to take the skills and experiences from the South Bronx and apply the best lessons learned in other communities to drive urban sustainability innovations. In areas like cities across America, I hope to show that the emerging green economy has legs, that is has public support, and that we can transform abandoned communities into sustainable communities.*

Installation of a Green Roof

PHOTO: MAJORA CARTER GROUP

MARC BEYELER *is an organizational and conservation services consultant, and holds a research appointment at the University of California, Santa Cruz, where he is conducting research on new collaborative models of natural resource conservation.*

Hermosa Beach's Pier Avenue Improvement Project

PHOTO: SARAH WOODARD

Funding for a Healthy Bay

MARK GOLD

THE HEALTH OF THE SANTA MONICA BAY has come a long way in the last two decades. In particular, great progress has been made in the areas of habitat preservation, sewage treatment plant upgrades, and Bay water quality and ecology adjacent to treatment plant outfalls. However, other than limited progress on summer beach water quality along the Bay and trash discharge reductions from Ballona Creek, efforts to reduce pollutant loads and the impact of urban runoff have not yet resulted in significant Bay water quality improvement.

One of the largest obstacles to progress in reducing urban runoff pollutant loads has been lack of funding. The cost of stormwater pollution prevention and reduction is extremely high for a built-out urban environment such as the greater part of the Santa Monica Bay watershed. Some progressive efforts have occurred to date, most notably the $500 million Proposition O for capital improvement projects for cleaning up Los Angeles' rivers, lakes, beaches, and bays. The bond measure was approved by an impressive 76% of the vote, and funds are now going towards year-round dry weather runoff diversions, catch basin trash excluder devices, stormwater infiltration, and lake clean up and restoration efforts. Proposition O has complemented state bond efforts such as Propositions 13, 40, 50, and 84 that allocated hundreds of millions of dollars for capital improvement projects designed to reduce dry weather and stormwater runoff pollution.

However, there is a problem: As Los Angeles continues to construct these much needed projects, the shortcomings of relying exclusively on the bond measure approach to tackling runoff pollution are such that problems continue to magnify. Bond measures can only fund capital improvements, so with every project that is built using city or state bond funds, the operation and maintenance funding shortfall continues to grow. The stormwater infrastructure crisis has expanded beyond the initial need to fund the construction of multi-use, green infrastructure projects, and we now struggle with inadequate funding to operate and maintain these new projects, let alone continue with basic stormwater programs such as street sweeping, catch basin cleaning, and public education.

With beneficial uses, such as recreational water contact and aquatic life, severely impaired because of urban runoff, local municipalities and LA County have had no choice but to aggressively reduce runoff pollution in order to comply with the Federal Clean Water Act's stormwater and Total Maximum Daily Load requirements. However, raising revenues for this purpose is a daunting task. Unlike sewer service charges or water rates, local governments cannot increase flood control or stormwater revenues without a two-thirds vote from the public or a majority vote of impacted property owners. Proposition 218 requires this super-majority vote despite the fact that flood control protects life and property, and stormwater pollution prevention protects public health. A simple state law can't change this burdensome situation. Instead, a two-thirds majority of the legislature is needed for a constitutional amendment, an unlikely outcome when the legislature can barely get a super-majority to approve a state budget.

The Proposition 218 hurdle is tremendous, but overcoming it is possible. In 2007, the City of Santa Monica barely approved Measure V with 100 votes to spare. Although the additional $2.3 million a year (overall, about $120 per parcel a year) has been a boon to Santa Monica's efforts

Funding Challenges

Polluted Stormwater Runoff
PHOTO: SARAH WOODARD

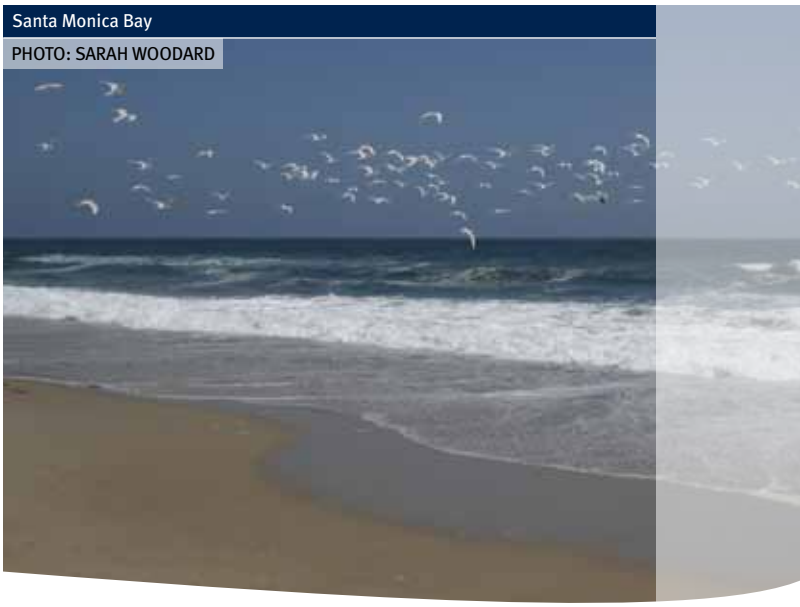
to clean up its beaches and transform the city into a low impact development community, the razor thin margin of success was not encouraging for Los Angeles County and the other 84 cities regulated under the County's stormwater permit

For the last two years, LA County and the City of Los Angeles have been discussing countywide stormwater pollution prevention measures. The need for funding can't be exaggerated: For example, Los Angeles' program currently costs approximately $60 million a year, representing a drain of over $30 million a year from the City's general fund. The City's Watershed Protection Division estimates the cost of implementing their superb Water Quality Compliance Master Plan – a stormwater cleanup program that will lead the City to Clean Water Act compliance – will exceed $120 million, and probably hit $150 million, every year. Clearly, more stormwater funds are sorely needed and the most viable source is a citywide, or countywide, funding measure.

Recently, the City and County agreed upon a countywide stormwater measure, the basis of which made up the language in AB 2554 (Brownley), recently signed into law by Governor Schwarzenegger. The law enables the Los Angeles County Flood Control District to raise revenues for stormwater pollution prevention in compliance with Proposition 218. Also, the law makes it clear that the County is moving to a true watershed based approach to improving water quality. The region will be broken down into nine regions, including the Santa Monica Bay watershed and the Ballona Creek watershed. Revenues generated within a watershed will stay in that watershed, and 90% of the funds will go to the cities for programs and projects with 10% going to the County for administration and monitoring. With this long awaited breakthrough, the funding measure is scheduled to be on the ballot in November 2012.

Meanwhile, urban runoff continues to be the biggest source of pollution in Santa Monica Bay and the biggest obstacle to Bay restoration. The City and the County are well on their way to negotiating a final stormwater funding measure that would include a watershed protection approach to compliance with water quality standards. Strict project and program eligibility criteria need to be developed and adhered to. Also, there needs to be public and technical oversight on how the funds will be spent. Misusing the funds for the pet projects of those elected, or to make up for park infrastructure maintenance shortcomings, should be prohibited.

The environmental harm caused by polluted runoff has occurred locally, and it is clear that hoping for the state legislature or Congress to provide adequate resources to solve these problems is a pipe dream. Meaningful legislative reform to modify Proposition 218 is not yet a priority in Sacramento: the state and federal government still appear wedded to the unsustainable paradigm of providing grants and loans to construct pollution prevention infrastructure. Although the benefits of these projects are tangible, the long-term water quality and the public health benefits are illusory because the money needed to operate and maintain them is not there. The most viable solution continues to be local, ongoing funding. The question is, can our locally elected officials, watershed protection agencies, environmental groups, and business communities get together to overcome the super-majority hurdle? Without this critical funding, a healthy Santa Monica Bay will not be achievable in the foreseeable future.



Santa Monica Bay
PHOTO: SARAH WOODARD

MARK GOLD *is President of Heal the Bay, an environmental group dedicated to making Southern California coastal waters and watersheds, including Santa Monica Bay, safe, healthy, and clean. Mark received his Bachelors and Masters in Biology and his doctorate in Environmental Science and Engineering from UCLA. Currently, Mark is vice chair of the National Estuary Program's Santa Monica Bay Restoration Commission, and he sits on the Board of UCLA's Institute of the Environment and Sustainability.*

Figure 1. Example of a Regional BMP: Ballona Freshwater Marsh

PHOTO: KEN SUSILO

Discussion: Low Impact Development

Urban Runoff and Stormwater: Strategies and the Need to Use All the Tools in Our BMP Toolbox

KEN SUSILO

In concept, the management of urban runoff impacts is a simple goal, and the means by which to achieve this goal are straightforward—avoid increasing runoff and pollutant generation (i.e., eliminate the sources), remove those pollutants that cannot be avoided, and restore hydrologic cycles. Understanding pollutant sources such as air deposition and reducing other sources through industry activities such as product replacement (e.g., through the California Stormwater Quality Association's Brake Pad Partnership efforts) are important parts of the solution.

The challenges involved with physically cleaning polluted urban runoff and stormwater lie in finding opportunities within our existing communities, and within these opportunities, selecting the most appropriate strategies and techniques. New construction (development and redevelopment) provides opportunities for protecting and improving water quality, but these new construction opportunities can be sparse in older urbanized areas.

The BMP Toolbox

The Best Management Practices (BMP) toolbox includes an array of proprietary and "public domain" flow control and water quality treatment BMPs; some utilize advanced treatment methods while others focus on natural treatment systems. Two fundamental distinctions can be made regarding BMP implementation. These are issues of scale and retention.

Scale

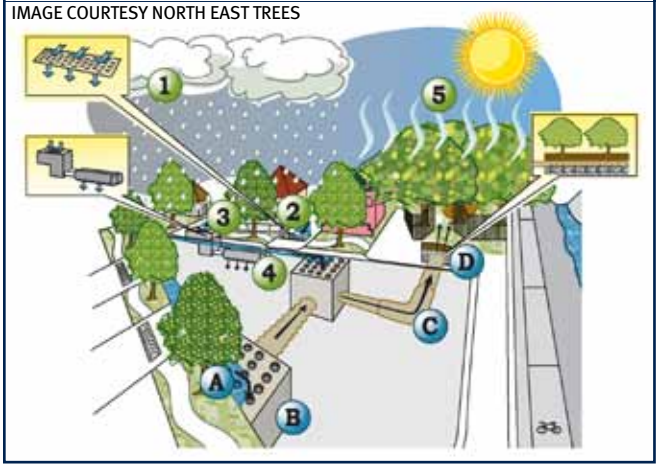
Issues of scale refer to the BMP in relation to its tributary drainage area. For purposes of discussion, three scales are proposed (Geosyntec 2008):

- Regional or sub-regional BMPs refer to BMPs that treat larger tributary drainage areas, typically on the order of 100 acres or more. These BMPs frequently require either incorporation at a master plan level or, in a retrofit condition, a diversion from an existing storm drain system. Examples include regional treatment wetlands or basins such as those planned or constructed in Malibu (Legacy Park Project), Playa Vista (Ballona Freshwater Marsh, Figure 1), and Central Orange County (San Diego Creek Natural Treatment System).

- Distributed BMPs treat smaller areas, typically on the order of tens of acres (e.g., one or more neighborhood

Figure 2. Example of a Distributed BMP: Oros Street Project

IMAGE COURTESY NORTH EAST TREES



blocks). Distributed BMPs are typically maintained by public entities or homeowners associations. Examples of distributed BMPs are the Oros Street and South Park Projects (Figures 2 and 3, respectively) in Los Angeles and Bicknell Avenue Green Street in Santa Monica.

- On-site BMPs refer to on-site Low Impact Development (LID) BMPs that are constructed at a parcel or lot level. These have also been referred to as institutional BMPs as their construction is typically the result of regulatory requirements imposed on private property owners for construction and maintenance, instead of on public works agencies (see the parking lot example in Figure 4).

Retention

The concept of "retention" is a critical term in the stormwater quality discussion. Retention, for the purposes of this paper, refers to those BMPs that have no surface water discharges (up to a water quality design event). These BMP types are sometimes called "zero discharge" BMPs, but this definition is not appropriate because they generally discharge to groundwater.

Retention BMPs rely on mechanisms such as infiltration (e.g., trenches, bioretention facilities, subsurface infiltration basins), evapotranspiration (e.g., green roofs), and harvesting (capture and use systems, such as cisterns). Infiltration BMPs may help restore some elements of the pre-urbanization hydrologic cycle through aggressive reintroduction of water into groundwater. Harvesting BMPs potentially offset some potable water demand. Both infiltration and harvesting approaches have the potential to provide water supply benefits.

For discussion of stormwater quality, however, each system is limited by different parameters. Infiltration BMPs are limited by the potential for the soil to safely and effectively accept large quantities of water without causing unintended consequences (Susilo, Matasovic, and Johnson 2009). Harvesting is limited by the ability to effectively use (e.g., for irrigation or indoor toilet use) captured stormwater, resulting in variable periods of transient storage, limiting the ability of the system to function effectively as a stormwater BMP (Strecker and Poresky 2010).

The corollary to retention BMPs are treatment BMPs with some surface discharges. The "natural treatment system" subset of treatment BMPs potentially reduces a fraction of the stormwater volume through evapotranspiration (e.g., bioretention with underdrains, bio-swales, green/brown roofs, amended soils, etc.), while the second subset of more engineered treatment BMPs, which includes filtration systems, gross solids removal devices, and proprietary settlement/deflection systems, do not reduce stormwater volumes.

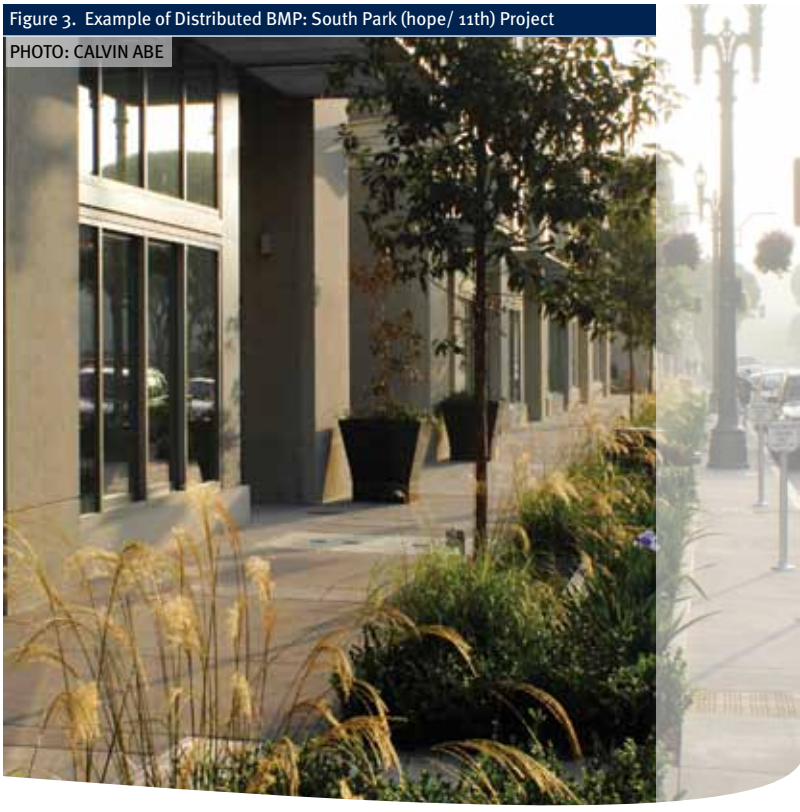
How Effective Are BMPs?

BMP performance is the subject of significant discussion and debate. From a surface water quality perspective, there are three critical elements to consider:

1. Hydrologic variability and design storm. Volume and flow-based design storms are often thought of as static criteria. Some BMPs, however, are highly sensitive to hydrologic conditions in relation to BMP operations. If, for example, captured stormwater takes a long time to infiltrate into the soil, or if diversion of the stormwater to a wastewater system depends on that system's capacity at a given time, then the system dynamics are highly sensitive to the transient storage conditions before and during the storm event. That is, if a system is already filled with stormwater, then a subsequent storm would result in a bypass of the BMP and potential exceedance of water quality targets (Susilo et al. 2009). Thus, particularly

Figure 3. Example of Distributed BMP: South Park (hope/ 11th) Project

PHOTO: CALVIN ABE



for large-scale systems, it is beneficial to evaluate real long-term precipitation data and drawdown rates to predict system effectiveness or to include real-time optimization methods and adapt the system over time (Quigley et al. 2008).

2. Treatment effectiveness. Two major sources of information are available to support the appropriate selection (and prediction of effectiveness) of BMPs. The International Stormwater BMP Database (Geosyntec and Wright Water Engineers 2008) is the most comprehensive database of BMP information and provides statistically based metrics on BMP effluent concentrations by pollutant type and BMP type (see Figure 5). The Water Environment Research Foundation's Critical Assessment of Stormwater Treatment and Control Selection Issues (Strecker et al. 2005) provides guidance based on fundamental unit processes, and emphasizes the importance of understanding pollutant types and forms as well as runoff hydrology before developing a treatment concept. The unit process approach is also incorporated in the Environmental Protection Agency (EPA) SUSTAIN model (U.S. EPA 2009). Both data types are critical to the understanding of BMP performance.

3. Operations and maintenance. If designed properly, BMPs will accumulate target pollutants and will require maintenance. Historically, there has been little effort to link operations and maintenance with BMP selection and required BMP performance. Recent efforts, such the BMP manuals developed for the County of Los Angeles Department of Public Works (2009) and the Los Angeles Unified School District (LAUSD 2009), place a heavy emphasis on maintenance practices.

The consequences of ignoring one or more of the above factors include increased risk of nonperformance of BMPs or worse, an exacerbation of the water quality problem we attempted to solve. There may also be false expectations of BMP performance, particularly when linked to specific pollutants of concern.

Strategies: What Do We Do and Where?

Not all BMP types and strategies are appropriate in all circumstances. For new development and redevelopment, where older regulatory requirements (Standard Urban Stormwater Mitigation Plans) were based primarily on design storm volumes and flow rates, new regulatory requirements appear to be much more prescriptive (e.g., limiting effective impervious areas), and much more focused on the on-site/LID scale of implementation, with a mandated emphasis on retention BMPs.

For agencies faced with Total Maximum Daily Load (TMDL) implementation requirements, opportunities are limited, and the needs are challenging, since the performance requirements include water quality standards-based metrics that differ among impairing pollutants. Regional BMPs have the potential to provide multi-benefit, cost-effective returns on investment and are potentially very valuable tools from the toolbox, but are often limited by land availability.

Figure 4. Example of On-site LID BMP in Parking Lot

PHOTO: GEOSYNTEC CONSULTANTS

Conclusions on Strategy

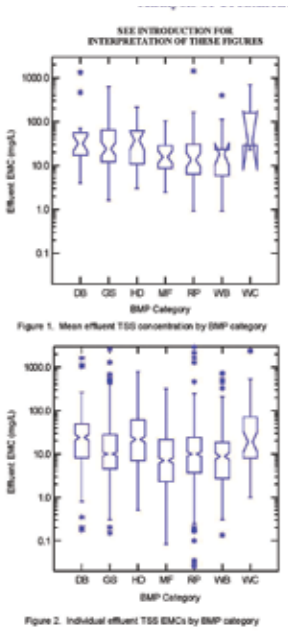
Strategically, examining the issue from a receiving water quality perspective, it is apparent that stormwater quality could benefit from a renewed focus on the use of the entire toolbox on a watershed basis. There are a number of potential arguments in favor of this position:

Design reliability: The state of the practice in stormwater BMPs is still developing. Implementation of a range of BMP strategies allows for adaptive incorporation of successful BMPs and phasing out of non-performing ones.

Long-term reliability: Operations and maintenance are keys to long-term success. Stormwater quality performance should consider variabilities with maintenance practices and the individuals or agencies responsible for maintenance.

System effectiveness and reliability: Regional BMPs are limited by land availability and hydraulics, but are often the last line of defense before discharge to a receiving water. In a developed urban area, covering all areas that contribute to stormwater pollution using only distributed and on-site BMPs is very difficult. It is also much more difficult to ensure that on-site BMPs are maintained over

Figure 5. Example of Effluent Statistics from the International BMP Database



the long-term. In combination, on-site BMPs can reduce flows so that capacity requirements for regional facilities can be reduced, allowing for smaller footprints and more opportunities for placement in a developed urban environment.

Opportunities: In urbanized environments, particularly those with aging infrastructure, the opportunities to improve stormwater quality are more constrained due to existing infrastructure issues, legacy contaminated soils, the cost of land, etc. Opportunities need to be created and then optimized. Encouraging creative solutions such as cross-agency and public-private partnerships can increase the potential to solve the larger water quality problem. Many of these opportunities can have additional public benefits as well (e.g., park or habitat development).

Water resources benefits: In Southern California, water is a valued resource, but water costs (relative to treated stormwater costs) benefit from an extensive water infrastructure. Focusing BMP types in areas with the highest water resources value (e.g., aggressive infiltration in areas that can benefit from supplemented groundwater) provides multiple benefits. Finally, implementing harvest and use strategies that are linked to potable water supply offsets (e.g., direct linkage of stormwater storage capacity to harvested indoor water use for toilet flushing) may not be consistently protective or cost-effective (as demand decreases, available storage decreases, increasing the potential for bypass events).

Perhaps the most pressing challenge to managers of stormwater quality is funding. While California and the Los Angeles Basin benefit from the availability of ballot-driven bond funds, these sources are not sustainable, and region-wide, there are very limited streams of continuous revenue (an exception is Santa Monica's Measure V Program). Integrated strategies have the potential to get access to funding by a) providing multiple mutual benefits and tapping into other funding sources (e.g., parks development, water supply, flood mitigation, street maintenance funds, urban forests, etc.); b) encouraging linkages to environmentally sensitive redevelopment, consistent with smart growth principles (Crabtree 2010) while creating new stormwater project opportunities; and c) demonstrating fiscal stewardship and promoting cost-effective strategic approaches in conjunction with sustainable funding strategies.

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Dominguez Gap Wetlands Project

PHOTO: L.A. COUNTY FLOOD CONTROL DISTRICT

Discussion: Low Impact Development

The County of Los Angeles' Integrated Watershed-Based Approach to Complex Urban Runoff and Stormwater Management

MARK PESTRELLA

With thousands of permitted, as well as nonpoint source, discharges into the receiving waters of the County of Los Angeles (County), improving the water quality of the region's coastal watersheds is a significant undertaking. To help public and private entities address the challenge of managing urban runoff and stormwater in such a complex environment, the County has taken an integrated, watershed-based management approach.

Background

Coastal watersheds in the County cover approximately 3,100 square miles (Figure 1). Portions of the rivers, lakes, creeks, streams, beaches, and coastal waters of these watersheds have been impacted by toxins and health-threatening pollutants at levels well above established public health standards.

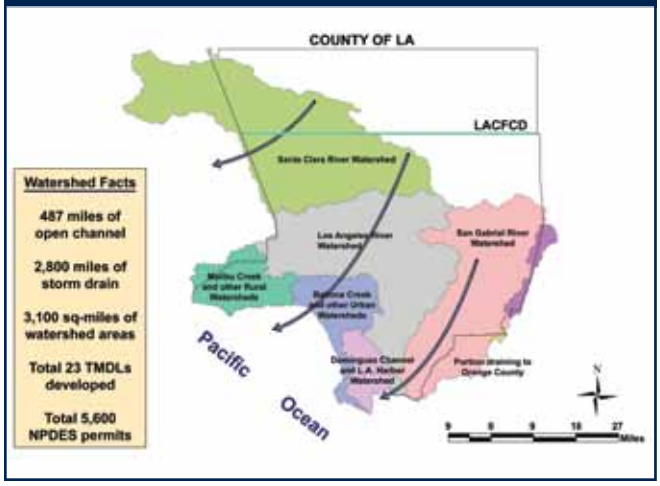
Some of these toxins and pollutants come from the untreated water that flows off rooftops, pavement, streets, and parking lots directly into our waterways, bays, and beaches. Runoff contains numerous pollutants, including industrial solvents, paints, bacteria, oxygen-choking pesticides and fertilizers, motor oil, trash, and even toxic heavy metals such as lead, mercury, chromium, and arsenic. This is called nonpoint source pollution because the contaminants come from many different sources. These pollutants often cause an impairment of beneficial uses of water bodies such as recreation areas and aquatic wildlife habitats. To protect such uses, water quality standards have been established for each beneficial use. Further, Total Maximum Daily Loads (TMDLs) are used to define the maximum allowable amount of pollutants introduced into water bodies while still meeting such water quality standards.

To date, water bodies within the County have been prescribed 23 TMDLs, including trash, metals, toxic pollutants, bacteria, nutrients, and chlorides. It is expected that approximately 30 additional TMDLs will be established in the next few years. Typical sources identified in the TMDLs for most of the County's watersheds are from nonpoint sources including aerial deposition, natural sources (forests and birds), and urban runoff.

Integrated, Watershed-Based Approach to Current Challenges

Urban runoff discharges occur through thousands of miles of stormwater conveyance systems under the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System Permit. It should be noted that, in addition to the discharges permitted by

Figure 1. Illustration and Facts of Los Angeles County's Coastal Watersheds



the Municipal Separate Storm Sewer System, a variety of other types of discharges occur every day under 5,600 active NPDES permits issued by state regulatory agencies. Consequently, it is nearly impossible to demonstrate the water quality improvement effect as a result of individual management actions toward water quality standards at the receiving waters. At any given time, the deterioration of water quality could be attributed to any one of the 5,600 separate permitted discharge activities.

To overcome these challenges, an integrated, watershed-based approach is needed to address the water quality of the County's watersheds. In the integrated, watershed-based approach, collective impact of a variety of pollutant sources from point to nonpoint is evaluated and thereby comprehensive, long-term strategies for overall water-quality improvement of the entire watershed can be planned. These strategies include: (1) plan for the entire watershed rather than local areas alone; (2) address multiple pollutants rather than an individual source; (3) develop multi-benefit BMPs rather than single purposed ones. To help achieve these goals, the County has initiated the Low Impact Development Ordinance and Watershed Management Modeling System. Details of these programs are discussed as follows.

Establishment of the Low-Impact Development Ordinance

The County has adopted the Low-Impact Development (LID) Ordinance to implement the watershed-based approach effectively and thereby mitigate widely scattered pollutant sources that have resulted from increased urbanization of the County's unincorporated areas.

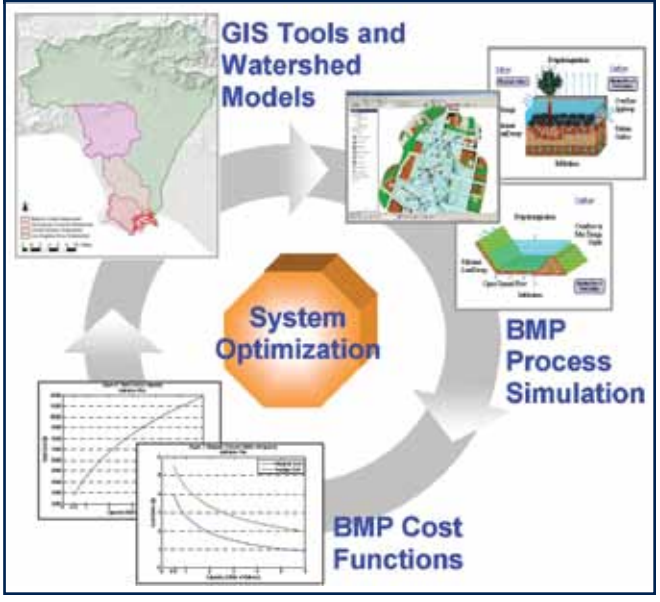
The County's LID Ordinance took effect on January 1, 2009 and required that all new development and redevelopment projects incorporate LID features into their designs. The goal of this requirement is to prevent pollutants of concern associated with development from impacting local water bodies and to mitigate hydromodification impacts to natural streams. In order to facilitate the implementation of the LID Ordinance, the County produced the County of Los Angeles' Low-Impact Development Standards Manual (January 2009) to guide developers in their effort to integrate LID features into their projects and to meet the LID Ordinance requirements, which specify infiltration or storage and reuse of excess runoff, or implementation of other listed LID features such as rain barrels and permeable pavements. It is estimated that 150 properties were conditioned to implement LID features prior to obtaining building permit approval in the first year of the ordinance.

Development of the Watershed Management Modeling System

As an effective stormwater management tool implementing the integrated, watershed-based approach, the Los Angeles County Flood Control District is developing the Watershed Management Modeling System (WMMS) for all of the County's coastal watersheds. This has been a cooperative effort with the United States Environmental Protection Agency (EPA). The EPA has provided technical expertise with a Best Management Practice (BMP) simulation system and watershed models that were previously created as part of existing TMDL development. A Technical Advisory Committee was formed to provide critical input in the system development. The Technical Advisory Committee consisted of watershed committee representatives, state and federal regulators, researchers, and nongovernmental organization representatives.

The WMMS simulates hydrologic and multi-pollutant transport processes in a watershed while evaluating the benefits and costs of different BMP options, with the goal of ultimately identifying a combination of the most cost-effective BMP solutions to a specific management objective, such as TMDL compliance. Built on an extensive body of relevant studies in the Los Angeles region and the state-of-the-art optimization techniques, the WMMS provides a unique framework where municipalities or watershed planners can evaluate alternative stormwater BMPs. See Figure 2 for a graphic representation of the WMMS and its optimization system.

Figure 2. Illustration of Watershed Management Modeling System's Main Structure



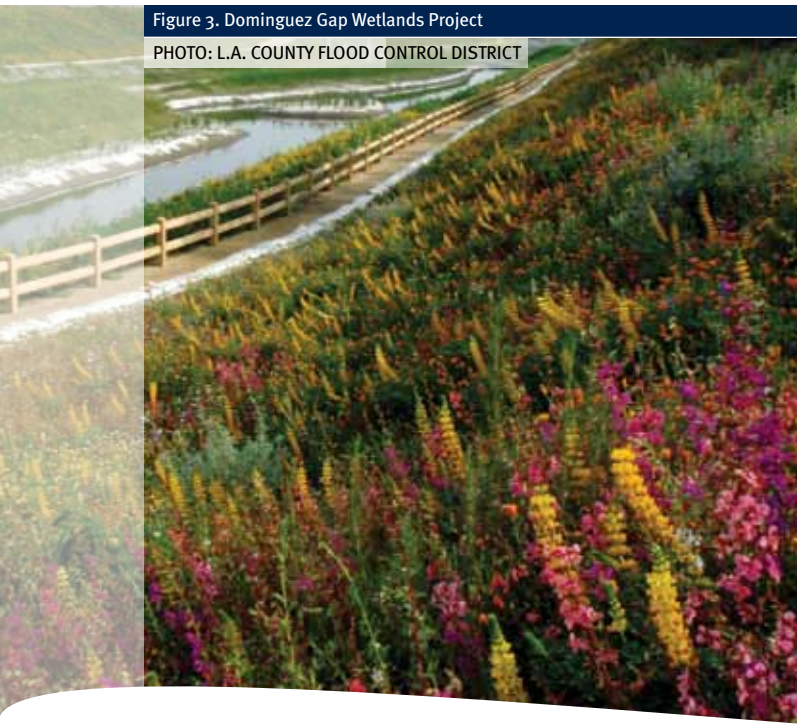


Figure 3. Dominguez Gap Wetlands Project
PHOTO: L.A. COUNTY FLOOD CONTROL DISTRICT

Typical BMPs considered by the WMMS include local scale (often referred to as LID-type BMPs) and sub-watershed scale BMPs. Local scale BMPs present a great option for individual cities to control pollution at their source. Examples include local bioretention or permeable pavements, which are typically installed in a small scale, distributed throughout a watershed. Sub-watershed scale BMPs treat or infiltrate residual runoff from the entire sub-watershed. The general scale of a sub-watershed is approximately one square mile. Sub-watershed scale BMPs include infiltration basins or treatment wetlands. Although often limited by available space in urban areas, they can create opportunities for new habitat areas and public open spaces. Examples of such projects include the Sun Valley Park and Dominguez Gap Wetland projects. The Sun Valley Park project addresses runoff from approximately 40 acres of urban area by providing flood protection, water conservation, and water quality improvement. The Dominguez Gap Wetland project (Figure 3) treats 1.3 million gallons per day diverted from the Los Angeles River and directly from local urban runoff.

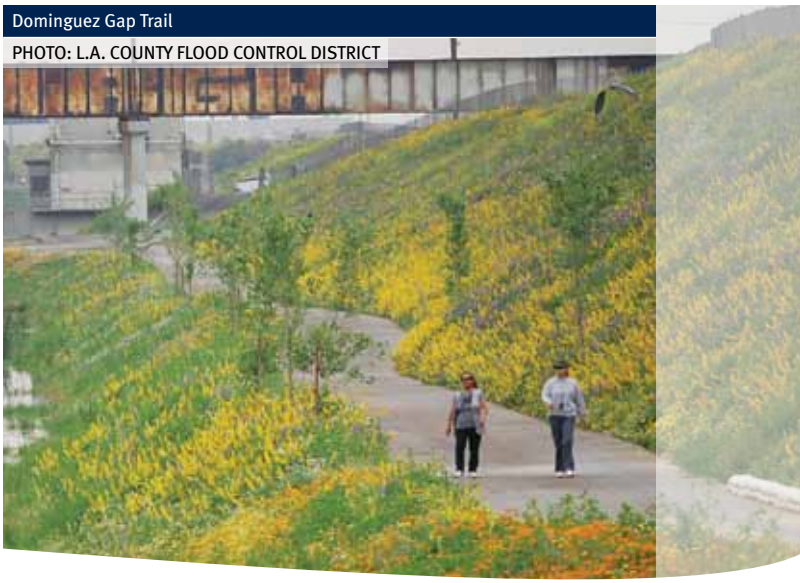
Although similar attempts have been made in other parts of the country, the scale and level of details of the WMMS is unprecedented. This is the first for a model of this type to provide unparalleled modeling that accounts for parcel scale details of hydrologic, pollutant transport, and BMP processes while encompassing 3,000 square miles of coastal watersheds

Using the integrated, watershed-based approach, the WMMS will help decision-makers use the results of the model to develop projects that achieve overall watersheds' goals (i.e., TMDL) while recognizing the needs of individual municipalities and other public and private entities within the watershed (i.e., open space development).

The model results will be presented in terms of type and quantity of BMPs allocated to specific land use parcels. This allows for decision-makers to conveniently select locally available parcels/areas and implement them. This will particularly help municipalities and other TMDL-responsible parties in preparing the multi-pollutant TMDL implementation plans that are required by regulatory agencies. During the TMDL implementation phase, the WMMS can be used to facilitate an iterative adaptive approach to ultimate water quality improvement goals through continuous refinement and improvement of the selected BMP solutions.

Furthermore, the WMMS provides an excellent framework that would help assess feasibility of projects with multi-benefits including water quality, water conservation, flood protection, and open-space development.

The WMMS and its results will be made available to the public. Using the WMMS, different entities within the watershed can work cooperatively to develop cost-effective and mutually beneficial solutions that address multiple issues, such as water quality, water conservation, flood protection, and open space development. This would eventually lead to an integrated, watershed-based stormwater management plan. Further, this would help to achieve the sustainable development of watersheds and stormwater infrastructure.



Dominguez Gap Trail
PHOTO: L.A. COUNTY FLOOD CONTROL DISTRICT

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Figure 1. Commercial Parking Lot BMP Train (Bio-swale, Overflow to MS4)

PHOTO: CITY OF DOWNEY

Discussion: Low Impact Development

Runoff Water Conservation Associated with Urban Redevelopment

DESI ALVAREZ

MUNICIPALITIES IN SOUTHERN CALIFORNIA are confronted by many challenges and a dearth of resources with which to address them all. Urban runoff impairment, during dry and wet weather, constitutes one of the more significant future challenges to the efficient provision of public services, including public safety, transportation, education, and recreation, especially within current fiscal constraints. While we would welcome the elimination of impairment-causing pollutants from our receiving waters, the pollutants' divergent sources, physical characteristics, strict standards, monitoring costs, and difficulty of removal make controlling runoff pollutants a classic "tragedy of the commons" issue, in which the societal benefits and costs are incremental and impossible to fairly distribute.

Local agencies are being asked to resolve receiving water impairments resulting from conflicting objectives that are outside our historic purview. A significant share of the copper in our rivers appears to have resulted from a federal initiative to reduce braking distances (and save lives) by increasing the copper content in vehicle brake pads. A similar assertion could be made with respect to legacy and currently approved pesticides. Some organizations demand the revitalization of rivers, while ignoring past flooding that claimed lives and property and the future costs of condemning thousands of privately owned riverside parcels. Cities are also confronted with the desire of residential and commercial property owners to improve their land, which usually means more people, impervious structures, and demands for government services. Momentarily ignoring these tensions, cities can be induced into embracing water quality protection through incentives and shared agency commitments. Taking advantage of beneficial geographic attributes, the City of Downey has implemented a runoff reduction and water quality protection program tied to owner-initiated parcel-level redevelopment projects. Over the last five years, this program has resulted in Low Impact Development (LID) Best Management Practices (BMPs) or Stormwater Control Measures (SCMs) on more than 1,000, of the 22,000, parcels within our municipal boundary.

Similar to most communities within the southern portion of Los Angeles County, the City of Downey is built out and mostly residential, with other portions zoned for industrial, commercial, and public use. The 2010 census should identify about 115,000 residents within our 12.6 square mile boundary, or nearly 10,000 per square mile and 16 per acre. The eastern half of the City drains to the San Gabriel River, while most of the remainder drains west to the Rio Hondo and Los Angeles Rivers, and just over 200 acres drain south to the Los Cerritos Channel. For drivers, the majority of the City is within the 5, 605, 105, and 710 freeways. By area, the majority of publically owned land is streets, schools, parks, fire stations, and other public facilities. The drainage system was primarily built by the Los Angeles County Flood Control District, more than a half century ago and, partially due to subsequent home improvements, is often deficient to convey the 25-year storm. Fortunately, levee improvements brought most of the City out of the regional floodplain by 2002, saving residents millions of dollars per year in flood insurance costs.

Stormwater initiatives are primarily supported by the City of Downey General Fund, meaning that new initiatives and projects divert funds from other services such as public safety, public works, and community services programs. With these fiscal constraints, and an exponentially growing list of federal and state mandates, the Engineering Division of the City of Downey Department of Public Works decided to focus our municipal National Pollutant Discharge Elimination System (NPDES) permit compliance effort on encouraging infiltration, or runoff retention, in redevelopment projects (figure 1). This benefits the community and environment in several ways: 1) runoff, and the constituents it contains, is not lost to the ocean and can resupply upper groundwater levels, where it is available for non-potable uses; 2) the drainage system conveyance load is reduced, reducing the likelihood of regional flooding; and 3) the burden is placed on those property owners changing the status quo, while still being proportional to the project.

In our community, this focus on redevelopment was initiated as a requirement for the installation of a runoff retention device whenever a project constructed, or replaced, 400 square feet or more of impervious surfaces on a parcel. The runoff retention device is sized based on the project. This generally is equal to a moderately sized room addition, which requires a Building and Safety Department permit but ignores patio pads and walkways that do not. The next design parameter was the depth of rainfall to retain, which is correlated with BMP cost. Annual rainfall in the City of Downey is about 13 inches, while the 25-year storm

is more than 5 inches in 24 hours, or 10 inches over 4 days, which are clearly extreme criteria with costs that are disproportionate to the benefits. The Regional Water Board Municipal Separate Storm Sewer System (MS4) permit and Standard Urban Stormwater Mitigation Plan requirement of 0.75 inches or 0.0625 feet (85th percentile) must be applied to large residential and commercial projects, but there was no inherently indefensible reason why this requirement could not be applied to smaller projects.

This parameter was easy to explain and calculate[1], and eliminated the need and expense for an engineer's determination for most projects. In application, this parameter is generally determined as a "dead" or "blind," rather than dynamic, water quality volume, meaning that we ignore infiltration rates. This is important for several reasons: first, the City can exert little control on soil compaction under small BMPs; second, BMP percolation rates are likely to slowly drop over time (although they can be "recovered" when the parcel is redeveloped); third, for the design storm infiltration BMPs generally focus infiltration by a ratio around 30 to 1, meaning that for every 30 square feet of impervious surface area, there is typically about 1 square foot of infiltration area; and finally, this parameter eliminated debates about infiltration rates and the need for engineered percolation studies that rarely resulted in design savings commensurate with costs. For reference, the Los Angeles County Department of Public Works Hydrology Design Manual Soil Maps suggest an infiltration rate of 0.35 inches per hour is appropriate for Downey. Since the most commonly used BMPs hold about 30 inches of water, percolation time is about 85 hours, slightly higher than the optimal 72-hour mosquito maturation time, but these BMPs are generally underground and cool, which significantly retards development.

Implementation of this program was devised based on the normal City of Downey plan check process. Project proponents, be they residents, developers, or code violators, begin at the Planning Counter, where zoning, setback, and landscaping requirements for the project are defined. The project is then reviewed by the Building and Safety Department, which clarifies on-site issues and determines the level of plan checking for the project. The proponents are then referred to the Department of Public Works, which reviews easement issues, traffic visibility, and encroachment. In cases of fences or walls, which have little impact on infiltration, the project is generally approved and returned to the Building Department, but for other projects, the proponents are introduced to the City of Downey runoff retention policy and given some BMP examples for how the project might proceed. Typically, this interaction highlights rain gardens, porous pavers, pervious pavement, and underground retention/infiltration systems (Figure 2). While a significant portion of naïve proponents are initially unreceptive to this requirement, they usually acknowledge the impact of state and federal regulations on local government and our reluctance to devote tax dollars toward the purchase and construction of regional treatment facilities that are needed a few weeks per year but must be continuously maintained by the City. Counter staff are trained to explain that large private and, most importantly, public projects must implement comparable measures, point

Figure 2. Residential Infiltration System at the Installation Midpoint

PHOTO: CITY OF DOWNEY

to some nearby examples, and then interactively discuss alternative proposals and concepts to gain proponent buy-in. The most recalcitrant proponents are encouraged to propose other (compliant) alternatives or abandon their projects, but most eventually select plastic half-barrel-shaped devices[2] surrounded by rock, and placed 4 feet underground, in the front yard. Rock pits are occasionally proposed and accepted with calculations, but since the void area is only about 35%, these pits are typically at least twice as large and use several times more rock.

Although no formal surveys have been conducted, proponents seem to favor these BMPs for the following reasons: 1) Sizing has been provided by the City, 2) City inspectors and local contractors are familiar with installation and inspection, 3) the BMP is essentially invisible to the property owner and can be placed away from any foundations, and 4) the City does not require a Covenant and Agreement since, once the BMP is installed, there is little incentive to fill or remove the BMP before the next redevelopment cycle. Once the BMP has been sized and shown on the building plans in sufficient detail to allow construction, they are approved by the Engineering Division and returned to the normal building process. (Larger Standard Urban Stormwater Mitigation Plan [SUSMP] or General Construction projects receive a greater level of attention and oversight, but similar criteria apply.)

For smaller, particularly residential, remodeling projects, "mitigation" is allowed whereby the proponent is allowed to build at the rear of the property, while installing the BMP in the mandatory setback area of the front yard. The runoff is collected from roof gutter downspouts or trench drains set in the driveway or near the front of the "side yard" areas. From the drainage inlet, filter fabric-lined rock trenches with an effective cross section of 1 square foot or effectively similar conveyances bring the runoff to the BMP. These BMPs are usually constructed as "blind sacs" that, once filled with the first flush of runoff, allow any additional water to surface flow, usually through turf grass, to the convey system. The incremental installation costs of these small parcel-level BMP projects is typically about $1 per square foot of impervious surface, while rain gardens are likely to cost significantly less. However, in our community, there seems to be either a reluctance to construct sunken "ponding" areas within the front landscape or, more likely, the government is perceived as intruding in the form of a

Figure 3. Municipal Golf Course Parking Lot Passing Bio-swale With Infiltration Inlet

PHOTO: CITY OF DOWNEY

Covenant and Agreement that is the restricting factor. Unfortunately, without such an agreement, there would be no constraint to filling in the rain garden, and enforcement would be nearly impossible.

For larger projects, or impervious areas that are likely to generate pollutants such as parking lots, project proponents are directed to first convey the runoff through at least 20 feet of bio-swale or across a narrower bio-strip (Figure 3). The waxy cuticle of the vegetation absorbs oils and grease and holds these pollutants so that later microbial processes can encourage the pollutants' decomposition. Solids and trash are likewise trapped among the grass blades where the pollutants can be collected during the next mowing or become enmeshed in the root mass. Very light storms, first flush from larger storms, and irrigation overspray can be trapped in a well-designed system and allowed to infiltrate into the landscape and be taken up by the vegetation. We have had the greatest success with Fescues and similar turf grasses, although some thick ground covers (e.g., Dutch Apple or Gazanias) also appear to work well. More drought-tolerant and slow-growing vegetation may eventually work as well but has generally required a degree of patience that exceeds regulatory constraints and is usually applied with mulch, which is easily mobilized by moderate storms and can produce problems of its own. After pre-treatment through the bio-swale or strip, significant runoff is allowed to pond slightly (< 6 inches) and then flow into a raised inlet and the infiltration portion of the BMP treatment system. The raised inlet is intended as a spill capture precaution, in case the parking lot is illegally used for oil changes or other car maintenance activities. Once the "blind sac" infiltration system captures the most contaminated runoff, additional runoff is allowed to enter the drainage conveyance system.

While the examples presented here relate to mostly residential and commercial parcel projects, including the City of Downey–owned Rio Hondo Event Center and Golf Course, the City of Downey has also undertaken several unique regional and sub-regional projects on public properties. A public street, Congressman Steve Horn Way, was constructed with an inverted median, meaning that flows are allowed to cross the traffic lanes and are then conveyed along a gutter and through periodic curb breaks and into a vegetated center median, which is lower than the paved street sections. Initial runoff and irrigation flows settle into the landscaping and evapotranspirate or infiltrate, while higher flows overspill into a drainage system. Along most of this street, which accepts runoff from a mostly impervious area of 60 acres, this drainage overflow is conveyed through twin continuous deflective separator (CDS) hydrodynamic separators to remove trash and debris and then into an infiltrating/detention basin constructed under Discovery Park (Figure 4). The 25-year storm runoff from this catchment is 120 cubic feet per second (CFS), and before this project, the downstream conveyance system was deficient and unable to convey more than a 3-year storm. In addition to allowing percolation at the two CFS, the multi-million-dollar BMP can store the difference between the 120 CFS design storm and the 20 CFS downstream conveyance capacity.

Since more than 1,000 parcels have been constructed to include runoff-retaining BMPs in the City of Downey, local agencies can clearly be motivated to support water quality protection. However, the regulatory process needs to encourage this effort and regulations such as Total Maximum Daily Loads (TMDLs) written to accommodate the slow path upon which redevelopment occurs. Alternatively, the current regulatory- and litigation-based stalemate will likely continue as few communities are able to afford the privately held land needed for regional BMPs or, worse yet, construct expensive treatment facilities that must operate only a few days per year.

Figure 4. Regional Infiltrating Detention System Construction Under City (Discovery) Park

PHOTO: CITY OF DOWNEY

(Endnotes)

[1] The calculation is impervious area in square feet, times 0.0625 feet = the retention volume in cubic feet.

[2] Examples include Cultec®, Stormtech®, and Trident®, but many other similar devices exist and are welcomed.

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Santa Monica Urban Runoff Recycling Facility

PHOTO: PETE FRIEDRICH, CITY OF SANTA MONICA

Discussion: Low Impact Development

Sustainable Watershed Paradigm Shift in Santa Monica

DEAN KUBANI, NEAL SHAPIRO, AND RICK T. VALTE

AGAINST THE BACKDROP OF THE PACIFIC OCEAN accentuated by the Santa Monica Pier stands the Santa Monica Urban Runoff Recycling Facility, also known as the SMURRF. The facility was built at the onset of the new millennium to harvest, treat, and reuse dry weather runoff and serves as a symbol of the City of Santa Monica's commitment to improving stormwater quality and reducing urban runoff.

Implementing low impact development (LID) in urbanized areas requires retrofitting of existing infrastructure, as well as taking advantage of redevelopment opportunities. LID should be approached from parcel to regional scales, as each contributes to current water quality impairments. Regional cooperative agreements are necessary to address roadways, "upstream" municipalities' inputs to "downstream" areas, and polishing of pollutants missed by smaller-scale projects. City-scale LID projects are necessary to address public buildings, parks, the transportation grid, and other public facilities, while parcel-scale LID ensures private landowners share the burden of meeting water quality objectives.

Legislation in the City of Santa Monica

This commitment dates back to 1992, when the City Council first approved the Urban Runoff Pollution Mitigation ordinance (the Urban Runoff ordinance), which required a 20% reduction in on-site urban runoff from new and retrofit development. The objective of this ordinance was to improve water quality at Santa Monica beaches. An epidemiology study along the coast completed at the time identified public health risks related to bacteria in flowing storm drains that empty into Santa Monica Bay.

The ordinance established a list of appropriate best management practices (BMPs) with an emphasis on LID so that runoff from the property would be infiltrated on-site and kept out of the public storm sewer system, reducing runoff to the Bay.

After five years of implementation, the County of Los Angeles, as the Principal Permittee for the region's National Pollutant Discharge Elimination System (NPDES) permit, established the Standard Urban Stormwater Management Plan (SUSMP), to encourage further urban runoff management. The most significant change was a requirement to reduce site runoff by up to 80%, which for the Los Angeles area translated into capture of runoff from a 0.75 inch storm event. In response, the City updated its Urban Runoff ordinance in 2000 to include the 0.75 inch standard and further promote strategies to reduce impermeable surfaces and promote more permeable surfaces.

The City is now revising the Urban Runoff ordinance to include an emphasis on rainwater harvesting for direct non-potable uses, as well as infiltration, and to de-emphasize treat and release BMPs. For treat and release BMPs, the City is exploring numeric standards for pollutants of concern (bacteria, trash, and chlorinated organic chemicals) that cause impairment to the Santa Monica Bay and Ballona Creek.

Figure 1. Virginia Avenue Park Retrofit Project

PHOTOS: NEAL SHAPIRO, CITY OF SANTA MONICA-OFFICE OF SUSTAINABILITY & THE ENVIRONMENT

Practicing What the City Preaches

Setting the example or living the law is how the City of Santa Monica wins over residents and businesses to a more sustainable watershed management path. In addition, raising the bar higher leads to further innovations and more sustainable practices. Establishing the Urban Runoff ordinance laid the foundation and put the City on a sustainable path for watershed management—reducing urban runoff pollution to Santa Monica Bay and harvesting runoff for non-potable use and reuse, which reduces dependence on limited groundwater or expensive imported water.

The next step after legislation was the creation of a watershed planning map, which established objectives for watershed management and a list of best management practices (BMPs) that are appropriate in the City's 13 sub-watersheds and that over time can be built through the City's Capital Improvement Projects (CIP) program. This map, the Santa Monica Watershed Management Plan, was approved by the City Council in 2006. The plan identifies specific projects for each sub-watershed to reduce urban runoff pollution and to harvest runoff for infiltration or direct non-potable uses. The plan anticipates completion of all the projects by 2025. After this plan was approved, the next step was to establish the City's stormwater priorities and implement relevant projects accordingly.

The City's 5-Year Low Impact Development (LID) action plan was approved by the City Council in early 2010. This plan establishes the most appropriate BMPs for the City, allocates funds for these categories and an annual budget for CIPs, and identifies approximate numbers of BMPs per year over five years.

The LID plan takes effect in fiscal year 2010-11 and has 12 major categories ranging from permeable driving surfaces to green streets—using infiltration—to rainwater harvesting for direct non-potable use, the pinnacle of sustainable strategies in which a local water resource is harvested and used in lieu of imported potable water resources.

Each year, the City resurfaces or reconstructs streets, alleys, and parking lots, presenting perfect opportunities to install LID BMPs such as permeable surfaces. Large street projects are ideal for conversion into green streets. Larger municipal projects, such as park retrofits or new residential and government facilities, have and will continue to have extensive BMPs, which also provide points for Leadership in Energy and Environmental Design (LEED) green building certification of the facilities. To date, the City has built numerous projects with LID features, demonstrating its commitment to sustainable solutions to urban runoff pollution.

City Projects

Six recent projects demonstrate the dedication to LID practices for watershed management solutions. Parks are perfect land uses for not only collecting and infiltrating on-site runoff but also harvesting off-site runoff; park open spaces provide areas for large BMPs. Streets and parking lots offer ideal locations for runoff harvesting; paralleling streets or in parking lots are parkways or planters, which are potentially good locations for storing runoff. Sub-surface storage under parking lanes or parking stalls also offer plenty of open space. Large facilities can also provide space for BMPs.

Virginia Avenue Park (VAP) and Airport Park

In addition to upgrading and expanding park facilities, the VAP retrofit project used a number of BMPs in the parking lot—permeable pavers for parking stalls, trench drains to pick up runoff from asphalt parking areas, and perimeter sub-surface infiltration zones to capture parking lot runoff and excessive runoff from the park's landscapes (Figure 1). An overflow parking lot used a product called

Figure 2. Airport Park Infiltration Project

PHOTOS: NEAL SHAPIRO

Figure 3. Green Beach Parking & Recreational Space

PHOTOS: NEAL SHAPIRO

Netlawn®, which is a permeable turf surface that vehicles can drive on. Airport Park was a new park project at the City's airport completed in 2007. Similar to VAP, perimeter sub-surface infiltration zones surround the park and capture runoff for percolation. In addition to on-site runoff, runoff from adjacent plane parking lots is directed to the infiltration zones (Figure 2). The two parking lots are finished with porous asphalt.

Beach Green Parking Lot

With financial assistance from the State Water Resources Control Board, the City built a beach parking lot greening project (completed in May 2008) to demonstrate a strategy of replacing impervious asphalt with the permeable Netlawn® product. Using this product demonstrates how a beach parking lot can harvest and infiltrate runoff, keeping it out of the Bay while still serving as a parking lot as well as new recreational open space (Figure 3). In addition, replacing impervious asphalt with a permeable surface reduces the heat island effect. If found to be effective and economical, beach parking lots along the coastal zone of the country can be converted to beach green parking lots, serving multiple benefits in watershed management.

Bicknell Avenue Green Street

The City completed its first street greening project in mid-2009. With a grant from the State Water Resources Control Board and the Santa Monica Bay Restoration Commission, one block of a typical urban residential-commercial street was retrofitted with four BMPs to demonstrate that an LID strategy has merits when rebuilding existing or planning new streets. Pervious concrete replaced impermeable asphalt for the parking lanes, and sub-surface plastic concave chambers under the parking lanes receive the harvested runoff for infiltration. The parkways were doubled in size and depressed to receive gutter runoff for infiltration. In addition, gutter catch basins with filters screen the runoff to remove trash and debris before runoff is infiltrated. Instead of transportation-generated and roof runoff flowing unabated to the Bay, the runoff is now captured by the street and parkway elements and infiltrated into the ground (Figure 4).

Figure 4. Bicknell Avenue Green Street

PHOTOS: NEAL SHAPIRO

Figure 5. Interior of SMURRF
PHOTO: KEN MCCOWN

Big Blue Bus Facility

The City's bus maintenance and storage facility has been completely renovated in two phases over many years. For each of the phases, underground filtering, storage, and infiltration systems were installed to capture all runoff from roofs and parking areas, keeping significant pollution out of the Bay and demonstrating how large government facilities can address runoff pollution.

Main Library

The most sustainable LID and BMP strategy is to harvest rainwater for direct non-potable uses. For the City's new Main Library, which was completed in January 2006, a 200,000-gallon cistern was constructed beneath the building and parking levels. Runoff from the roof and parking lot is filtered before being stored in the cistern. A pumping system distributes the stored water to the site's low-volume irrigation system and its associated climate-appropriate flora.

Regional Projects

Santa Monica has also joined with its neighboring cities to build BMPs to address runoff from multiple jurisdictions.

SMURRF

The Santa Monica Urban Runoff Recycling Facility was completed in early 2001. As beneficiaries of the project, the Cities of Santa Monica and Los Angeles shared 50% of the construction costs, and the Cities share the ongoing operation and maintenance (O&M) costs and revenues. The SMURRF captures and treats dry weather urban runoff from the Pico-Kenter and Promenade/Pier drainage areas for reuse. Disinfected recycled water is pumped to a number of locations around Santa Monica for use in landscape irrigation and for toilet flushing (Figure 5). About 320,000 gallons per day are treated. The SMURRF is the first urban runoff treatment facility of its kind in the world.

Mar Vista Park

The project, completed in mid-2006, is located beneath Mar Vista Park in the City of Los Angeles, originally planned to be in the City of Santa Monica. The project consists of a two-stage treatment system that treats Santa Monica and Los Angeles dry and wet weather runoff. Treated water flows directly into the Ballona Creek on its way to the Bay. The treatment system has full capture screens for trash and includes a BMP to remove soluble pollutants through cartridges filled with different filtering media, to comply with Total Maximum Daily Load (TMDL) requirements.

The City of Santa Monica will also be participating in a new project at the City of Los Angeles Penmar Recreation Center, which is on the City's southern border and includes baseball fields and a golf course. Two City sub-watersheds flow under and through this recreation center on the way to the Bay. Los Angeles is building a

Figure 6. Residential Rain Barrel

PHOTO: SARAH WOODARD

phase one screening and separation and sanitary sewer diversion system, followed by phase two, a treatment and non-potable use system so that the retained runoff can be used for irrigation at an adjacent Santa Monica park.

Private Developments

In the 18 years of urban runoff mitigation through the City of Santa Monica's ordinance, more than 1,000 private BMP systems have been installed throughout the City and will continue to be installed in the years ahead. The City has more than 22,000 parcels that will be retrofitted over time until all parcels have BMPs mitigating runoff pollution. More than 80% of these BMPs are of the LID type.

With a new program to promote rain barrels (Figure 6) and cisterns, the City is encouraging property owners to harvest rainwater for direct non-potable uses, such as irrigation, toilet flushing, and clothes washing. Harvesting rainwater on-site for direct non-potable uses reduces potable water use and saves on water and wastewater discharge costs. This strategy is the ultimate sustainable, self-reliant solution. If all private parcels could capture most of the rainfall each year for uses on-site and if all buildings had the most efficient water features and climate-appropriate landscapes and low-volume irrigation systems, then the demand for limited potable water would be significantly reduced, along with a significant source of runoff pollution. LID strategies are simple and cost-effective multi-benefit solutions to two of the most serious problems facing California, water shortages and pollution.

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Restoration Project Planting

PHOTO: ABIGAIL SMIGEL

Establishing High Marsh Habitats within the San Dieguito Lagoon Wetland Restoration Project

PETER TOMSOVIC

The goal of the 150-acre San Dieguito Lagoon Wetland Restoration Project is to restore the structure and function of coastal wetlands near the mouth of the San Dieguito River. This restoration effort is being carried out by Southern California Edison (SCE) and was required by the California Coastal Commission (CCC) to partially mitigate for the estimated impacts on marine fish populations resulting from the operation of cooling water systems for the San Onofre Nuclear Generating Station (SONGS, SCE 2005).

One of the project's main features is the creation of 34 acres of high coastal salt marsh habitat. Based on the experience gained from other coastal salt marsh restoration projects throughout Southern California, the high marsh habitat has been one of the most challenging habitat types to establish (Callaway and Zedler 2004; Zedler 1984, 1996; Kentula 2002). In these areas, tidal inundations typically occur only a few times per year, solar radiation is very high, and salinity levels within the soil are elevated. Before this project was implemented, several greenhouse nursery and field experiments were conducted, and a planting plan was developed to ensure the success of this project.

The San Dieguito Lagoon is located in the city of Del Mar, California, north of the city of San Diego (Figure 1), and was selected as the project site because the lagoon presented the best opportunity to meet the objectives required by the CCC.

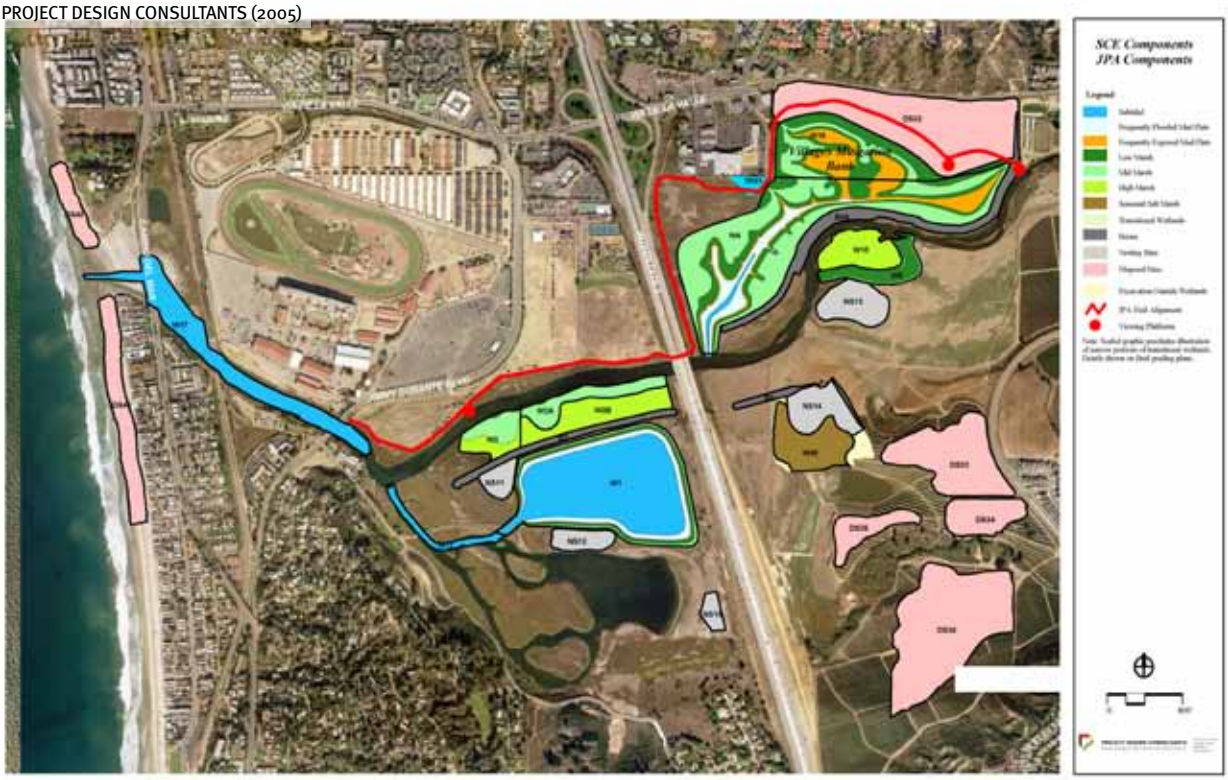
Project Background

The San Dieguito Lagoon was once the largest of six San Diego County coastal lagoons with the largest watershed. The marsh area alone has been estimated to have once covered more than 600 acres, while the entire lagoon encompassed more than 1,000 acres (SDRP 2010). Over the years, the lagoon has been subjected to major filling activities due to development and has lost more than half of its marshland. The filling activities have included the construction of Highway 101 (Interstate 5), Jimmy Durante Boulevard, residential development, the Del Mar Fairgrounds, and a World War II era airport. Two large dams have been constructed upstream of the lagoon on the San Dieguito River. All these activities have resulted in reduced freshwater flows through the river mouth and an eventual closure of the lagoon at the beach. The initial inlet closure to the ocean was documented in the 1940s. Since then, only large winter floods or dredging by earth moving equipment to flush the lagoon have opened the mouth periodically.

The $86 million San Dieguito Lagoon Wetland Restoration Project includes the following eight elements designed to expand and restore the marsh: 1) tidal inlet maintenance to promote regular tidal exchange through excavation of the river channel and periodic maintenance dredging, 2) excavation of tidal and upland areas to create a subtidal

Figure 1. Project Overview

IMAGE: PROJECT DESIGN CONSULTANTS (2005)



and intertidal habitat, 3) creation of a seasonal salt marsh, 4) creation of up to 19 acres of nesting habitat for the California least tern (*Sternula antillarum browni*) and western snowy plover (*Charadrius alexandrinus nivosus*), 5) construction of berms within the San Dieguito River's effective flow area to maintain the existing sediment flows within the river and to the beach, 6) creation of dredge disposal sites within the project boundary, 7) restoration of upland native habitat on dredge disposal sites, and 8) creation of public access trails and opportunities for public education (SCE 2005).

Pre-restoration Soil Analysis

Restoration of high intertidal habitat zones is difficult due to the infrequency of inundation and high soil salinities (Figure 2). This is especially true in the arid southwestern coastal region and with instances in which marsh restoration involves excavation and the underlying saline subsoils are left as the primary substrate remaining for planting (Josselyn, Acker, and Tomsovic 2006). In a study conducted by an environmental consulting firm, WRA, soils from six nearby coastal salt marsh reference sites and the subsoils at the San Dieguito Lagoon restoration site were analyzed for pH, salinity, organic matter, soil texture, and bulk density. The subsoils that were to be exposed following grading activities within the San Dieguito Lagoon were found to have a higher pH, higher bulk density, lower organic matter, and lower clay content (WRA 2006).

Based on the results of the soil sampling conducted by WRA, salt marsh plant growth experiments were conducted in a nursery to examine what soil amendments might improve the surface soil conditions at the restoration site to promote the survival of planted container stock. The selection of soil amendments was guided by existing salt marsh restoration literature and traditional soil-amendment practices used in wetland restoration projects within the region. The soil treatments included the following: 1) Biosol Mix®, a commercially available and general-purpose soil fertilizer, 2) clay, to increase clay content in soil, 3) diatomaceous earth, to increase water retention in soil, 4) wetland topsoil, harvested from existing areas of salt marsh vegetation to provide essential plant nutrients and mycorrhizae, 5) kelp, to increase organic matter, and

Figure 2. High Salinity Soil

PHOTO: RECON ENVIRONMENTAL

6) compaction of non-amended soil to approximately 80%. A control group was also created using non amended subsurface soils from the San Dieguito Lagoon.

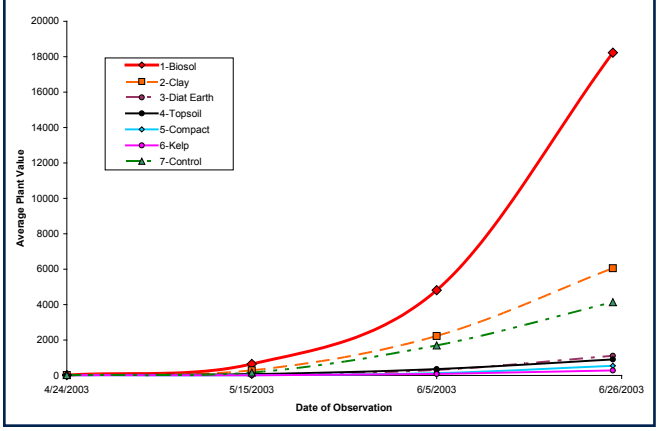
To create the experimental soil mixtures for planting, each soil amendment was added to subsoils harvested from the San Dieguito Lagoon in an approximate rate of 20% amendment to 80% subsoil blend. Soils were mixed thoroughly using shovels and then potted into 4-inch container pots. For the compaction group, pure subsoil was filled into 4-inch pots and then compacted with a 4- by 4-inch post.

Nursery Study

For this study, the survival and vigor of pickleweed (*Sarcocornia virginica*) plantings were measured to evaluate soil suitability for salt marsh restoration. Pickleweed was chosen because it tends to be the dominant plant species within Southern California salt marsh habitats and is the primary species to be planted at the San Dieguito Lagoon. In preparation for the nursery experiment, a single pickleweed cutting, between two and three inches in length, was planted in the center of each 2-inch container pot containing one of the seven soil amendments. One hundred plants were potted up for each treatment group for a total of 700 container plants.

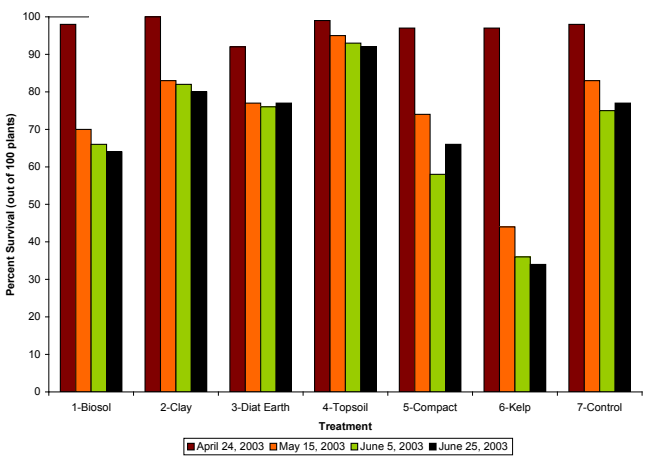
Data were collected once every three weeks over the course of two months. Data collection included survival (determined by visual observation whether the plant was still green) and vigor, which consisted of measuring the height, average canopy spread (in centimeters), and number of lateral branches of each container plant. A numerical representation quantifying the vigor of each individual was generated by multiplying the plant height by its average canopy spread and by the number of lateral branches (vigor = plant height (cm) x average canopy spread (cm) x number of lateral branches). This formula and a comparison of the averages of the treatment groups showed that the Biosol Mix® group outperformed in vigor the second-highest group by more than threefold (Figure 3).

Figure 3. Pickleweed Growth Experiments - Treatment Versus Time



However, the highest rate of survival of pickleweed was encountered in the topsoil-amended soil: 92% of the individuals were alive at the end of the study (Figure 4). Following the topsoil group was the clay group with 80% survival, the diatomaceous earth and control groups with 77% survival, the compaction group with 66% survival, the Biosol Mix® with 65% survival, and the kelp-amendment group with 35% survival.

Figure 4. Pickleweed Growth Experiment- Plant Treatment Percent Survival



It is likely that the Biosol Mix® group had the greatest performance for individuals that survived because Biosol is a long-lasting balanced fertilizer that may increase humus growth, reduce pH and salt concentrations in soil, and increase root production in plants (Insam n.d.; Glatzel and Fuchs 1986). However, why the Biosol group exhibited poor plant survival when compared to the topsoil, clay, and diatomaceous earth treatment groups is unclear and may be a topic for a future study.

The results of the amendment study suggest that topsoil amendments may provide beneficial effects on wetland restoration plantings by increasing the short-term growth rate and overall survival of planted materials. Using topsoil was also an economically and logistically favorable amendment since topsoil was readily available on-site and was of low cost to salvage and distribute over the restoration areas.

Small-scale Field Experiment

Using topsoil as the preferred soil amendment, a field experiment was then conducted to demonstrate that transplanting container stock—healthy plants with established root systems—would help to establish the newly created restoration areas, resulting in rapid growth and colonization of the area by coastal salt marsh plants. The experiment was also designed to test the survival and growth of 2-inch containerized pickleweed individuals in two different planting layouts proposed for this project, 1) evenly spaced versus 2) a clustered pattern (Figure 5), to find out which planting layout would yield greater overall aerial plant canopy coverage over time.

Figure 5. Pickleweed Test Plots: Evenly Spaced Versus Clustered

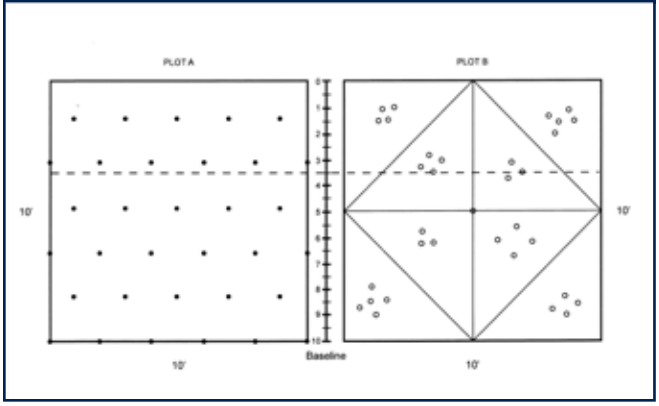
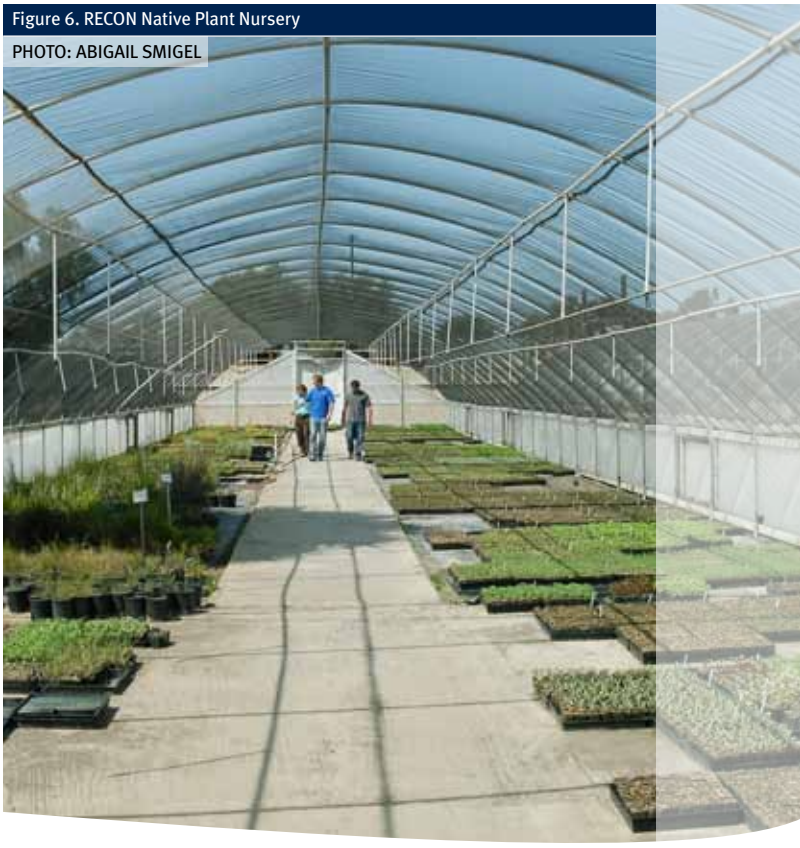


Figure 6. RECON Native Plant Nursery

PHOTO: ABIGAIL SMIGEL



In preparation for planting of the pickleweed test plots, an area was excavated to the approximate final grade elevation for pickleweed growth, between +3.5 and +4.5 feet National Geodetic Vertical Datum (NGVD) within one of the final planting areas of the San Dieguito Lagoon Restoration Project. The graded area was adjacent to the San Dieguito River and was sloped down toward the river at an angle of approximately 1% such that water would drain into the river following tidal inundation. During grading, the test plots were over-excavated and then backfilled to the final grade elevation with 12 inches of wetland topsoil containing plant fragments and seeds of native wetland species. Container plants for the pickleweed test plots had been propagated at RECON Native Plant Nursery (Figure 6) from seed collected in the San Dieguito Lagoon the previous winter. The seeds were initially sewn into flats containing a portion of topsoil that was collected at the lagoon and then transplanted into 2-inch containers following germination. Each month, survival and percent cover within each test plot were evaluated qualitatively and assessed quantitatively at four and six months following planting. The test plots were monitored for survival, percent canopy cover, and volunteer species natural recruitment.

The evenly spaced and the clustered planting layouts exhibited healthy pickleweed growth, aerial coverage, and recruitment of a variety of wetland species, indicating that either layout would allow for development of a healthy wetland marsh. Planting layout did not appear to affect the survival of the pickleweed container plants. A variety of wetland species such as pickleweed, coast saltgrass (*Distichlis spicata*), jaumea (*Jaumea carnosa*), sea-blite (*Suaeda sp.*), and alkali heath (*Frankenia salina*) had recruited into the sample plots, indicating that the graded elevations of the test plots and the viability of the wetland topsoil were functioning as designed. Four months after planting, the pickleweed in the evenly spaced planting group showed 3% greater aerial coverage than the clustered planting group (Figure 7). Six months after planting, the evenly spaced group had 11% greater aerial coverage of pickleweed. The evenly spaced group performed better in this study because, in the clustered group, the canopies of each plant began to overlap one another, and this overlap did not increase the overall aerial coverage of the planting group. Each plant within the evenly spaced planting group had more room to grow without overlapping adjacent plants. The conclusions from this study include the following:

- An evenly spaced pickleweed planting layout appears to provide greater aerial percent cover than the clustered planting scheme.

- Survival of pickleweed container plants does not appear to be affected by planting layout.

- Natural recruitment within the test plots was low at less than 5% cover within the study period.

Figure 7. Percent Pickleweed Cover Versus Time

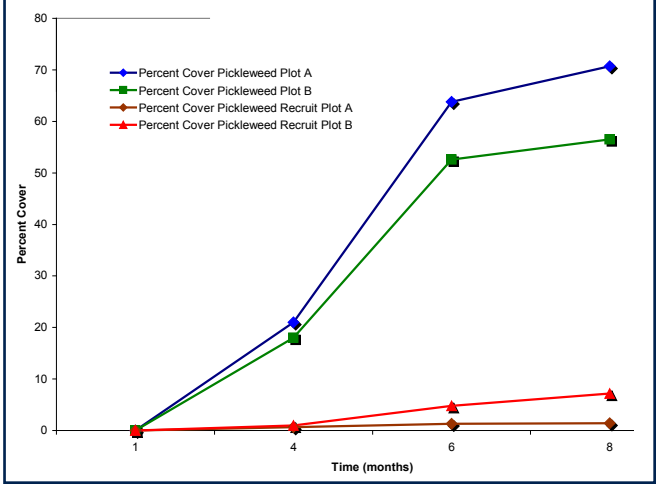


Figure 8. Month One: Shrunken Biomass

PHOTO: RECON ENVIRONMENTAL

Large-scale Field Experiment

In May 2008, to replicate coastal salt marsh vegetation establishment on a larger scale, a 3-acre test planting was conducted using the knowledge gained from the small-scale test plot. Unlike the small-scale field experiment, the site selected for the large 3-acre test plot was a broad, approximately 100 meters wide, shelf that was graded between 3.5 and 4.5 feet NGVD adjacent to the San Dieguito River. Additional comparisons conducted as part of this test plot included using container stock of various ages, introducing multiple associate native plant species, and planting across the entire mid- to high marsh zone between 3.5 and 4.5 feet NGVD. In this study, more than 22,000 container plants were planted.

In the first month following planting, a severe dieback was observed of the planted individuals. This was characterized by dry and shrunken above-ground biomass (Figure 8). At that time, mortality was estimated to exceed 80%. This occurrence was likely due to several factors, including lack of rainfall, extremely hot weather conditions immediately following planting, warm soil temperatures, lack of inundation by tidal action, immature plants upon planting, and high salt content and clay concentrations within the topsoil.

By the second month following planting, a large portion of the pickleweed plants that had once been observed to be desiccated showed signs of recovery by resprouting shoots from the base of the plant (Figure 9). At that time, mortality was estimated at approximately 70%.

During the third month, the plants that had survived continued to become established and showed signs of vigorous growth. Overall mortality of the planted individuals seemed to have stabilized at approximately 70% (30% survival). Survival of planted individuals was highest in the lowest elevations (3.5 feet NGVD) and lowest in the highest elevations (4.5 feet NGVD). This occurrence is likely due to the fact that lower elevations received tidal inundations more frequently than the upper end of the planting area. The lower elevations around 3.5 to 4.0 feet NGVD received several inundations per month, but the upper elevations of 4.0 to 4.5 feet NGVD were inundated maybe once every two months. The uppermost end of the planting area was never inundated throughout the study.

The results of this study seemed inconclusive since there were several factors at play that could have contributed to poor survival. Following this study, an action plan was developed to increase the probability of success when full-scale restoration was to take place. These action items included using only mature plants and planting would occur only from December through March, which would coincide with periods of cooler temperatures, higher tides, the rainy season, and lower soil salinity levels.

Figure 9. Month Two: Resprouting Shoots

PHOTO: RECON ENVIRONMENTAL

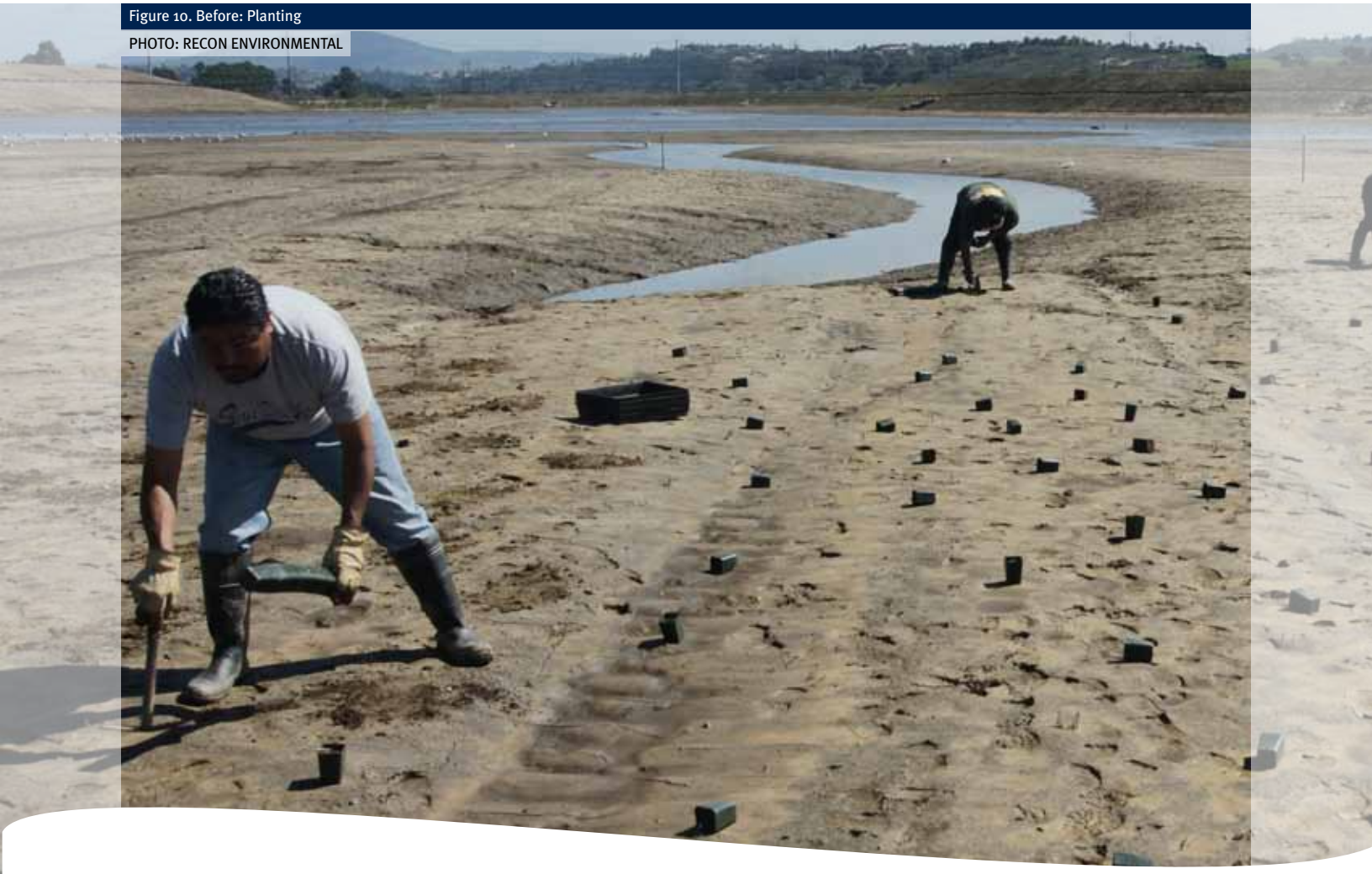


Figure 10. Before: Planting

PHOTO: RECON ENVIRONMENTAL

Full-scale Restoration

Seed collection for container plant production began in late fall of 2006 and 2007. When available, all seeds were collected from remnant coastal salt marsh populations within the San Dieguito Lagoon. When plant populations on-site were in short supply for seed collection, adjacent lagoons were used as donor sites. Such was the case with shoregrass (*Monanthochloe littoralis*) seeds. Seeds were harvested three times during the period of seed dispersal in order to obtain seeds in all stages of maturity. For each seed collection visit, seeds were collected, bagged, and labelled, noting the collector, date, and location of collection. Seeds were then brought to RECON Native Plant Nursery for cleaning and propagation.

Containerized pickleweed plants were propagated at RECON Native Plant Nursery located in Imperial Beach, California. This nursery is situated within the floodplain of the Tijuana River Valley and in close proximity to the Pacific Ocean. The climate in this region is nearly identical to the conditions found at the San Dieguito Lagoon Restoration site. All pickleweed container plants were germinated under a shade structure and later moved out into the open as the plants matured. This process helps the plants adapt to local climatic conditions once transplanted.

Seeds were sewn directly into 2-inch pots containing a mixture of nursery and native wetland soils from impacted areas of the San Dieguito Lagoon. Native soil was used because of its beneficial properties (e.g., mycorrhizae) for native plant growth. Initially, the seeds and seedlings were watered using freshwater from the nursery. As the plants reached maturity in the 2-inch pots, approximately one month before transplanting, they were watered using brackish water. This process hardened the pickleweed plants by helping them acclimate to brackish water before transplanting.

Planting

Planting began on December 20, 2008, following approximately 2.8 inches of winter rains and continued through March 2, 2009—a duration of 45 work days (Figure 10). Nearly 6 inches of rain fell on the project site over the planting period. In total, 335,918 2-inch container plants were installed within 36 acres of designated high salt marsh habitat. Planting densities ranged from 1.5 to 2.1 feet between individuals. Higher planting densities occurred in areas of higher elevation (above the 4.0-foot NGVD contour), where past field experiments had indicated that container plantings may be more difficult to establish.

Figure 11. After: One Year Later

PHOTO: RECON ENVIRONMENTAL

First-year Results

One year after planting, beneficial results can be easily observed throughout most of the planting areas. Quantitative data have not yet been collected, but qualitative monitoring has indicated that coastal salt marsh plant species, including pickleweed, saltgrass, alkali heath, jaumea, and shoregrass, are rapidly becoming established (Figure 11).

One of the planting areas has had only marginal success. The area of the large-scale field experiment has continued to have poor pickleweed growth and establishment. An adaptive management approach is being taken to monitor and correct this area appropriately. Currently, the soil composition (higher clay content), soil compaction (much tighter soils), tidal regime (less frequent inundations), topographic placement (greater distance from river), and other environmental factors are being investigated as possible causes of the poor plant survival.

Signs of success are also indicated by the increased number of wildlife observed within the area. According to anecdotal evidence from a local birding observers group, a semipalmated plover (*Charadrius semipalmatus*) has been observed feeding on the mudflats, a species not commonly observed before within this lagoon. In addition, the same observer noted two light-footed clapper rails (*Rallus longirostris levipes*) calling to each other from two newly emerged stands of marsh vegetation created by this project.

The CCC has collected baseline vegetative data for comparison and will be monitoring and reporting on the performance of this site over the next several years.

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Before

PHOTO: RECON ENVIRONMENTAL

After

PHOTO: RECON ENVIRONMENTAL

Before

PHOTO: RECON ENVIRONMENTAL

After

PHOTO: RECON ENVIRONMENTAL

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Solstice Canyon Creek

PHOTO: LIA PROTOPAPADAKIS

Development of Bankfull Regional Relationships in the Los Angeles Area for Application in Local Stream Restoration Projects

ALLEN HADEN AND JESSICA HALL

Widespread alterations to streams in the Santa Monica Bay and Los Angeles region have resulted in a loss of physical and ecological function that has recently been recognized. Attempts to restore these functions are confounded by the lack of knowledge about pre-disturbance conditions and a method for determining the present-day potential for the restoration of the altered streams. Developing a regional understanding of how the processes of sediment and hydrologic transport are expressed in the morphology of streams facilitates stream protection and water quality policies, flood management practices, and restoration. The most basic expression of regional stream morphology is a regional curve for estimating stream dimensions (cross-sectional area, width, and depth) from watershed size. The Los Angeles Regional Curve was developed as a geomorphic tool for estimating channel dimensions in stream assessments and restorations. The curve derived from measurements of local channel morphology is similar to other curves derived from the southwestern U.S. and indicates that the extremely altered environment of the Los Angeles region still supports the processes that build and maintain natural stream channels. Additional work is still necessary, as additional stream assessments in coastal, urban, and suburban watersheds are likely to create distinct sub-regional curves. Additional surveys need to be tied to sites with stream gauges to improve our understanding of the frequency of channel forming flows and mean velocities experienced during these flows.

IT ISN'T NEWS THAT STREAMS in the Santa Monica Bay watershed, as in the Los Angeles region, have been heavily impacted by development. Over the past 250 years, watershed alterations have changed runoff and sedimentation rates, while agencies and individuals also straightened, leveed, and ultimately culverted or armored waterways to increase developable land area and to decrease the associated flood hazards.

Today, approximately 90% of both perennial and intermittent streams in Los Angeles' urban areas are encased in concrete (Figure 1). Wetlands and backwaters are also mostly drained, although in some sensitive cases, they are now supported with either reclaimed or imported potable water. In today's watershed, paving and storm drains ensure that groundwater no longer receives annual recharging; this contributes to a regional deficit in groundwater resources while streams themselves are no longer recognizable as such to the average resident. Aquatic and stream-side (riparian) flora and fauna have mostly disappeared with the streams; the complex relationship between sediment, water, stream geometry, flood regimes, and vegetation that provided the matrix for now endangered fish is isolated to a few streams through state park lands – when not disturbed by gabions, rip rap, Arizona crossings, check dams, debris dams, irrigation, or flood control dams.

Also lost with these waterways is an understanding of a stream's structure and processes. Today, we may see a habitat restoration project that focuses on structures or conditions, such as trees, ponds, gravel beds, and soon for target species, but this does not allow the natural processes of a stream to rebuild the habitat through its own channel-forming processes, and thus we are missing the opportunity of a more resilient, self sustaining project. Additionally, water quality managers who seek to capture and infiltrate all runoff from small storms may ultimately undermine the processes that build and maintain stream channels if they do not also provide for the channel-maintaining function of sediment transport. Throughout the region, we have observed planning authorities routinely demonstrating a lack of understanding of the function of floodplains to safely dissipate and detain large volumes of water, a feature that benefits local water supplies, agriculture, and wildlife. This misunderstanding has led to permitting development in the floodplain, confining river channels to ever-narrower rights-of-way. Better integration of urbanization and streams will require advances in local understanding of how streams function and maintain their channels. An understanding of how stream dimensions and form support increased flood capacity, sediment transport, and aquatic and riparian ecological function will be a major step toward improving water quality, flood control, and habitat issues in the Los Angeles region.

The form of a stream channel is directly related to its ability to transport flow and sediment and dissipate energy. Channel slope, width, depth, sinuosity, and other characteristics regulate how sediment and flow are carried. Understanding channel form and dimension will give us an understanding of channel function. Rebuilding this knowledge base is rooted in empirical observations of natural stream morphological dimensions throughout the Los Angeles basin.

A framework for understanding form and dimension was developed starting in the 1950s, when United States Geological Survey (USGS) scientists, led by Luna Leopold, systematically surveyed natural streams throughout the United States and consistently found relationships between stream form (morphology), such as bankfull channel features, and discharge (rainfall-related flow) or the size of the watershed area. Their geomorphic approach quantified the physical characteristics of stream channels and identified patterns common to a watershed or region, developing an objective, standardized system of stream assessment in which the consistent identification of common reference points among the variety of natural channels within a region became possible. They found that, generally, low-gradient alluvial channels are composed of two important physical components: a low-flow "bankfull" channel and an adjacent floodplain. The bankfull stage is described as the point of incipient flooding, the point at which flow overtops the natural channel and spreads across the floodplain (Leopold et al. 1964). Empirical evidence from a large number of rivers in the other regions of the United States suggests that these flows are frequent, moderate events with a typical return interval of one to two years and that they represent a channel forming or maintenance flow (Dunne and Leopold, 1978). The channel features observed are depositional; sediment deposited by these moderate events forms the stream's flood plain and can be visually differentiated from the erosive cutting of a bank.

Figure 1. Concrete Channel

PHOTO: SMBRF

In stable channels, the dynamics of sediment input (deposition) and output (erosion) are in balance, reflected in the stream's channel form. Streams that experience changes to sediment flows adjust through variations of channel form, pattern, and/or slope, which often disturbs the development of bankfull channels. Bankfull is a widely accepted feature from which to observe and understand stream processes and illustrates equilibrium conditions that can serve as a starting point for restoration. If channel processes maintain bankfull flows in identifiable ways, they can serve as a common point of reference across a variety of streams. Earlier studies have identified relationships between bankfull channel geometries and drainage area (Leopold et al. 1964; Emmet 1975; Jackson 1994; Castro 1997; Moody and Odem 1999; Knight et al. 1999). These relationships have been termed regional curves.

Perennial and ephemeral streams in arid regions pose special challenges in assessment, classification, and restoration. Southern California is dominated by winter rain events that produce infrequent, short-duration, high-discharge stream flows. In the southwestern United States, hydrologic processes influenced by varied topography, geology, soils, and vegetation produce a wide range of channel forms. With a general awareness of the braided, shallow Los Angeles and San Gabriel Rivers, and much theorizing as to the level of instability of many headwater streams, stream restoration advocates were left to wonder if the streams of Los Angeles were exceptional or likely to develop observable and consistent channel features that indicate channel forming flows in other regions of the world. Despite the challenges presented by the urban setting of the Los Angeles area, the quantification of a regional curve for bankfull dimensions would indicate

Figure 2. Survey Sites

that this region could approach stream assessment and restoration in a similar manner to other regions.

In 2006, Natural Channel Design, Inc. and staff from the Santa Monica Bay Restoration Commission surveyed 29 stream reaches. The goal was to identify at least 10 sites representing a range in watershed sizes within a homogenous hydrophysiographic region. Sites that were not surveyed were bypassed for several reasons. In some cases, the bankfull features were not clear – the stream was in the process of reestablishing itself after major disturbances such as flooding or debris flows, was influenced by flow regulation such as diversions or dams, or was restricted as private property and rugged topography. On the other hand, the dearth of natural channels in the lower elevations of the Santa Monica Bay watershed limited the team's ability to use entirely local references. For this reason, the 15 stream sites ultimately surveyed ranged across several major Southern California watersheds including the Santa Clara River (San Francisquito and Santa Paula Creeks), the San Gabriel River (East Fork and Graveyard Creeks), the Los Angeles River (Devil's Canyon, Brown's Canyon, Aliso Canyon, and Limekiln Creek), Ballona Creek (Stone Canyon), and smaller coastal watersheds (Topanga Creek, Las Virgenes Creek, Arroyo Sequit, Peck Park Creek, and Miraleste Creek) (Figure 2). The elevations ranged from sea level to over 1,300 feet above mean sea level. Watershed area for each site ranged from 0.3 to 58 square miles, with varying watershed characteristics including average annual rainfall amounts. Sites furthest inland were generally highest in elevation and were the least impacted, although northern coastal sites (Arroyo Sequit and Topanga Creek) had less developed watersheds in state park lands. Southern coastal sites (Peck Park, Miraleste, and Stone Canyon) were in suburban and urban areas and tended to represent the smaller watershed sizes. The streams surveyed represented a range of channel slopes, entrenchment, meander patterns, and sediment sizes. The presence or absence of base flow was not considered relevant, and streams representing both conditions were surveyed.

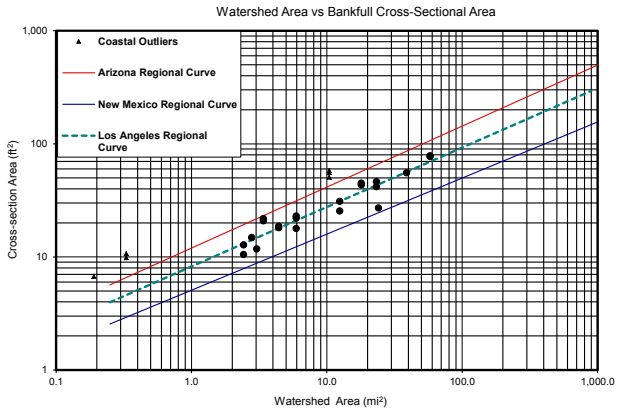
Bankfull features were clearly identified at the 15 surveyed sites. Bankfull stage was identified using procedures described by Dunne and Leopold (1978). Walking the channel, depositional features indicative of bankfull stage, such as floodplains, point bars, changes in bank slope, and changes in particle size, were noted. Vegetation served as a secondary indicator. These features were surveyed and described for analysis. High and low terraces as well as consistent vegetation were included in the surveys. A longitudinal profile equal to a distance of 20 to 40 channel widths was surveyed using a tape and laser level. One to three cross-sections were surveyed at riffle sections within the reach. Channel thalweg (lowest point of the flow line), water surface, and alluvial features were included in each profile and cross-section. Bed and bank materials were characterized using the Wolman Pebble Count Method (Harrelson et al. 1994) (Figure 3).

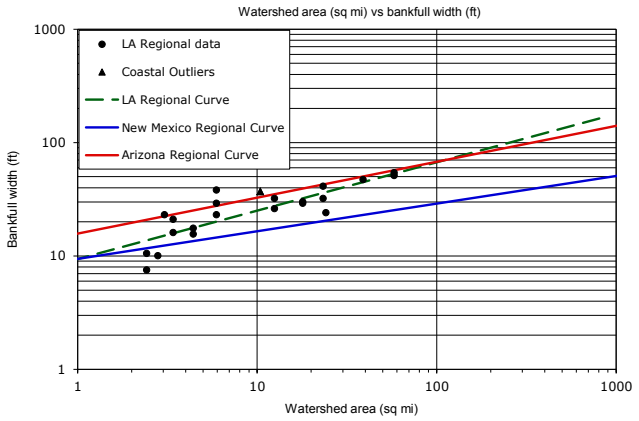
Data was analyzed for channel slope, bankfull width, bankfull cross-section area, mean depth, maximum depth, flood prone width (width at twice maximum bankfull depth), and super flood prone width (width at three times maximum bankfull depth). Watershed areas were delineated with topographic maps. After initial analyses, cross-sections that were affected by disturbances caused by logs, culverts, or other flow disruptions were eliminated. Reliable cross-sectional areas were plotted against watershed area on a log-log scale. A slope was fitted to the line using regression techniques.

Figure 3. Channel Surveys

PHOTOS: JESSICA HALL

Figures 4&5. Los Angeles Area Regional Curve Superimposed Over New Mexico & Arizona Regional Curves





There was a strong relationship between watershed size and bankfull cross-sectional area, where R^2 (0.89, n = 10) showed little scatter in the data (Figure 4). The data was then compared to regional curves that previously have been developed for other southwestern regions. The Los Angeles regional curve was found to fall within the New Mexico and Arizona regional curves, with a similar slope, confirming the team's hypothesis that the rainfall patterns and watershed conditions produce similar stream channels throughout much of the Southwest.

When watershed size and bankfull width were compared, R^2 (0.69) also indicated a fairly strong relationship (Figure 5). Width varied among the different channel shapes, thereby weakening the correlation. However, other regional curves have found similar strength of correlation for bankfull width. Given more data points, the relationship could be stratified by channel type and provide a more useful, predictive relationship.

There was no significant relationship between watershed size and mean depth due to the range of channel shapes encountered. However, the ratios of mean depth to maximum depth were consistent with values found for cross-sections taken at stream riffles in sites in Arizona, New Mexico, and Utah, indicating that Los Angeles area streams had a similar range of variation compared to other southwestern regions.

Five plotted cross-sections were found to be obvious outliers and eliminated from the fitted regression curve (Figure 4). They showed significantly larger cross-sectional areas per watershed size than the other channels surveyed, indicating watersheds that may have different runoff yields or receive larger amounts of rainfall. Those outliers came from three low elevation coastal sites (Miraleste, Peck Park, and Arroyo Sequit), and quite possibly could be the beginning of a different regional curve for the specific conditions they represented. Additional data collected in similar watersheds will be needed to show if they represent a single additional regional curve or several. The Los Angeles area represents a variety of elevations, watershed types, and rainfall types. Several curves may be needed to reflect this regional variety accurately.

These regional curves provide a starting point for inventory and analysis of Los Angeles area streams. This initial project, to construct regional curves for the area, indicates that morphological features can be reliably utilized to construct regional curves. We recommend additional surveys to gather more data points throughout Southern California. More data points would improve the curve, and may start to break out subregional curves, as is suggested by the coastal outliers. Additional data will also allow stratification of data by stream type, allowing for reliable construction of dimensionless ratios that can be utilized for stream restoration design. Importantly, morphological information tied to stream gauges is lacking from this analysis. Suitable sites with reliable periods of record were not found for this survey. Surveys associated with gauging stations allow for the validation of flood frequency estimates of bankfull discharge and an estimation of stream velocities during bankfull events. This is important data that should be understood if the regional curves are to be validated and utilized. Collection and analysis of additional data should become a priority for agencies charged with assessing stream conditions and the restoration or enhancement of streams.

The Los Angeles Regional Curves Assessment demonstrated a clear relationship between the sediment transport process of a watershed, the watershed's size, and bankfull channel formation. It confirms that, despite common perception, the streams of the region have observable, consistent features, patterns, and profiles, much like streams elsewhere in the southwest. Currently, the regional curve provides a baseline for the assessment of stream conditions and a comparison for additional geomorphic studies. It provides an important starting point for restoration and enhancement activities.

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This work could not have been accomplished without the expertise and commitment of Tom Moody, P. E. Tom leaves a legacy of good works and potent ideas as a contribution to the evolving science of stream restoration in the southwest. His wit and intellect are sorely missed.

L.A. Streams: A Closer Look

Seven years ago, a resident on a small stream in Brentwood called environmental groups for help. A neighbor had dug out one bank of the creek and packed it up against his own – giving himself more room for his remodel. Permitting authorities missed the presence of the stream; it was not mapped nor indicated on a survey. Exempt from the California Environmental Quality Act (CEQA) as a single family residence, state and federal environmental agencies were not notified and hadn't permitted the impact to the stream. This was initially viewed as a NIMBY dispute.

A few years later a developer squeezing homes into confined lowlands between Mandeville Canyon Road and a steep canyon wall located septic seepage pits in the banks of a "swale" that is the physical remains of Mandeville Canyon stream – the high and continuous flows of the stream being directed into a box culvert beneath the swale. The fight that ensued wasn't even about whether the seepage pits should be 100' away, a Plumbing Code standard – the lots were too shallow for that – or about the soundness of developing lots that couldn't adequately accommodate seepage pits. The fight was over whether or not Mandeville Canyon even had a stream around which to apply the Plumbing Code setbacks.

A 1906 USGS map shows that the Los Angeles region had considerably more perennial and intermittent streams than today. By one estimate, there were almost 150 miles of watercourses just in the Ballona Creek watershed at that time. After a century of concrete channelization and culverting, about six miles of those same streams remain, and those precious six miles are being lost to piecemeal development and environmental laws that encourage, rather than enforce, environmental standards.

In 2006, motivated by a desire to address this loss, the City of Los Angeles invited state environmental agencies and local nonprofits to assist in the drafting stream protection measures. After reviewing myriad stream definitions, the committee agreed on a stream definition that incorporates an understanding of stream function. This definition was included in a policy for locating septic systems appropriately in new development and has advanced water quality protection at the local level.

While state and federal law mandates a process for reviewing impacts to streams and wetlands, it doesn't actually prohibit development in streams. Environmental protection is encouraged by assessing mitigation measures for impacts. This has not translated into "no net loss" of dynamic riparian or wetland systems. Actual stream protection – the prohibition of filling or armoring of a stream channel, and the prevention of impacts to the wooded riparian corridor that lines streams – has to be initiated at the local level. The City's committee took this on, studying examples of ordinances from around the country. The best of these models preserves a stream's ability to function dynamically – flooding within its riparian corridor, moving sediment, and rebuilding its channel over time – by creating a protected stream buffer setback zone. Finding the right formula of setbacks for LA's short lots led to lively discussions that remain unresolved. However, while still in consideration of an ordinance, the City, along with state regulators, has moved forward with limiting urban runoff.

This has long been desired by scientists who've observed the impacts of urbanization to degrading water quality, such as spiking stream flows and initiating channel instability. Yet, completely halting discharge for low and moderate storms – the storms that carry most of the bankfull-forming sediment – could have the unintended consequence of also disrupting the stream's ability to rebuild its channel. From a geomorphic standpoint, it would be preferable to mandate that runoff from a development mimics the rate and timing of discharge that would be found in a natural condition, and then manage water quality in other ways.

Stormwater Runoff Debris near Santa Monica Pier

PHOTO: KIRSTEN JAMES, HEAL THE BAY

Averting the Scourge of the Seas: Local and State Efforts to Prevent Plastic Marine Pollution

Case Study: Plastic Bags

SARAH SIKICH AND KIRSTEN JAMES

Marine debris is a global problem that threatens marine life and ocean environments. It is largely comprised of plastic materials, which can take years to break down and may never truly biodegrade in the marine environment. Single-use plastics, such as plastic bags, bottle caps, and polystyrene pieces, are frequently found during creek and beach clean-up events. Of these items, plastic bags and polystyrene food packaging have been common targets for policy-based approaches to pollution prevention at local, state, and national levels. This article focuses on single-use plastic bag policies, discusses lessons learned from international and U.S.-based models, and provides recommendations for effective policy-related reduction and prevention measures within California.

SINCE THE 1970S, MARINE DEBRIS, which is simply man-made trash and materials that litter our beaches and seas, has been widely recognized as a threat to the marine environment (Figure 1). Quantities of marine debris are increasing at an alarming rate, despite past control measures such as the MARPOL (MARine POLlution) international treaty prohibiting dumping plastics at sea (California Coastal Commission 2006; MARPOL 1988). An estimated 80% of marine debris comes from land-based sources, while only 20% comes from sea-based sources (U.S. Department of Commerce 1999).

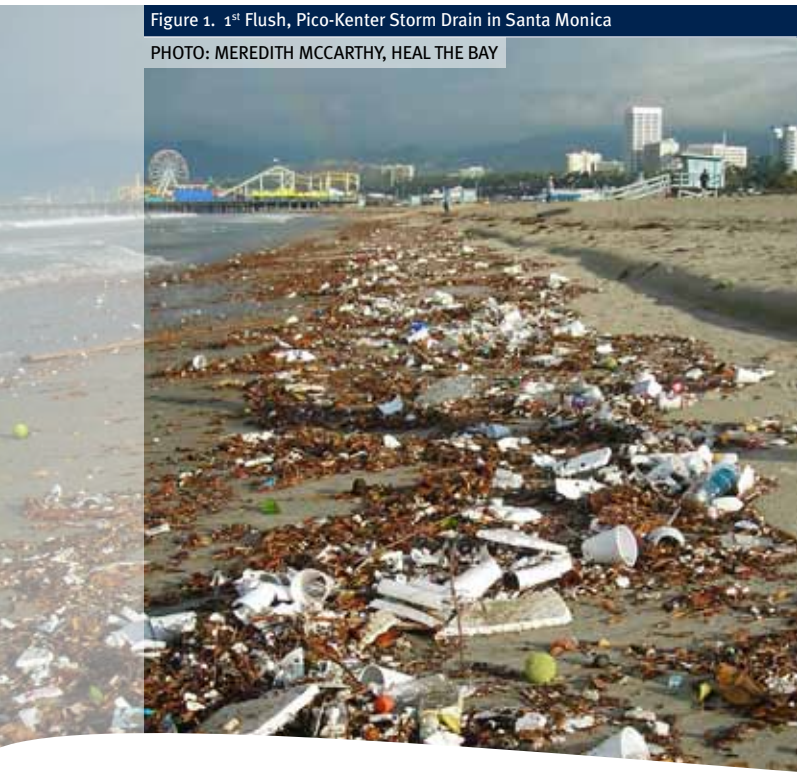
Marine debris is primarily comprised of plastic materials, which make up roughly 60–80% of all marine debris and 90% of all floating debris (California Coastal Commission 2006). Plastic resin polymers are so durable that it can take hundreds of years for plastics to break down at sea, and some may never truly biodegrade in the marine environment (California Coastal Commission 2006). A study conducted by the Algalita Marine Research Foundation in the North Pacific Gyre found six times more plastic particles than plankton, by mass, in these waters (Moore et al. 2001).

This pollution threatens the health of the marine ecosystem, as well as mariner safety. More than 267 species worldwide have been injured or killed by marine debris, primarily through ingestion and entanglement (Laist 1997). Marine debris is particularly detrimental to seabirds, marine mammals (Figure 2), and sea turtles (Laist 1997). Plastic marine debris can also attract dangerous chemicals present in the marine environment, such as polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT): researchers have found concentrations of these chemicals on plastics in the marine environment at nearly one million times above background levels (Mato et al. 2001). More research is needed to better understand the effects on marine life of ingesting chemical-laden plastics.

Marine debris is also a significant economic burden for local and state governments. Public agencies in California spend millions annually on litter cleanup (California Department of Transportation 2008). In fiscal year 2005–2006, Caltrans spent $55 million to remove litter and debris from roadsides and highways, which otherwise could have drained to the

Figure 1. 1st Flush, Pico-Kenter Storm Drain in Santa Monica

PHOTO: MEREDITH MCCARTHY, HEAL THE BAY



ocean. Locally, the Los Angeles County Department of Public Works and the Flood Control District spend an annual average of $18 million on street sweeping, catch-basin cleanouts, cleanup programs, and litter prevention and education efforts (Los Angeles County Board of Supervisors 2007). Marine debris is becoming a globally recognized environmental problem, and stakeholders can learn from the successes and obstacles of policies to address the issue explored elsewhere. Single-use plastics, such as plastic bags, bottle caps, polystyrene pieces, and cigarette lighters, are among the types of marine debris commonly found during beach and creek cleanups (Moore and Allen 2001). Of these items, plastic bags and polystyrene have been common targets for policy-based approaches to pollution prevention. This article will focus on single-use plastic bag reduction and prevention measures.

Lessons Learned from International and U.S. Models

Enacting plastic bag pollution prevention policies is not a new concept. Local governments and countries around the world, from Bangladesh to Belgium, have adopted measures, ranging from fees to bans, aimed at decreasing plastic bag pollution. Ireland is an example of a particularly successful program.

Ireland's Plastic Bag Levy, a Success Story

Ireland has been a global leader in curbing plastic bag pollution through a consumer-based fee approach. The Irish government adopted the "Plastic Bag Levy" in March 2002, with the intent of reducing the consumption of disposable plastic bags (Department of the Environment, Heritage and Local Government 2007). To effectively deter the use of plastic single-use bags distributed at the point of sale and to encourage consumers to switch to reusable bags, the Levy was designed to be placed at a price point high enough to change consumer behavior.

Before the measure was introduced in 2002, an estimated 1.3 billion shopping bags were issued annually in Ireland, and plastic bags were commonly found as litter. The Levy, which is currently set at an equivalent of US$0.33, has decreased plastic bag distribution by more than 90% (Department of the Environment, Heritage and Local Government 2004). The Levy is applied equally to plastic and compostable single-use bags, as both forms cause environmental blight. Although the Plastic Bag Levy was adopted as a litter-control reduction measure, the Levy has raised more than 117 million pounds as of January 2009. These funds are used to support waste management, recycling, and other environmental projects, including litter prevention efforts, environmentally friendly product promotion, environmental partnerships, and education and outreach efforts (Mulhall 2009). Over the lifetime of the program, Ireland has increased the fee once to keep plastic bag distribution stable at a low level (Department of the Environment, Heritage and Local Government 2007).

The Plastic Bag Levy has successfully reduced plastic bag litter and resulted in a savings to local authorities, which now spend less on litter cleanup and abatement (Mulhall 2009). The Levy has also garnered wide public support. A nationwide survey on public perception of the Levy, conducted in 2003, found that 91% of those surveyed supported the fee, for a variety of reasons, including its environmental benefits, the aesthetic benefits from plastic bag litter reduction, and because they found reusable alternatives to be more convenient and durable (Mulhall 2009).

Figure 2. Sea Lion Pup with Plastic Bag

PHOTO: PETER WALLERSTEIN, MARINE ANIMAL RESCUE

Seattle Action Thwarted by Industry Opposition

Possibly taking a cue from Ireland, in 2008, the Seattle City Council adopted a $0.20 green fee on single-use shopping bags. Concerned by the negative energy, climate, wastewater, litter, and water quality impacts of disposable plastic and paper bags on Seattle's environment, the council introduced the green fee as an environmentally beneficial measure (Seattle Public Utilities 2008). The fee structure is consumer-based and applies to paper and plastic single-use shopping bags provided at the point of sale at grocery stores, drugstores, and convenience stores.

The price point that will influence consumer behavioral change is often at question in the design of fee-based environmental policy measures. Producer- or retailer-based fees are not as effective at changing consumer behavior (Green Cities California 2010). A consumer study of Seattle residents conducted in 2008 indicated a fee of $0.20 would reduce the distribution of single-use plastic bags by 70% or more at participating stores (Seattle Public Utilities 2008). Although the green fee was designed to be a litter prevention measure, Seattle planned to use associated revenues for education and outreach efforts, including fee and waste prevention, recycling, and environmental education programs.

Seattle's green fee was to take effect on January 1, 2009, but soon after the City Council adopted the measure, efforts to fight the fee ensued. The Progressive Bag Affiliates of the American Chemistry Council collected enough voter signatures to put the green fee measure on the August 2008 primary ballot as a referendum, and subsequently spent $1.4 million to defeat the measure (Thompson 2009). In the end, the referendum was defeated. The American Chemistry Council's investment to prevent regulation of single-use plastic bags proved successful in Seattle. Along with affiliates, the American Chemistry Council continues to fight local and state action intended to reduce plastic pollution in the United States, including California.

Local and State Action and Policy Options in California

Local Plastic Bag Measures Face Challenges, Yet Persevere

Californians use approximately 19 billion single-use plastic bags each year. However, less than 5% of single-use plastic bags are actually recycled (California Department of Resources Recovery and Recycling n.d.). Instead, many of these plastic bags become litter and eventually end up in our oceans as marine debris.

In March 2007, the City of San Francisco became the first U.S. city to ban single-use plastic bags at large supermarkets and pharmacies (City of San Francisco Ordinance 81-07). Many environmental groups heralded this action as a major win for the environment (Figure 3), while some questioned the decision to allow the continued distribution of single-use paper and compostable bags in many outlets. It is no surprise that industry groups such as plastic bag manufacturers and the American Chemistry Council criticized the decision entirely and saw the ordinance as a threat to their livelihood.

Figure 3. San Francisco Storm Drain with Plastic Trash

PHOTO: SARAH WOODARD

The San Francisco action sparked a wave of momentum surrounding single-use bags, in California and beyond. Many California communities quickly became motivated to follow suit. At the same time, industry opposition began to coalesce. San Francisco's neighbor, the City of Oakland, was one of the next municipalities to pass a single-use bag ban. However, in an attempt to reverse Oakland's decision and intimidate other local governments from doing the same, a group calling itself The Coalition to Support Plastic Bag Recycling sued the city over its failure to complete an Environmental Impact Report (EIR) under the California Environmental Quality Act (CEQA). In other words, the industry was turning CEQA against itself to halt, instead of promote, environmental progress. As a result of the lawsuit, Oakland moved to a voluntary ban of single-use bags.

The Oakland lawsuit marks one of the many legal challenges and threats against communities exploring single-use bag policies. However, despite the legal threats, several Southern California communities have moved forward with policies of their own. The City of Malibu adopted a policy in May 2008 (City of Malibu Ordinance No. 323). Learning from some of the weaknesses in the San Francisco policy, Malibu decided to ban plastic and "compostable" single-use bags, because compostable bags do not degrade in the aquatic environment. The City also recommended that their Council should consider a fee on plastic bags in the future. (As discussed later in the article, state law AB 2249 preempts levying fees on plastic bags.) In addition, Malibu expanded the definition of "store" to include all retailers, so that more of the single-use pollution problem could be addressed.

Trash Boom between the Lincoln Blvd and Culver Blvd Overpasses in Ballona Creek
PHOTO: SMBRF

In July 2008, Manhattan Beach adopted a nearly identical policy to Malibu's ordinance (City of Manhattan Beach Ordinance No. 2115). While Malibu may have slipped through the cracks on a legal challenge, Manhattan Beach was sued by a newly formed industry group named Save the Plastic Bag. Save the Plastic Bag held that Manhattan Beach failed to look at the impacts on the environment from banning plastic bags and not paper ones (Save the Plastic Bag Coalition v. City of Manhattan Beach). Again, CEQA was used opposite of its intent. Unfortunately, thus far, the courts have ruled in favor of the plaintiff, but the case was appealed to the State Supreme Court and will be heard in the near future.

Many municipalities are still charging forward. In an effort to sustain momentum on this issue, a group of 12 cities from Green Cities California spearheaded an effort to complete a Master Environmental Assessment (MEA) on single-use plastic bag policies that could serve as a template for an Environmental Impact Report (Green Cities California 2010). The final MEA was released in March 2010. The MEA explores a range of policy options, including bans and fees. Additionally, the County of Los Angeles issued a Countywide Environmental Impact Report for a single-use plastic bag ban ordinance in June 2010. It is designed to be used by any of the 88 cities in Los Angeles County that are interested in adopting similar ordinances.

Due in part to the MEA and Los Angeles County EIR, we expect to see many California cities pursue single-use bag policies in the upcoming year. Many of these municipalities will probably consider plastic, paper, and compostable bags in their policies, since negative environmental impacts are associated with all three types of bags. In addition, we anticipate a broadening of the definition of "store" in order to capture more of the distributed bags. Despite municipalities pursuing exactly what Save the Plastic Bag and other industry groups have called for (an Environmental Impact Report), the industry will likely continue to fight on other fronts.

California Makes Strides Toward Effective Prevention Measures

Since 2005, the introduction of single-use bag legislation has proceeded steadily in the California legislature. In 2006, AB 2449 (Levine) was signed into law. This law created an in-store recycling program for collecting and recycling plastic "carry out" bags. In addition, the author made a last-minute industry concession to preempt local municipalities from levying fees on plastic single-use bags. Since the implementation of this law in 2007, there has not been a marked increase in the plastic-bag recycling rate. The status quo recycling rate of less than 5% (Los Angeles County Board of Supervisors 2007) has not increased and barely puts a dent in the pollution problem (California Department of Resources Recovery and Recycling n.d.). The local preemption has greatly limited the policy options available to local municipalities. Several industry-backed bills over the past few years have also focused on voluntary approaches and recycling—policies shown to be insufficient for addressing the pollution problem created by single-use bags.

Several bills in recent years have proposed placing a fee on single-use plastic, paper, and compostable bags with the majority of the funds collected going back to local governments for single-use bag pollution abatement (AB 2869 [Levine]; AB 68 [Brownley]; AB 87 [Davis]). Not only have fee policies worked well to reduce bag usage in countries such as Ireland, but the funds generated can also help budget-strapped communities. However, in part due to the economic downturn in recent years, the California legislature has not been willing to pass a bag bill that places a fee on the consumer.

Given the legislature's negative record on bag fee legislation, this legislative session has marked a shift in proposed single-use bag policy. AB 1998 (Brownley) proposed a ban on single-use plastic and compostable bags by January 1, 2012, and an at-cost charge on high recycled content paper bags. Many environmental groups found this policy preferable to fees because a straight ban on plastic would result in fewer bags in the environment.

A Win-Win for the Economy and the Environment: Will Bags Be Sacked in California?

As discussed above, there is much momentum on the issue of single-use bags at the state and local levels. Ideally, California will have a statewide policy that bans plastic and compostable single-use bags and bans or places a fee on paper bags at all large supermarkets, pharmacies, and convenience stores in the near future. This would lead to the greatest reduction in single-use bag pollution and would drive consumers toward reusable bags, the environmentally preferable alternative (Figure 4). As a result of such a policy, municipalities would have fewer cleanup costs, and stores would not need to imbed the price of "free" bags in the cost of consumer products.

Figure 4. Plastic Bag Monster Distributing Reusable Bags in Huntington Park

PHOTO: SAIRA GANDHI, HEAL THE BAY

Despite the buildup in momentum, the last four years have demonstrated that it is not easy to pass single-use bag legislation at the state level. AB 1998 passed out of the state Assembly with a vote of 42-27. Notwithstanding a unique and broad coalition of supporters including the California Grocers Association, local governments, United Food and Commercial Workers Union, environmental groups, and the Governor, the bill failed to pass the state Senate. The American Chemistry Council poured millions into an anti-AB 1998 advertisement campaign as well as donations to strategic high-powered lobbyists and senators. This effort was likely a big contributor to the bill's demise.

Despite this setback at the state level, it is essential for policy to move forward at the local level—not only to create positive environmental change but also to drive state action in the future. Many local governments were waiting to hear the results AB 1998 before moving forward with their own policies. In the short time since the end of the legislative session, local governments are already starting to take action on plastic bags. Hopefully the momentum at the local level in the coming months, and the possible reality of a "patchwork" of plastic bag policies throughout the state, will send a strong message to the legislature that a statewide approach is needed.

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Rotterdam and Erasmus Bridge at Night

PHOTO: ARCADIS

Climate Change Adaptation in Smart Delta City Rotterdam

PIET DIRCKE, PETER WIJSMAN, AND ARNOUD MOLENAAR

The majority of the world's population will soon live in delta cities that face the challenge of climate change. Rotterdam, situated in the heart of the Dutch delta and one of the biggest ports in the world, is dealing with climate change in a proactive way, turning these challenges into opportunities. The city lies largely below sea level (up to 6 meters), and the city is protected from the sea by a complex system of dikes, closure dams, and storm surge barriers. Rotterdam wants to protect its citizens against the future impacts climate change, like sea level rise and intensified rainfall, by making Rotterdam "climate proof" by 2025. Rotterdam is the perfect showcase for climate change adaptation in the Netherlands and an inspiring example for delta cities worldwide. Rotterdam will prove that dealing with climate change in a proactive way creates opportunities for an attractive, economically strong, and technologically smart delta city.

Introduction

More and more people live in delta cities. By 2025, the majority of the world's population will live in cities in or near deltas, estuaries, or coastal zones. All of these cities will face more or less the same challenges. Hurricane Katrina, and later Al Gore, were wake-up calls, creating a growing awareness of the impact and consequences of climate change, in particular the increased risk of flooding due to sea level rise. Floods are already the natural disaster with the most casualties and the biggest economic impact. The impact of climate change in Rotterdam is not limited to just sea level rise, increased peak river discharges and more severe storm events will affect the city as well. At the same time, land is subsiding, and the city's population and economic activity continue to grow.

Present Situation

Rotterdam is situated in the heart of the Dutch delta and is one of the biggest ports in the world. The city lies largely below sea level (up to 6 meters), and the city is protected from the sea by a complex system of dikes, closure dams, and storm surge barriers, part of the famous Dutch Delta Plan. The Delta Works were established after the disastrous 1953 floods, when more than 1,800 Dutch citizens died, and the Dutch said: "Never again!" One of the main aspects of the Delta Plan was to improve the protection of the Port and the City of Rotterdam with the famous Maeslant Storm Surge Barrier (Figure 1). This barrier protects the city during a storm event, but remains open under normal conditions to allow navigation to the port areas and inland shipping canals behind the barrier. Today, Rotterdam is a safe city with a flood protection level of 1 in 10,000 years, 100 times safer than the US national flood safety standard of 1 in 100.

Rotterdam's urban water system has its own challenges, since it is an internal drainage system below sea level. This is a well-designed system of canals, lakes, drainage basins, and pumps. The Rotterdam Urban Water Plan focuses on both the challenges and the opportunities of living near the water. In this location, water challenges and urban spatial planning are fully integrated.

Climate Change and Flood Risk

Rotterdam has a climate influenced by the North Sea, with moderate temperatures and precipitation occurring in all four seasons. More intense rain events and longer dry spells are some of the expected impacts of climate change, in addition to sea level rise. Therefore, Rotterdam has established the RCP, the Rotterdam Climate Proof program. The objective of the RCP is to make sure that Rotterdam will be "climate proof" by 2025. The first priority for the RCP is the safety of the city. The Dutch protection standards are currently the highest in the world, and the 1 in 10,000 year protection level was established as a result of both the number of inhabitants and the economic value of assets to be protected. The existing urban levees, some of which cross through the heart of the city, will be strengthened and raised with innovative and multifunctional levees to incorporate them in the city landscape. The existing storm surge barrier system will be re-evaluated, extended, and improved, in close cooperation with the Dutch Federal Government and the water boards.

Rotterdam deals with the challenges of climate change in many other ways, for instance with an extensive green roofs program, the development of urban water plazas, climate robust buildings, and amphibian or even floating home communities.

Rotterdam City Ports

Rotterdam is looking for opportunities that enhance flood protection and at the same time, add value to the attractiveness of the city, for instance with the redevelopment of 4,000 acres of former city port areas (Figure 2). Attractive new climate proof waterfronts with sustainable and climate proof areas for living, working, education, and recreation will be developed in the centre of the city: the Rotterdam City Ports Project. The City Ports Project is currently one of Europe's largest urban redevelopments. One of the major drivers for redevelopment of the 4,000-acre old port areas will be knowledge and business development in the fields of water, climate change, and sustainability. This development is necessary in order to learn how to deal with climate change in the best way possible, to develop best practices, and to educate future generations of water and climate managers. One example is the development of new ways of creating buildings that allow flood water to move through the neighborhood without causing casualties or severe damage.

Figure 1. Maeslant Barrier

PHOTO: ARCADIS

Figure 2. Rotterdam City Ports

PHOTO: ARCADIS

These new technologies are being developed at knowledge centers like the RDM (Research, Design, and Manufacturing) Campus, an initiative of Rotterdam University of Applied Sciences, the Rotterdam Port Authority, and several other public and private partners. At the RDM Campus, previously the old RDM Shipping wharf, now education, knowledge development, and innovation go together; students of Rotterdam University work together with small, innovative companies on new sustainable research projects.

Rotterdam National Water Centre

Rotterdam will become an innovative center for water management and climate change, a truly smart delta city. International collaboration with other delta cities will be intensified. The leading role of Rotterdam as the Netherlands' international showcase for water management and climate change was underlined by the decision of the Dutch water sector, which established a national Water Centre in Rotterdam, also reflecting the desire on a national level to connect deltas. Rotterdam will be ready to host guests from all over the world who will visit the opening event in 2012. The Rotterdam Floating Pavilion (Figure 3), a visible icon for climate change adaptation, a resilient building, and a landmark for the City, will serve as the exposition space of the National Water Centre.

Connecting Delta Cities

Rotterdam, as an affiliate member of the C40 initiative, is also heading the "Connecting Delta Cities" initiative. The objective is to establish a network of delta cities that are active in the field of climate change adaptation, to exchange knowledge, and share best practices. Under this initiative, the delta cities Rotterdam, New York, Jakarta, London, New Orleans, Ho Chi Minh City, Hong Kong, and Tokyo have decided to join forces and exchange knowledge on climate change adaptation, starting with an overview of best practices in these cities, documented in a book that was presented by Major Ahmed Aboutaleb of Rotterdam to His Royal Highness the Prince of Orange at the recent "Deltas in Times of Climate Change" conference in Rotterdam in 2010. Other cities, including Melbourne, Shanghai, and Copenhagen, are keen to join this initiative. Also, cooperation with other delta networks like the Delta Alliance and the Estuary Alliance is increasing. This expanding and well operating network of knowledge-driven delta cities is one of the best answers for coping with the challenges by turning them into opportunities for safe and attractive living with water.

Rotterdam: Smart City, Smart Flood Control

Rotterdam is currently developing innovative technologies to become a smart city of the future. The integration of information technology into the most modern and innovative adaptive flood control science and development plans in the world is one of the tools. "Flood Control 2015," a public-private consortium, will research the feasibility of developing a smart flood control system for the city. The aim is to make decisions during an emergency, like a flood, two times better and two times faster than the present rate, using tools like smart gaming, a demonstrator control room, decision support systems, and the application of sensor technology in levees. Students from the Rotterdam University of Applied Sciences are also involved in developing these tools. In this way, future generations are attracted to start a career in water and climate change, making Rotterdam a smarter and safer city in the future.

Figure 3. Floating Exposition Center at Night

PHOTO: ARCADIS

PIET DIRCKE *is a Water Program Director for ARCADIS in the Netherlands and a part-time professor in Urban Water Management at the Rotterdam University of Applied Sciences. In his work for ARCADIS, he leads many strategic growth initiatives in the Netherlands related to climate change adaptation and intelligent flood management techniques. In the US, Mr. Dircke is involved in projects in New Orleans, New York, and San Francisco.*

PETER WIJSMAN *is the Water Resources Program Manager for ARCADIS in California. As a Dutch native currently based in San Francisco, one of his responsibilities is technology transfer of expertise in water management, flood protection, and climate change adaptation between the Netherlands and the US.*

ARNOUD MOLENAAR *has served as Program Manager of the City of Rotterdam's ambitious Rotterdam Climate Proof program since his appointment in 2008. In previous positions, he served as a senior advisor for Environmental Policy at the City of Rotterdam, where he played a crucial role in the Rotterdam Environmental Policy Plan and the Water Plan of Rotterdam. In 2001, he became the Deputy Head of the Water Management Department of the City of Rotterdam.*

Figure 1. Kaplan Cove, Fall 2009

PHOTO: MARK CORCORAN, STARCREST PRODUCTIONS

Giant Kelp Community Restoration in Santa Monica Bay

TOM FORD AND BRIAN MEUX

To address the loss of approximately 80% of the giant kelp forests (MBC Applied Environmental Sciences 2009, Wilson and North 1983) in Santa Monica Bay, the Santa Monica Baykeeper has been engaged in the ecological restoration of kelp forests off Malibu and the Palos Verdes Peninsula. Two techniques are applied in this effort, sea urchin relocation and sporophyll bag stocking and deployment. To date, efforts off Escondido Beach in Malibu have resulted in a spatially and temporally stable kelp forest since 2004. Similar success has been documented in Long Point, Palos Verdes, with the rapid return of giant kelp and other algae to the reef once sea urchin densities were reduced to 1 to 2 per square meter in 2008 and again in 2009. In total, 7.5 acres of giant kelp communities have been reestablished.

DR. WHEELER NORTH WAS A PIONEER of giant kelp restoration, and he originally found the density of one to two sea urchins per square meter to be indicative of spatially stable forests in Southern California in the 1970s (W. North, pers. comm.). Dr. North, the California Department of Fish and Game, and hundreds of volunteer SCUBA divers attempted to restore giant kelp to the Palos Verdes Peninsula. In this instance, ten years were spent literally smashing sea urchins with hammers underwater and transplanting kelp from Malibu and Catalina Island. In the end, this effort was quite successful, and the Palos Verdes Peninsula for the first time since the 1940s had a stable kelp forest. Both the North-led efforts in the 1970s and the Santa Monica Baykeeper efforts in the late 1990s and 2000s focused on reducing grazing pressure by sea urchins on these reefs. The hypothesis tested was that if sea urchin grazing was reduced the kelp would be able to recruit and grow.

Giant kelp (*Macrocystis pyrifera*) is a large brown alga found along the coasts of Alaska, central and Southern California, and in many places in the Southern Hemisphere. Giant kelp typically grows from the ocean floor to the surface in 3 to 24 meters (10 to 80 feet) of sea water (Abbott and Hollenberg 1976), and in ideal circumstances may grow two feet per day. In most cases, giant kelp attaches itself to rocks on the bottom with a holdfast, or haptera that anchors this buoyant giant in place. Giant kelp in Southern California has a fairly short life span; one to three years is typical. During this short life span, a giant kelp plant is a source of food, shelter, or substrate for numerous species. Many kelp plants drift up and down our coastline following currents and waves with many of these species still attached or associated with the plant (Dayton 1985; Foster and Schiel 1985; Hobday 2000).

In Southern California, the giant kelp forest community supports roughly 716 described or known species, encompassing marine mammals, birds, fishes, and invertebrates (Graham 2004). For giant kelp to persist, the ecosystem, of which the kelp is the foundation, must be resilient to disturbance and have the proper environmental conditions and ecological controls. The environmental conditions can be simplistically described by ocean climate and chemistry: clear, cool nutrient-rich water (Jackson 1977; Zimmerman and Kremer 1986). Ecological controls are specific to the interaction between the various individuals living on the reef and in the kelp. Assuming there has not been a huge change in the ocean,

Figure 1. Pre-Restoration: Site Dominated by Purple Urchins

PHOTO: MARK CORCORAN, STARCREST PRODUCTIONS

Figure 2. Quadrant Species Count

PHOTO: BAYKEEPER

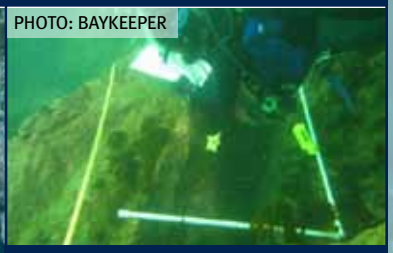


Figure 3. Urchin Removal

PHOTO: DAVE WITTING, NOAA

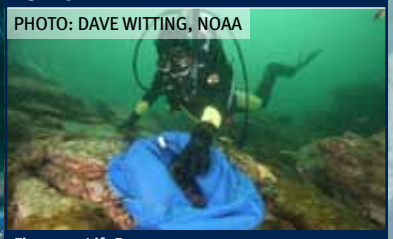


Figure 4. Lift Bag

PHOTO: BAYKEEPER

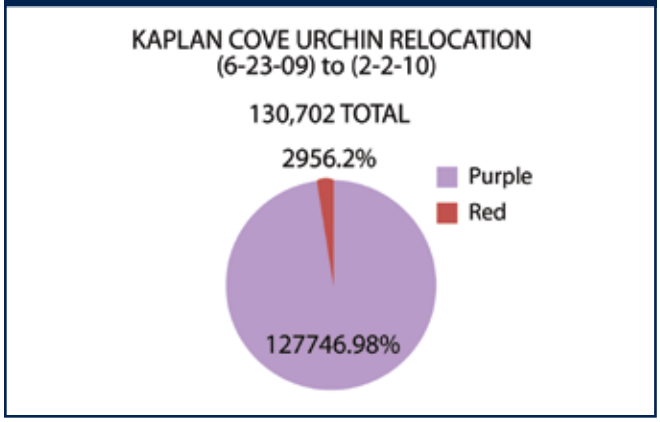
the fish and wildlife play key roles (Edwards 2004; Harold and Reed 1985). Predators keep herbivore populations in check through depredation, competitors jostle for food and space, etc. When most of the players are present, the system has a set of checks and balances that regulate the structure and function of the ecosystem, and it remains robust through time and space (Edwards 2004; Harold and Reed 1985).

The numerous stressors affecting the kelp beds in Santa Monica Bay are not an isolated phenomenon. Studies of kelp communities around the globe demonstrate kelp loss due to the changing climate, overfishing, habitat loss, invasive species, and pollutants (Steneck et al. 2002). In most places, too many urchins now graze the rocky reefs, removing giant kelp before the next generation can grow while marginalizing the health of standing adults (Steneck et al. 2002). Control of the urchin population in Southern California was maintained by three principal predators: the southern sea otter (*Enhydra lutris nereis*), California spiny lobster (*Panulirus interruptus*), and California sheephead (*Semicossyphus pulcher*). The southern sea otter was locally extirpated by Russian furriers in the mid-1800s (Jackson 2001). Both sheephead and lobster are intensively fished by recreational and commercial fisheries (California Department of Fish and Game 2001; California Fisheries Fund 2009). Notably, in the newly established marine reserves in the northern Channel Islands, where fishing is prohibited, the sheephead and lobster are relatively abundant, and the kelp forest is larger, denser, and more stable (Behrens and Lafferty 2004; Airame and Ugoretz 2008).

The principal method used to restore kelp forests in this project mimics the effect of the predators that naturally limit or control their prey. So if the otters are locally extinct and the lobster and sheephead are scarce, humans were needed to remove the sea urchins from the system. The target density for our project over the past ten years has been to reduce sea urchin densities to one or two per square meter. Recent research from Chile, New Zealand, and South Africa determined this sea urchin density to be the threshold between a stable kelp forest and one destined to become or remain an "urchin barren." An urchin barren is a reef supporting not much more than the urchins themselves (Figure 1). As further cause for restoration, urchin barrens have the potential to last for many years in an ecological and economically depauperate condition (Steneck et al. 2002; Tegner and Dayton 2000).

The earliest phase of fieldwork involves the establishment of sites on the rocky reefs. These sites will serve as the controls, references, and restoration sites for this experiment. Through this experimental design, we are able to describe the natural trends affecting all of our sites and determine if our restoration efforts are producing a result. Over time, our monitoring has undergone some modifications to improve its accuracy and increase its applicability to other efforts. In short, various monitoring methods are employed at each established site before restoration actions, during restoration, and following restoration for a period of five years. Monitoring methods include fixed and random quadrats (1 meter square, 12 pairs) (Figure 2) and band transects (2 meters by 30 meters). The

Figure 5. Relocated Urchins: Quantity and Type



quadrats and band transects target benthic organisms from different trophic levels. These organisms are selected for a few reasons: 1) for their known ecology, 2) rarity, 3) species likely to benefit or respond to kelp restoration efforts, and 4) invasive or non-endemic species. The relationship between giant kelp and sea urchins requires extra scrutiny. Therefore, giant kelp and sea urchin size and frequency sampling is performed to describe the density of these organisms and to infer less specific information regarding age class, fecundity, and responses to a variety of biotic and abiotic factors or events.

In efforts to advance the applicability of our monitoring and compliment monitoring efforts throughout Southern California, we are increasingly using Cooperative Research and Assessment of Nearshore Ecosystem (CRANE) methods. These methods are applied in whole or in subsets to quantify and qualify many of the same characteristics that our other monitoring achieves. With the addition of CRANE methods, the relative ecological values for all our sites can be compared with other reefs throughout Southern California and in some areas of the central coast (Point Conception to Santa Cruz). In summary, these methods are used to track key species and ascertain the presence or absence of certain ecosystem functions and structure. Underwater photography has been a wonderful tool used in this project to document conditions, demonstrate progress, and assist our public outreach and volunteer training.

The first method employed involved the relocation of sea urchins to reduce the densities from, in extreme cases, 70 sea urchins per square meter to 1 to 2. Urchin relocation for three acres of sea floor in Escondido totaled 32,428 individuals. This work is done by manually plucking or prying the sea urchins off the rocks, placing them in large nylon mesh bags, and floating them to the surface with lift bags (Figures 3 and 4). Lift bags are large bladders that are inflated at depth from SCUBA tanks or other air sources. Once at the surface, the bags are collected at the side of the boat and hoisted on board with a crane. All the sea urchins were typed by species and counted. The sea urchins were then distributed across broad areas of the ocean floor away from the reefs where the sea urchins had been collected.

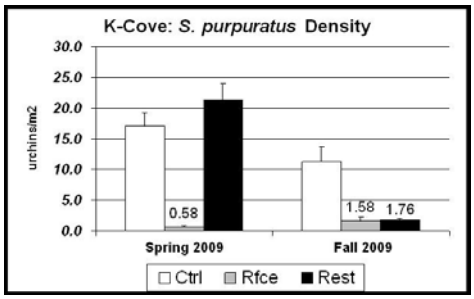
The second method involved the deployment of sporophyll bags. Sporophyll bags replicate the production of spores in the absence of a mature kelp plant. A sporophyll bag is a mesh bag containing 50 to 80 ripe sporophylls anchored to and floating at one meter above the bottom. Giant kelp reproduction starts with the production of spores. These spores are generated in sporangia located in sporophylls, specialized reproductive blades found near the holdfast (Abbot and Hollenberg 1976). In cases where the giant kelp adults are too far away or they have been absent for a few years, enhancing the dense settlement of kelp spores would expedite the reestablishment of the kelps. After placing the sporophyll bags strategically and repeatedly restocking them over periods of two weeks to one month, we were able to enhance the dense settlement of kelp spores on the rocky reef, a key step in the restoration of a kelp forest.

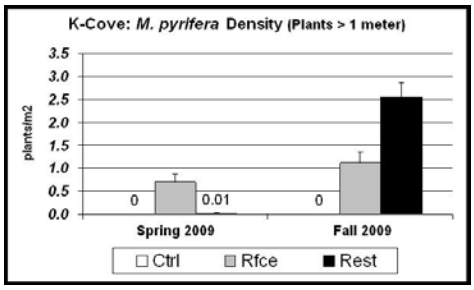
In 2005, the Kelp Project focused this suite of restoration techniques on a section of reef off Long Point, Palos Verdes. This area was larger, has greater exposure to winter storms, and contained higher relief substrate than the reefs off Escondido Beach. Restoring giant kelp to this reef would be a good test of the applicability of our techniques. Persistent red tides in 2005 and 2006 and a 200-year wave event greatly limited our access to the site and reduced our operational windows dramatically. By September 2008, 281,710 sea urchins were relocated from Long Point to restore three acres of kelp forest. In April 2009, restoration immediately up coast from our first Long Point site began, and within a few short months, the ecologists and volunteers of the Kelp Project relocated 118,092 urchins from a 1.5-acre area (Figure 5). In November 2009, giant kelp was already returning to this last site at or above the target densities (Figure 6).

Figure 6. K-Cove: Six Months Post-Restoration

PHOTO: BAYKEEPER

Figures 7 & 8. Restoration Results





CONTROL

REFERENCE

RESTORATION

The densities of urchins and kelp at Kaplan Cove (K-Cove) are depicted in Figures 7 and 8.

Both the Malibu and Palos Verdes Kelp Projects have demonstrated the success of these techniques when applied to the restoration of historic kelp forests. The barren reefs are transformed, benefiting the natural community of fish and wildlife, tourism, recreation, and local fisheries. Areas once dominated by urchins are now full of life, increasing the quality of life for the people of Los Angeles that pursue hobbies and other activities in or around the kelp forests.

TOM FORD *is the Director of Marine Programs for the Santa Monica Bay Restoration Commission. Mr. Ford was the Kelp Restoration Project Director for the Santa Monica Baykeeper from 2004 through 2010. Mr. Ford earned a Masters Degree from UCLA in 2005, with a focus on giant kelp forest dynamics. Mr. Ford has logged greater than 600 scientific SCUBA dives in Southern California since 1999.*

BRIAN MEUX *is the Marine Programs Manager for the Santa Monica Baykeeper. Brian has an M.S. in Regenerative Studies from Cal Poly Pomona. His master's thesis "Emergy Analysis of Santa Monica Baykeeper's Kelp Project" was completed in 2008. Brian's interests include marine restoration ecology, marine spatial planning, and fisheries.*

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Ballona Freshwater Wetland System

PHOTO: SARAH WOODARD

Constructed Wetlands Help Achieve Water Quality and Conservation Goals at Ballona

EDITH READ

The 51.1 acre Ballona Freshwater Wetland System was conceived in the early 1990's as part of the First Phase of the Playa Vista project, a residential and mixed use development located on a former airport and aircraft manufacturing facility to the west of Culver City. One goal of the project was to re-establish the freshwater habitat that had been lost with the channelization of Ballona and Centinela Creeks. A second goal was to help improve the quality of urban runoff into Ballona Creek and Santa Monica Bay. A third goal was to provide stormwater management and flood control. Phased construction of the wetland system began in 2001 and was completed in 2008 at a cost of more than $30 million. Monitoring results indicate rapid achievement of habitat and water treatment goals. Nesting bird species now include one State Species of Special Concern (the least bittern) and another species thought to have been extirpated from the Ballona Wetlands after 1902 (the Virginia rail). Comparisons of average modeled effluent concentrations versus measured effluent concentrations show the wetland system performing as well as, or better than, similarly designed treatment systems nationwide.

Background

It is important to recognize that the success of the Ballona Freshwater Wetland System is as much a product of its history and governance as of its design. Like other estuaries on the California coast, the Ballona estuary has a centuries-old history of watershed urbanization and loss of essential wetland functions. As part of constructing the Playa Vista project, the developer re-established a portion of the Ballona Wetlands, which had suffered from decades of neglect and inflows of urban pollutants, as a multi-function Freshwater Wetland System. Various land use permits, and approvals of the Playa Vista project, obligated the developer to construct the wetland and to ensure that the system is maintained in perpetuity.

The Freshwater Wetland System is managed and maintained by the non-profit Ballona Wetlands Conservancy, which is governed by a board with representatives from the Friends of Ballona Wetlands, the State of California, the City of Los Angeles, and the developer. Funding for the Ballona Wetlands Conservancy is entirely private and is derived from the Playa Vista community, thereby facilitating the "in perpetuity" obligation for wetland protection.

Design

There is a substantial body of research and numerous case studies regarding the design and effectiveness of treatment wetlands (e.g. Kadlec and Knight, 1996; Moshiri, 1993). The basic concept of a treatment wetland is to use natural wetland processes, such as uptake of nutrients by plants, to improve water quality. This concept is based on the premise that wetlands have a higher rate of biological activity than most ecosystems and can transform many common pollutants into harmless byproducts or even into

Figure 1. Overview of Ballona Freshwater Wetland System

essential nutrients (Kadlec and Knight 1996, 3). However, to achieve these functions without overloading the system with pollutants, the design of the treatment wetland must include (among other considerations) sufficient retention capacity, freshwater inflows, and upstream best management practices (BMPs) such as catch basins to prevent trash in storm runoff from reaching the wetland.

Additional design considerations for the Ballona Freshwater Wetland System included its location within the Ballona watershed and provision for a wildlife habitat. Conceived when all of the property was still under one private land owner, restoration plans for the freshwater wetland were designed with the adjacent Ballona Wetlands in mind. Since December 2003, the Ballona Wetlands have been owned by the State of California, which is currently planning restoration of the salt marsh and surrounding habitat.

The urbanized watershed that drains into the Freshwater Wetland System consists of about 1,040 acres, including 440 acres of the Playa Vista project and over 600 acres of off-site areas. The design of the Freshwater Wetlands System was intended to manage the amount and quality of freshwater flowing into the Ballona Wetlands salt marsh, and to enhance the quality of dry-weather and stormwater runoff into Ballona Creek and Santa Monica Bay. Figures 1 and 2 show hydrologic features of the Freshwater Wetland System, consisting of: 1) a 2-mile long, 25-acre riparian corridor along one of the historic flow lines of Centinela Creek, through which a minimum of one cubic foot per second (cfs) of treated groundwater is released to ensure freshwater supply to the system; 2) a 26-acre freshwater marsh connected to the riparian corridor through a box culvert under a major road; 3) within the freshwater marsh, a riparian corridor inlet as well as two additional storm drain inlets; 4) a primary outlet to manage water level and control releases into Ballona Creek; and 5) two secondary outlets (spillway and sluice gate) for freshwater overflow into the adjacent Ballona Wetlands Ecological Reserve. Treatment basins at the drain inlets to the Freshwater Marsh were expected to receive the brunt of pollutant inflows. Therefore, design of these basins focused on reducing inflow velocities and maximizing pollutant removal while keeping areas of intensive maintenance to a minimum (Figure 3).

Figure 2. Design Features of the Freshwater Marsh

Results

With more than 160 environmental parameters monitored over the past six years, only a few results can be summarized here. Details are in the latest annual monitoring report for the Ballona Freshwater Wetland System (Read and Strecker, 2009).

While the wetland system has met or exceeded conventional biological performance criteria such as habitat acreage, tree height, and dominance of native vegetation, there has been no greater surprise than the rapid return of bird species thought to have been extirpated at Ballona as breeding populations (Cooper 2006, 2008). One example is the least bittern (*Ixobrychus exilis*; Figure 4), a Species of Special Concern which was first observed nesting in the freshwater marsh in 2005, only two years after construction was completed. A more recent example is the Virginia rail (*Rallus limicola*), first observed nesting in the riparian corridor in 2009 and believed to be the first breeding record at the Ballona Wetlands since 1902 (Cooper 2009).

Figure 3. Sediment Basin at Jefferson Inlet

PHOTO: SARAH WOODARD

Table 1. Predicted vs. Measured Wet-Weather Constituent Concentrations for the Ballona Freshwater Wetland System

Modeled Constituent	Units	Modeled Average Concentration[a]	Average (Range) of Wet-Weather Grab Samples, 2004-2009[b]	95% Confidence Interval of the Average Retention Pond Effluent Concentrations from International BMP Database (Oct. 2007)	Interquartile Range (25th - 75th percentiles) of Retention Pond Effluent Concentrations from International BMP Database (Oct. 2007)
Total Suspended Solids (TSS)	mg/L	10.2	20.5 (6-63)	22.1-29.2	4.3-28.3
Total Phosphorus (TP)	mg/L	0.06	0.23 (0.01-0.63)	0.28-0.56	0.06-0.28
Dissolved Phosphorus (DP)	mg/L	0.03	0.06 (0.002-0.24)[c]	0.08-0.12	0.04-0.12
Total Nitrogen	mg/L	0.56	1.39 (0.8-2.1)[d]	1.23-1.55[e]	0.77-1.57[e]
Nitrate (NO_3)	mg/L	0.23	0.15 (0.1-0.37)	0.37-0.70	0.11-0.63
Total Copper (TCu)	ug/L	8.17	5.65 (1.8-11)	8.9-12.2	3.1-9.0
Total Lead (TPb)	ug/L	23.86	1.2 (0.2-2.5)	11.4-16.0	1.0-15.8
Total Zinc (TZn)	ug/L	41.51	20.97 (3.5-50)	28.3-37.6	7.2-37.2

[a] Computed from modeled annual load and modeled annual runoff volume leaving the Freshwater Marsh as reported in Playa Vista Phase I Environmental Impact Report (EIR) (CDM, 1992)
[b] Detection limits were substituted for all non-detects prior to computing summary statistics.
[c] DP is not monitored, therefore orthophosphate (PO4-P), which is the most bioavailable form of phosphorus and typically the largest component of dissolved phosphorus, has been compared with the modeled dissolved phosphorus value.
[d] TN is not monitored, so the calculated sum of total Kjeldahl nitrogen (TKN), nitrate, and nitrite is compared to the modeled TN value.
[e] TKN reported from the BMP Database as TN was not summarized.
International BMP Database: www.bmpdatabase.org

Figure 4. Least Bittern

PHOTO: EDITH READ

Treatment wetlands have been evaluated in terms of percentage of pollutants removed, but for various reasons this "removal efficiency" method has been found to be inadequate for measuring BMP performance (U.S. EPA 2009). Instead, outflow (effluent) water quality is evaluated. Performance of the Ballona Freshwater Wetland System as a treatment wetland was evaluated by comparing average modeled versus average measured outflow concentrations (Geosyntec 2010) (Table 1). Average measured concentrations have been lower than predicted for total copper, total lead, total zinc, and nitrate. Other constituents such as total suspended solids and total phosphorus have been more variable, but compared to the range of outflow values reported in the International Best Management Practice Database, the system appears to be performing better than similarly designed treatment systems for dissolved phosphorus, nitrate, total copper, total lead, and total zinc (Geosyntec 2010). Despite extensive use of the wetland by wildlife, measured outflow densities of fecal indicator bacteria, such as total coliforms, have not exceeded 5,000 MPN/100 ml, and are more typically below 1600 MPN/100 ml. These values are in the lower end of the range of total coliform densities of 1,000 to 1,000,000 MPN/100 ml reported for tidal channels of the Ballona Wetlands and Ballona Creek (Dorsey 2006).

Overall, monitoring results indicate that the Ballona Freshwater Wetland System is performing better than predicted for biological and water quality parameters, thus serving as a model for other systems that may be contemplated for urban watersheds. However, in addition to the high construction costs, it should be noted that this system is not self-sustaining and is costly to maintain because of its position in a highly urbanized watershed. Accordingly, it is critical that other contemplated systems account for ongoing, dedicated maintenance funding.

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Ballona Freshwater Wetlands

PHOTO: SARAH WOODARD

EDITH READ, *Ph.D., has managed and monitored the Ballona Freshwater Marsh since construction was completed in 2003. She has conducted numerous botanical surveys in the Ballona Wetlands over the past 17 years and serves as a technical advisor on the Board of Directors of Friends of Ballona Wetlands.*

Palos Verdes Peninsula, Portuguese Bend

PHOTO: SARAH WOODARD

The Notes and Abstracts section contains summaries of research and policy submitted to *Urban Coast*, as well as abstracts from current literature. In this section *Urban Coast* brings together innovative environmental research, technical studies, BMP or LID implementation, and policy developments to keep our readers abreast of the latest developments in urban coastal research and policy. We welcome suggestions for abstracts to include in this section as well as submittals. By submitting to *Urban Coast*, you will be reaching our stakeholders and decision makers, keeping them apprised of the latest thinking about environmental issues and solutions, and helping practitioners to share knowledge of how the vast array of techniques and tools available are being applied in urban coastal regions. Please direct correspondence to sbergquist@santamonicabay.org and swoodard@waterboards.ca.gov.

Policy

Scaling Up to Networks of Marine Protected Areas in the Philippines: Biophysical, Legal, Institutional, and Social Considerations. Lowry, G.K., A.T. White, and P. Christie. 2009. Coastal Management. 37(3&4):274-290.

Abstract

The growing number of marine protected areas (MPAs) globally represents an increasing interest in marine conservation and fisheries management and the potential of planned and managed MPA networks as a way of strengthening local management. This study documents the development of MPA networks in the Philippines and identifies critical success factors and issues. Methods were field observation by participation in MPA and fisheries management projects and focused interviews that gathered opinions and observations of primary MPA network stakeholders in the central Visayas region. Findings show that an MPA network is defined through social and ecological criteria. From a social perspective, a network is comprised of people and organizations that manage component MPAs, benefit from the network, and promote the network's viability through shared administrative responsibility and information. To qualify as part of an ecological network, individual MPAs must interact ecologically (e.g., source or sink of larvae and propagating organisms, protection for habitat, and threatened or endangered species) to enhance fisheries and biodiversity conservation. The study found that while social and ecological criteria are shaping MPA networks through science-based planning, integrated management, and coordination, there exist numerous institutional issues related to scaling up to networks from single MPAs. Issues pertain to: limiting access to resources, boundary delineation, monitoring compliance, finding common goals and identity, and conflict resolution. Factors correlated with management success included common institutional processes and legal support, improved understanding of benefits from a network and improved habitat conditions and fishery yields associated with MPAs.

Practicing Coastal Adaptation to Climate Change: Lessons from Integrated Coastal Management. Tobey, James, P. Rubinoff, D. Robadue Jr., G. Ricci, R. Volk, J. Furlow, and G. Anderson. 2010. Coastal Management. 38(3):317-335.

Abstract

The challenges faced in adapting to climate change present themselves with increasing urgency. Nowhere will these challenges be greater than in the developing world where often weak institutions and governance systems struggle to deal with mounting pressures from population growth, inadequate infrastructure, and diminishing or already

depleted natural resources. This article synthesizes the many global climate change and other anthropogenic threats to coastal ecosystems and draws on lessons and good practices from global experience in integrated coastal management (ICM) that can be transferred to coastal adaptation to these challenges. The case is made that the process and best practices of ICM are not radically changed by applying a climate lens. For the most part, the good practices of planning and implementation coastal management measures apply equally to climate change as they do to other coastal issues. However, there are some new and important considerations that enter into planning and decision-making with respect to climate change. These considerations include the need for an even greater emphasis on nature-based coastal protection strategies and measures, more pronounced issues of uncertainty in decision-making, the need for a longer planning horizon, and the importance of including in the decision-making equation opportunities to mitigate the sources of climate change with adaptation measures.

The Challenge of Threatened and Endangered Species Management in Coastal Areas. LeDee, Olivia E., K.C. Nelson, and F. J. Cuthbert. 2010. Coastal Management. 38(4):337-353.

Abstract

A substantial proportion of U.S. federally listed species inhabit a small fraction of the nation's land mass, the coastal zone. Historically, management in this region has been conflict-ridden among diverse parties interested in natural resource extraction, land use, and conservation. This tension persists today, albeit in a more contemporary form: public access demand versus ecosystem conservation. The focus of this study is the influence of this tension on local-level management of federally threatened and endangered species. We surveyed managers of 43 locations of ecological importance for a threatened shorebird, the Piping Plover (*Charadrius melodus*). Reflecting the federal mandate to accommodate both public access and ecosystem conservation, we detected a shift in mission from sole-purpose initiatives (e.g., public access or ecosystem conservation) to a multiple-use mission (i.e., resource-based recreation). Public access and ecosystem conservation were the primary management goals at surveyed sites, 97 and 93%, respectively. Accessible public recreation is common at most locations; however, active management for listed species is rare. Ultimately, local land managers are accountable for managing coastal sites for dual use, thus the tension; however, coastal management activities have yet to resolve the conflict between concurrent management of public access and ecological requirements of listed species.

Land Changes and Conflicts Coordination in Coastal Urbanization: A Case Study of the Shandong Peninsula in China. Xu, Xuegong, H. Peng, Q. Xu, H. Xiao, and G. Benoit. 2009. Coastal Management. 37(1):54-69.

Abstract

The coastal zone is an interaction region between land and ocean and an interface of geosphere, hydrosphere, atmosphere, and biosphere, as well as greatly affected by human activities. Driven by economic activities and increased population, urbanization is rapidly developing in coastal zones, and a series of land resource and environmental conflicts have occurred, especially in developing countries at times of economic transition. This article reports a case study of the Shandong Peninsula of East China. We analyze the land-use practices and land cover changes of six cities over a timeframe of nearly a decade. We then review the management conflict issues. The most commonly encountered conflicts fall into three categories: those between expanding constructed land and decreased cultivated land; those between land resource utilization and conservation; and those between increasing demand for land and degrading land quality. All in all, they reflect the fundamental conflicts between short-term economic development gains and long-term food security and ecosystem sustainability. This article puts forward an institutional approach to coordinate these conflicts so as to realize integrated and coordinated coastal management

Sea-level Rise Research and Dialogue in North Carolina: Creating Windows for Policy Change. Poulter, Benjamin, R.L. Feldman, M.M. Brinson, B.P. Horton, M.K. Orbach, S.H. Pearsall, E. Reyes, S.R. Riggs, and J.C. Whitehead. 2009. Ocean & Coastal Management 52(3-4):147-153.

Abstract

Coastal areas are among the world's most vulnerable landscapes to impacts related to climate change, including inundation from sea-level rise (SLR), increased exposure to shoreline erosion, and greater frequency and intensity of storms. The status of research on the physical, ecological, and socio-economic effects of vulnerability to SLR and progress toward planning for its consequences varies from region to region worldwide. Here, we synthesize the results of three decades of SLR research and the development of coastal management policies in North Carolina, USA. We identify the major factors responsible for opening new policy 'windows' that address SLR, including how stakeholders have developed an increased understanding of the risks, the extent of public dialogue about potential response strategies, and advances in political receptivity to policy change. Research and policy progress in North Carolina continue to provide a model for other regions to help guide and evaluate the development of coastal policies.

The Convergence of Integrated Coastal Zone Management and the Ecosystems Approach. Forst, Mark F. 2009. Ocean & Coastal Management. 52(6):294-306.

Abstract

The primary role of the Integrated Coastal Zone Management model was to arbitrate conflicts between stakeholders in a living and natural resource environment characterized by a common property and open access doctrine. A chronology of events describes how the development and acceptance of an ecosystems approach policy began to converge and coincide with the spread and development of Integrated Coastal Zone Management. Those organizations that gave representation

to the conservation ethic became internationally recognized as surrogate natural resource 'users', the interests of which possessed commonality with all stakeholder interests in general. The tenants of conservation policy were therefore largely employed to decide the merits of disputes over ocean and coastal resources. In the 1990s, scientists created a forum to debate, better define, and institutionalize a sound basis for ecosystem management theory and practice. Protocols were developed that embedded science in living and natural resources planning and management. These protocols were shaped and adopted to serve an evermore contemporary Integrated Coastal Zone Management model. Improvements in methodology include the use of adaptive management, ecological modeling and monitoring, appropriate temporal and spatial scales, salient indicators, and stakeholder participation. This contemporary approach is dependent upon recognizing the benefits inherent in utilizing instruments capable of managing resources on a holistic level. Bioregional planning and zoning accommodate the successful management of resources on this level. It is a direct outcome of the convergence of Integrated Coastal Zone Management and the ecosystems approach. Bioregional zoning schemes are capable of traversing the private property and common property doctrines that define the respective terrestrial and aquatic environments of the coastal zone. A comparative case study of the Great Barrier Reef Marine Park and the Belize Marine Protected Area Program is included as an annex, the analysis of which is predicated upon the principles espoused in the literature.

Integrated and Interdisciplinary Scientific Approach to Coastal Management. Tintoré, Joaquín, R. Medina, L. Gómez-Pujol, A. Orfila, and G. Vizoso. 2009. Ocean & Coastal Management. 52(10): 493-505

Abstract

Coastal zones and beach management practices, regulatory decisions, and land use planning activities along coastal zones have historically been made with insufficient information concerning the dynamic coastal environment. In this study we address and integrate an interdisciplinary scientific approach to Coastal Management in a scenario where lack of this information has resulted in the alteration of the natural dune system of the beach of Cala Millor (Mallorca, Balearic Islands, Spain), and also in the perception of the beach retreat and in a parallel way, a risk for the tourism resources. In this work the detailed studies on beach morphodynamics have been developed as a basis for integrating proper beach management, beach natural dynamics and local users and economic agent interests. From this point of view a set of solutions are considered as the basis for a management policy that links beach science and beach use as a tourism resort resource.

Sustainable Coastal Resources Management: Principles and Practice. Turner, R.K., W.N. Adger, S. Crooks, I. Lorenzoni, and L. Ledoux. 2009. Natural Resources Forum. 23(4):275-286.

Abstract

Coastal zones are currently experiencing intense and sustained environmental pressures from a range of driving forces. Responsible agencies around the globe are seeking ways of better managing the causes and consequences of the environmental change process in coastal areas. This article discusses the basic principles underpinning a more integrated approach to coastal management, as well as the obstacles to its implementation in both developed and developing countries. The fulfilment of the goal of sustainable utilisation of coastal resources via integrated management is likely to prove to be difficult. Any successful strategy will have to encompass all the elements of management from planning and design through financing and implementation. An interdisciplinary analytical and operational approach is also required, combined with a more flexible and participatory institutional structure and emphasis to account for multiple stakeholders and resource demands. As historical and institutional perspectives as well as socio-economic and cultural contexts are also important, two case studies (based on UK and Vietnamese experiences) are presented in order to identify arguments and examine these aspects in more detail.

Integrated Coastal Management: A Comparative Analysis of Four UK Initiatives. Stojanovic, T.A. and R.C. Ballinger. 2008. Applied Geography. 29(1):49-62.

Abstract

The effectiveness of institutional arrangements and policies for governance has become a key question within the sustainability paradigm, not least in coastal areas which have unique issues and jurisdictions across the land–sea interface. In the UK, approximately 60 non-statutory coastal management initiatives have been established at the local/regional level since the 1990s, based on a variety of programmes and projects. Proposals for a UK Marine Bill have raised questions about the role of non-statutory initiatives in the system of governance. The traditional sectoral approach to management and planning is being modified due to the pressure of increased human activities, but doubts exist about what effective contribution local and regional partnerships can make. The paper reports extensive examples of Integrated Coastal Management initiatives engaging institutions and society to produce outputs which have transformed management, promoting long-term, collaborative, participatory and ecologically sustainable approaches. The paper concludes that there are demonstrable benefits in taking a partnership approach to coastal management at a local level, yet these forms of planning and management are not widely accepted or embedded within the current system of governance.

Balancing Science and Society through Establishing Indicators for Integrated Coastal Zone Management in the Balearic Islands. Diedrich, A., J. Tintoré, and F. Navinés. 2010. Marine Policy. 34(4):772-781.

Abstract

This paper explores the process by which indicators may be developed as tools for communicating science to decision-makers using the participatory approach demonstrated by the Balearic Indicators Project. This initiative reflects a series of compromises considered necessary to achieve the objective of generating an indicator system that is

scientifically viable, comparative internationally yet locally relevant, and to facilitate its implementation. The article highlights questions regarding the utility of science for addressing current global issues related to sustainability and why science often fails to promote change at the societal level.

The Role of Research Networks for Science-policy Collaboration in Coastal Areas. Stojanovic, T.A., I. Ball, R.C. Ballinger, G. Lymbery, and W. Dodds. 2009. Marine Policy. 33(6):901-911.

Abstract

This paper reviews the approach taken by several UK coastal partnerships in developing research strategies and programmes. It reports on the status of these research initiatives and describes how the co-ordination and communication of scientific research have been approached through active partnerships with universities and the wider research community. Results of semi-structured interviews are followed by in-depth case studies of research networks on the Sefton Coast (focusing on coastal morphology) and the Severn Estuary (focusing on coastal change and climate change impacts). The results reveal the constraints and opportunities that exist in bringing together a variety of knowledge holders in the coastal zone. The paper identifies key elements of these initiatives and highlights lessons that can be applied to the development of other research initiatives in order to achieve science supported, ecosystem-based management.

Practice Versus Policy-led Coastal Defence Management. O'Connor, M.C., G. Lymbery, J.A.G. Cooper, J. Gault, and J. McKenna. 2009. Marine Policy. 33(6):923-929.

Abstract

Throughout northwest European coastal countries risks associated with coastal erosion are significant but spatially and temporally variable. The level of this risk is largely dependent on the extent of development within the coastal zones and a variety of approaches have been adopted for its management. The decision-making process for responding to erosion risk depends to a large extent on national policy. Coastal protection policy in northwest European countries varies in terms of the level of centralisation and formality of arrangements. In this paper the practical outworking of the informal practice-based system of Ireland, where there is no national policy framework, is compared with the policy-led system of England and Wales where formal national guidelines exist. Using case studies, the strengths and weaknesses of both the bottom-up and top-down approaches are assessed. The findings reveal strengths and weaknesses in both existing types of approach.

Successful Integrated Coastal Zone Management (ICZM) Program Model of a Developing Country (Xiamen, China) – Implementation in Bangladesh Perspective. Islam, Kazi Shakila, X. Xue, and M.M. Rahman. 2009. Journal of Wetland Ecology. 2(1&2):34-40.

Abstract

This paper represents the overall current situation of two Integrated Coastal Zone Management (ICZM) programs- one is as a successful model like Xiamen ICZM program in China and another is as a developing project like ICZM program in Bangladesh. The paper begins with an attempt to track the evolution of policies and their implementation on coastal zone management with particular reference from both the countries. It then discusses the coastal management and livelihood issues that predicate the different socio-economic and environmental situation between the two countries. The paper then goes on to discussion how the institutional management and policy initiatives of Xiamen ICZM have dealt with in the perspective of Bangladesh. There is a brief consideration of the progress of the management for ICZM of Bangladesh and how this project might be more effective and beneficial for Bangladesh.

Geographic Information Systems Applied to Integrated Coastal Zone Management. Rodríguez, I., I. Montoya, M.J. Sánchez, and F. Carreño. 2009. Geomorphology. 107(1-2):100-105.

Abstract

The littoral is the area where marine and terrestrial processes superpose and interact. Limits of their respective actions are imprecise, as processes which are characteristic of each of these environments do overlap. This particular characteristic makes the littoral zone complex and vulnerable to human activity, which in many cases, causes irretrievable damage to the natural equilibrium. Integrated Coastal Zone Management (ICZM) promotes sustainable coastal development by adapting the use of natural resources in a way that avoids serious damage to the natural environment. This requires an integrated and organized action of all institutions that are involved in coastal development. Geographic Information Systems (GIS) besides being a useful tool for drawing maps on different scales and projections constitutes an excellent instrument for data analysis and integration due to its ability to identify spatial connections between different information layers. In this way, it is possible to build models for geomorphological evolution and predict changes in the coastal areas. In order to illustrate this, three examples of GIS applications are presented, which are currently being developed in different areas of the Spanish littoral, coastal hazards, shoreline evolution and coastal sand dune evolution, respectively.

Nature Conservation for Future Sustainable Shorelines: Lessons from Seeking to Involve the Public. Milligan, Jessica, T. O'Riordan, S.A. Nicholson-Cole, and A.R. Watkinson. 2009. Land Use Policy. 26(2):203-213.

Abstract

The soft coastline of eastern England is dynamic, with much of it subject to the risk of erosion or flooding. A number of internationally important coastal nature conservation sites are under threat. This paper explores the character and reasoning behind changing coastal management policies and governance practices in England. It reveals how Natural England is tackling these changes, notably with regard to establishing

reconstituted nature conservation sites and re-designed coastlines. Such an approach requires the close involvement of policy leaders, agency officers, local maritime authorities and local residents. This paper explains how participatory processes play a critical role in the design of new coastlines that are ecologically and geomorphologically sustainable yet enable local communities to survive and flourish. A case study involving a visioning exercise at Winterton-on-Sea in Norfolk, UK, highlights the many practical difficulties around planning for the uncertain future of internationally important nature conservation sites, and local economies and communities. Future moves toward sustainable coastal alignments will have to involve a wide mix of public and civic bodies, as well as local communities, and will be underpinned by risk-based planning and well-researched adaptation and relocation arrangements.

Multiscale Analysis of Restoration Priorities for Marine Shoreline Planning. Diefenderfer, Heida L., K.L. Sobocinski, R.M. Thom, C.W. May, A.B. Borde, S.L. Southard, J. Vavrinec, and N.K. Sather. 2009. Environmental Management. 44(4):712-731.

Abstract

Planners are being called on to prioritize marine shorelines for conservation status and restoration action. This study documents an approach to determining the management strategy most likely to succeed based on current conditions at local and landscape scales. The conceptual framework based in restoration ecology pairs appropriate restoration strategies with sites based on the likelihood of producing long-term resilience given the condition of ecosystem structures and processes at three scales: the shorezone unit (site), the drift cell reach (nearshore marine landscape), and the watershed (terrestrial landscape). The analysis is structured by a conceptual ecosystem model that identifies anthropogenic impacts on targeted ecosystem functions. A scoring system, weighted by geomorphic class, is applied to available spatial data for indicators of stress and function using geographic information systems. This planning tool augments other approaches to prioritizing restoration, including historical conditions and change analysis and ecosystem valuation.

Managing Coastal Area Resources by Stated Choice Experiments. Liu, Xin and K.W. Wirtz. 2009. Estuarine, Coastal, and Shelf Science. 86(3):512-517.

Abstract

In many coastal regions, oil spills can be considered as one of the most important and certainly the most noticeable forms of marine pollution. Efficient contingency management responding to oil spills on waters, which aims at minimizing pollution effects on coastal resources, turns out to be critically important. Such a decision making highly depends on the importance attributed to different coastal economic and ecological resources. Economic uses can, in principal, be addressed by standard measures such as value added. However, there is a missing of market in the real world for natural goods. Coastal resources such as waters and beach cannot be directly measured in money terms, which increases the risk of being neglected in a decision making process. This paper evaluates these natural goods of coastal environment in a hypothetical market by employing stated choice experiments. Oil spill management practice in German North Sea is used as an example. Results from a pilot survey show that during a combat process, beach and eider ducks are of key concerns for households. An environmental friendly combat option has to be a minor cost for households. Moreover, households with less children, higher monthly income and a membership of environmental organization are more likely to state that they are willing to pay for combat option to prevent coastal resources from an oil pollution. Despite that choice experiments require knowledge of designing questionnaire and statistical skills to deal with discrete choices and conducting a survey is time consumed, the results have important implications for oil spill contingency management. Overall, such a stated preference method can offer useful information for decision makers to consider coastal resources into a decision making process and can further contribute to finding a cost-effective oil preventive measure, also has a wide application potential in the field of Integrated Coastal Zone Management (ICZM).

Pollution

A Comparative Study of Macrobenthic Community from Harbours Along the Central West Coast of India. Ingole, B., S. Sivadas, M. Nanajkar, S. Sautya, and A. Nag. 2009. Environmental Monitoring and Assessment. 154(1-4):135-146.

Abstract

Harbours are heavily stressed coastal habitats characterised by high concentration of contaminant and low diversity of benthic community. The west coast of India harbours most of the major harbours compared to the east coast. Very few studies have compared the macrobenthic community between different Indian harbours. The present study was therefore conducted in three important harbour (Ratnagiri, Goa, Karwar) along the central west coast of India. The paper discusses the health status of the three harbours diagnosed using various biotic indices. Sediment samples were collected using van Veen grab (0.11 m2) on board CRV Sagar Sukti. A total of 55 macrobenthic taxa were identified and were numerically dominated by polychaete. Biomass was high (0.14–145.7 g m−2) and was made largely by echiurans (›80%). Overall, polychaete dominated the macrobenthic diversity. Opportunistic *P.pinnata, Notomastus sp. and Mediomastus sp*., dominated the macrobenthic community responding to the increased in the harbour. Biotic indices (Polychaete:Amphipod ratio, ABC curve and geometric class abundance) and the dominance of opportunistic species indicate that, the three harbours are under stress from anthropogenic activities.

Marine Debris Contamination along Undeveloped Tropical Beaches from Northeast Brazil. Santos, Isaac R., A.C. Friedrich, and J.A. Ivar do Sul. 2009. Environmental Monitoring and Assessment. 148(1-4):455-462.

Abstract

We hypothesize that floating debris leaving polluted coastal bays accumulate on nearby pristine beaches. We examined

composition, quantities, and distribution of marine debris along ~ 150 km of relatively undeveloped, tropical beaches in Costa do Dendê (Bahia, Brazil). The study site is located south of Salvador City, the largest urban settlement from NE Brazil. Strong spatial variations were observed. Plastics accounted for 76% of the sampled items, followed by styrofoam (14%). Small plastic fragments resultant from the breakdown of larger items are ubiquitous all over the area. Because the dominant littoral drift in Bahia is southward, average beach debris densities (9.1 items/m) along Costa do Dendê were threefold higher than densities previously observed north of Salvador City. River-dominated and stable beaches had higher debris quantities than unstable, erosional beaches. Areas immediately south of the major regional embayments (Camamu and Todos os Santos) were the preferential accumulation sites, indicating that rivers draining populous areas are the major source of debris to the study site. Our results provide baseline information for future assessments. Management actions should focus on input prevention at the hydrographic basin level rather than on cleaning services on beaches.

Anthropogenic Impacts on Heavy Metal Concentrations in the Coastal Sediments of Dumai, Indonesia. Amin, Bintal, A. Ismail, A. Arshad, C.K. Yap, and M.S. Kamarudin. 2009. Environmental Monitoring and Assessment. 148(1-4): 291-305.

Abstract

Concentrations of Cd, Cu, Pb, Zn, Ni and Fe were determined in the surface sediments to investigate the distributions, concentrations and the pollution status of heavy metals in Dumai coastal waters. Sediment samples from 23 stations, representing 5 different site groups of eastern, central and western Dumai and southern and northern Rupat Island, were collected in May 2005. The results showed that heavy metal concentrations (in μg/g dry weight; Fe in %) were 0.88 (0.46–1.89); 6.08 (1.61–13.84); 32.34 (14.63–84.90); 53.89 (31.49–87.11); 11.48 (7.26–19.97) and 3.01 (2.10–3.92) for Cd, Cu, Pb, Zn, Ni and Fe, respectively. Generally, metal concentrations in the coastal sediments near Dumai city center (eastern and central Dumai) which have more anthropogenic activities were higher than those at other stations. Average concentration of Cd in the eastern Dumai was slightly higher than effective range low (ERL) but still below effective range medium (ERM) value established by Long et al. (Environmental Management 19(1):81–97, 1995; Environmental Toxicology Chemistry 17(4):714–727, 1997). All other metals were still below ERL and ERM. Calculated enrichment factor (EF), especially for Cd and Pb, and the Pollution load index (PLI) value in the eastern Dumai were also higher than other sites. Cd showed higher EF when compared to other metals. Geo-accumulation indices (I geo) in most of the stations (all site groups) were categorized as class 1 (unpolluted to moderately polluted environment) and only Cd in Cargo Port was in class 2 (moderately polluted). Heavy metal concentrations found in the present study were comparable to other regions of the world and based on the calculated indices it can be classified as unpolluted to moderately polluted coastal environment.

Power Analysis for Biomarkers in Mussels for Use in Coastal Pollution Monitoring. Fang, J.K.H., R.S.S. Wu, C.K.M. Yip, and P.K.S. Shin. 2009. Marine Pollution Bulletin. 58(8):1152-1158.

Abstract

Data from literature on neutral red retention time (NRRT) in lysosomes, micronucleus (MN) frequency and condition index (CI) in mussel *Mytilus*, especially *Mytilus edulis* and *Mytilus galloprovincialis*, were re-analyzed to ascertain their statistical power in detecting a minimum 20% spatial/temporal change in field studies. Results showed that CI largely displayed higher statistical power (›90%) than lysosomal NRRT and MN frequency (‹50%), suggesting that data from the latter two biomarkers may lead to erroneous conclusions if sample size is inadequate. Samples of green-lipped mussel *Perna viridis* were also analyzed in Hong Kong. To achieve statistically valid power, the optimal sample sizes for monitoring lysosomal NRRT, MN frequency, CI and gonosomatic index (GSI) were determined as 34, 90, 16 and 29, respectively. Natural variability of lysosomal NRRT and MN frequency was significantly greater than CI and/or GSI in mussels, rejecting the general belief in the greater variability of higher-tiered hierarchical biomarkers.

Temporal Variation of Chlorophyll a Concentration in the Coastal Waters Affected by the Hebei Spirit Oil Spill in the West Sea of Korea. Lee, Chung Il, M.C. Kim, and H. C. Kim. 2009. Marine Pollution Bulletin. 58(4):496-502.

Abstract

Time series changes in chlorophyll a concentration before and after the Hebei Spirit oil spill that occurred in December 2007 were analyzed using NCEP wind and SeaWiFS/MODIS ocean color data. Prevailing southwesterly winds and northeast/southwestward tidal currents pushed the oil towards Korea's West Sea coast of Taean. After the oil spill, daily chlorophyll a concentration decreased about 45–50% compared to the normal condition before the oil spill, and this decrease continued for about two weeks. Monthly mean chlorophyll a concentration in December 2007 was lower compared to the average value for the same month between 1998 and 2007, but, in October and November 2007 before the spill and in January–February 2008 after the spill, the concentration value was higher than average for the same period between 1998 and 2007.

Detection of Spatial Fluctuations of Non-point Source Fecal Pollution in Coral Reef Surrounding Waters in Southwestern Puerto Rico using PCR-based Assays. Bonkosky, M., E.A. Hernández-Delgado, B. Sandoz, I.E. Robledo, J. Norat-Ramírez, and H. Mattei. 2009. Marine Pollution Bulletin. 58(1):45-54.

Abstract

Human fecal contamination of coral reefs is a major cause of concern. Conventional methods used to monitor microbial water quality cannot be used to discriminate between different fecal pollution sources. Fecal coliforms, enterococci, and human-specific *Bacteroides* (HF183, HF134), general *Bacteroides*-

Prevotella (GB32), and *Clostridium coccoides* group (CP) 16S rDNA PCR assays were used to test for the presence of non-point source fecal contamination across the southwestern Puerto Rico shelf. Inshore waters were highly turbid, consistently receiving fecal pollution from variable sources, and showing the highest frequency of positive molecular marker signals. Signals were also detected at offshore waters in compliance with existing microbiological quality regulations. Phylogenetic analysis showed that most isolates were of human fecal origin. The geographic extent of non-point source fecal pollution was large and impacted extensive coral reef systems. This could have deleterious long-term impacts on public health, local fisheries and in tourism potential if not adequately addressed.

Impact of Petroleum Pollution on Aquatic Coastal Ecosystems in Brazil. Da Silva, Eduardo Mendes, M.C. Peso-Aguiar, M.D.F.T. Navarr , and C.D.B.E.A. Chastinet. 2009. Environmental Toxicology and Chemistry. 16(1):112-118.

Abstract

Although oil activities generate numerous forms of environmental impact on biological communities, studies of these impacts on Brazilian coastal ecosystems are rare. Results of tests for the content of oil in sediments and organisms indicate a substantially high rate of degradation. Results for uptake of polycyclic aromatic hydrocarbons in bivalves suggested the recent occurrence of oil spills and that these organisms differed in their capabilities to bioconcentrate oil. The mangrove community has suffered constant inputs of oil and has responded with increased numbers of aerial roots, generation of malformed leaves and fruits by plants, and a decrease in litter production. Studies of the impact of oil on rocky shore communities and the toxicity of oil and its by-products to marine organisms have confirmed the results reported in the literature. Presently most of the available studies deal with the macroscopic effects of oil on organisms and have indicated that the nature of oil, climate characteristics, the physical environment, and the structure of the community influence the symptoms of oil contamination in organisms of coastal waters. Longterm studies should be carried out to assess changes in community structure, sublethal effects in populations, and the resilience of contaminated ecosystems.

Predicting Toxicity in Marine Sediments with Numerical Sediment Quality Guidelines. Long, Edward R., L.J. Field, and D.D. MacDonald. 2009. Environmental Toxicology and Chemistry. 17(4):714-727.

Abstract

Matching synoptically collected chemical and laboratory bioassay data (n = 1,068) were compiled from analyses of surficial sediment samples collected during 1990 to 1993 to evaluate the predictive ability of sediment quality guidelines (SQGs), specifically, effects range - low (ERL), effects range - median (ERM), threshold effects level (TEL), and probable effects level (PEL) values. Data were acquired from surveys of sediment quality performed in estuaries along the Atlantic, Pacific, and Gulf of Mexico coasts. Samples were classified as either nontoxic ($p > 0.05$ relative to controls), marginally toxic ($p < 0.05$ only), or highly toxic ($p < 0.05$ and response greater than minimum significant difference relative to controls). This analysis indicated that, when not exceeded, the ERLs and TELs were highly predictive of nontoxicity. The percentages of samples that were highly toxic generally increased with increasing numbers of guidelines (particularly the ERMs and PELs) that were exceeded. Also, the incidence of toxicity increased with increases in concentrations of mixtures of chemicals normalized to (divided by) the SQGs. The ERMs and PELs indicated high predictive ability in samples in which many substances exceeded these concentrations. Suggestions are provided on the uses of these estimates of the predictive ability of sediment guidelines.

Identifying Major Pesticides Affecting Bivalve Species Exposed to Agricultural Pollution Using Multi-biomarker and Multivariate Methods. Damásio, Joana, A. Navarro-Ortega, R. Tauler, S. Lacorte, D. Barceló, A.M.V.M. Soares, M.A. López, M.C. Riva, and C. Barata. 2009. Ecotoxicology. 19(6):1084-94.

Abstract

The aim of this investigation was to identify major pesticides that may cause detrimental effects in bivalve species affected by agricultural pollution. Investigations were carried out using freshwater clams (*Corbicula fluminea*) transplanted in the main drainage channels that collect the effluents coming from agriculture fields in the Ebro Delta (NE Spain) during the main growing season of rice (from May to August). Environmental hazards were assessed by measuring simultaneous up 46 contaminant levels and 9 biomarker responses. Measured biological responses showed marked differences across sites and months. Antioxidant and esterase enzyme responses were in most cases inhibited. Lipid peroxidation levels increased steadily from May in upstream stations to August in drainage channels. Principal Component (PCA) and Partial Least Squares to Latent Structure regression (PLS) analyses allowed the identification of endosulfan, propanil, and phenylureas as being the chemical contaminants causing the most adverse effects in the studied species.

Coastal Zone Mapping For Oil Spill Emergency Management. Assilzadeh, H., Y. Gao, and J.K. Levy. 2009. Sea Technology. 50(9):33-38.

Abstract

The Canadian coastal and marine environments contain many sensitive species, habitats and resources that could be severely affected by oil pollution. Accordingly, protection of the marine environment from oil spills is a high priority for Canada. Since it is not always possible to prevent these spills, it is important to address their consequences. In order to combat pollution from marine oil spills successfully, Canada must have an effective response strategy. A successful operation to combat a marine oil spill depends on a rapid response, from the time the oil spill is reported until it has been fully combated. The use of modeling, spatial analysis and a near-real-time system can assist decision makers in making better informed judgments that will affect the governance and management of the ocean environment during an oil spill.

Monitoring

Monitoring the Effects of Temperature Variability and Fishing Pressure on Fish Populations at Rocky Point, Palos Verdes. Muñoz, Chelsea E., M.L. Hansler, D.L. Hanson, J. P. Williams and D.J. Pondella, II. 2010. Vantuna Research Group at Occidental College.

Project Summary

The Vantuna Research Group at Occidental College has been performing diver transects of fish at Rocky Point, Palos Verdes since 1974. This extensive database allows us to see the effects of large scale, long-term oceanographic phenomena, changes in fishing regulations, and assess the health of one of the largest kelp forest communities in Santa Monica Bay. An examination of the abundance and age of commercially and recreationally important species over the last 35 years shows significant changes in the community structure in relation to specific oceanographic events and changes in fishing regulations. These observations can show us what to expect as the next regime shift looms and areas like Rocky Point remain unprotected from recreational and commercial fishing pressure.

The Pacific Decadal Oscillation (PDO) regime shift of the late 1970's resulted in warmer waters along the Eastern Pacific coastline and an increase in ambient temperature. In particular, blue rockfish (*Sebastes mystinus*) and the olive rockfish (*S. serranoides*) showed a distinct drop in numbers after the PDO shift of 1977. This may be attributed to their affinity for cold-water environments of deeper waters and more northern latitudes. The regime shift also caused an increase in sightings of fish with warm-water affinities such as the California sheephead (*Semicossyphus pulcher*). Sheephead appear to be a strong indicator species for this reef as, their density correlates with the temperature fluctuations caused by the El Niño/Southern Oscillation events and Pacific Decadal Oscillation. The increase in abundance in the late 1970s and early 1980s is highly correlated with the shift to a PDO warm phase. Their subsequent decline in numbers was most likely due to increased commercial fishing pressure during the 1980's. Once stricter size and bag limit regulations were imposed in 1999, the size and density of sheephead increased within six years. Unlike the California sheephead, fishing regulations for kelp bass (*Paralabrax clathratus*) have remained unaltered since the 1950s. Following the peak in abundance during the early 1980's, kelp bass decreased in size and number, suggesting heavy fishing pressure.

The nearshore gillnet ban that was enacted in 1994 has previously been shown to increase the number of large, predatory fishes that are not typically seen during diver surveys. One of those species, the giant seabass (*Stereolepis gigas*) had not been seen on a transect since the beginning of the study, but has been seen with regularity since. Other fish species included in this study are likely to have benefited for the ban as well, but most were never targeted and appeared in gillnets only as bycatch. The potential increase in abundance for these species is likely negated by other fishing pressures and habitat degradation.

Given the continuation of current trends, and without further protection in the form of slot limits, bag limits, and general protection of the reef community, the average size and number of commercially and recreationally important species at Rocky Point will continue to decline.

Rain Barrel Usage in Los Angeles. Chang, Johanna and M. Hanna. 2010. Los Angeles Department of Water and Power.

Project Summary

A simple spreadsheet model was developed to understand the water conservation benefits of rain barrels in Los Angeles. Input data include precipitation, rain barrel capacity, tributary roof area, number of days following a rain event before the rain barrel is used, and the number of gallons used per rain barrel per day. Using actual precipitation data from 1938 to present, a 60-gallon rain barrel, and a tributary roof area of 600 square feet, while assuming that the rain barrel will not be used for seven days following a rain event and that 10 gallons per day will be used, a rain barrel could potentially be filled and emptied seven times per year, on average. Seven fills in a 60-gallon rain barrel equates to 420 gallons of water. Interestingly, the year type (wet or dry) had little effect on this value. In wet years the rain barrel overflows. Conversely in dry years the rain barrels caught much of the rain, there just was not much to catch. The model is very sensitive to rain barrel size and tributary roof area, especially when both variables were adjusted in concert.

Results of this modeling effort were applied to projected water rates from the Metropolitan Water District of Southern California (MWD). Beginning on January 1, 2010 MWD rates for Tier II treated water will be $810.00 per acre-foot (approx. 326,000 gallons). Assuming the life of a rain barrel is 30 years and that water rates will increase at 5% per year, the overall water supply benefit for a rain barrel equates to close to $70.00. Unfortunately the additional benefits of water quality and flood protection are not included in this analysis, however it is presumed that the overall benefits in terms of dollars would be much greater if those were calculated and included.

Spatial and Temporal Modeling of Beach Use: A Case Study of East Anglia, UK. Coombes, E.G., A.P. Jones, I.J. Bateman, J.A. Tratalos, J.A. Gill, D.A. Showler, A.R. Watkinson, and W.J. Sutherland. 2009. Coastal Management. 37(1):94-115.

Abstract

As tourists are sensitive to weather conditions and changes to the environments they visit, it is likely that climate change will affect coastal recreation in the future. To understand these impacts, it is first important to quantify how visitor numbers are associated with beach characteristics and weather patterns. Using the East Anglian coastline, UK, as a case study, information on the spatial distribution of visitors recorded

from aircraft flights is combined with beach characteristic data in a Geographical Information System. In addition, surveys are undertaken at two beaches to assess temporal variations in visitation. The study finds a diverse range of characteristics are associated with visitor numbers. These findings are evaluated alongside the anticipated effects of climate change and management policies. Although it is predicted that warmer weather will increase visitor numbers overall, sea-level rise may reduce numbers at wide sandy beaches, which are currently most preferred by tourists.

Accelerating Loss of Seagrasses Across the Globe Threatens Coastal Ecosystems. Waycott, Michelle, C.M. Duarte, T.J.B. Carruthers, R.J. Orth, W.C. Dennison, S. Olyarnik, A. Calladine, J.W. Fourqurean, K.L. Heck, Jr., A.R. Hughes, G.A. Kendrick, W.J. Kenworthy, F.T. Short, and S.L. Williams. 2009. Proceedings of the National Academy of Sciences of the United States of America. 106(30):12377-12381.

Abstract

Coastal ecosystems and the services they provide are adversely affected by a wide variety of human activities. In particular, seagrass meadows are negatively affected by impacts accruing from the billion or more people who live within 50 km of them. Seagrass meadows provide important ecosystem services, including an estimated $1.9 trillion per year in the form of nutrient cycling; an order of magnitude enhancement of coral reef fish productivity; a habitat for thousands of fish, bird, and invertebrate species; and a major food source for endangered dugong, manatee, and green turtle. Although individual impacts from coastal development, degraded water quality, and climate change have been documented, there has been no quantitative global assessment of seagrass loss until now. Our comprehensive global assessment of 215 studies found that seagrasses have been disappearing at a rate of 110 km2 yr–1 since 1980 and that 29% of the known areal extent has disappeared since seagrass areas were initially recorded in 1879. Furthermore, rates of decline have accelerated from a median of 0.9% yr–1 before 1940 to 7% yr–1 since 1990. Seagrass loss rates are comparable to those reported for mangroves, coral reefs, and tropical rainforests and place seagrass meadows among the most threatened ecosystems on earth.

An Integrated Approach to Assess Broad-scale Condition of Coastal Wetlands—The Gulf of Mexico Coastal Wetlands Pilot Survey. Nestlerode, Janet A., V.D. Engle, P. Bourgeois, P.T. Heitmuller, J.M. Macauley, and Y.C. Allen. 2009. Environmental Monitoring and Assessment. 150(1-4):21-29.

Abstract

The Environmental Protection Agency (EPA) and U.S. Geological Survey (USGS) initiated a two-year regional pilot survey in 2007 to develop, test, and validate tools and approaches to assess the condition of northern Gulf of Mexico (GOM) coastal wetlands. Sampling sites were selected from estuarine and palustrine wetland areas with herbaceous, forested, and shrub/scrub habitats delineated by the US Fish and Wildlife Service National Wetlands Inventory Status and Trends (NWI S&T) program and contained within northern GOM coastal watersheds. A multi-level, stepwise, iterative survey approach is being applied to multiple wetland classes at 100 probabilistically-selected coastal wetlands sites. Tier 1 provides information at the landscape scale about habitat inventory, land use, and environmental stressors associated with the watershed in which each wetland site is located. Tier 2, a rapid assessment conducted through a combination of office and field work, is based on best professional judgment and on-site evidence. Tier 3, an intensive site assessment, involves on-site collection of vegetation, water, and sediment samples to establish an integrated understanding of current wetland condition and validate methods and findings from Tiers 1 and 2. The results from this survey, along with other similar regional pilots from the Mid-Atlantic, West Coast, and Great Lakes Regions will contribute to a design and implementation approach for the National Wetlands Condition Assessment to be conducted by EPA's Office of Water in 2011.

Monitoring the Changing Position of Coastlines Using Aerial and Satellite Image Data: An Example from the Eastern Coast of Trabzon, Turkey. Sesli, Faik Ahmet, F. Karsli, I. Colkesen, and N. Akyol. 2009. Environmental Monitoring and Assessment. 153(1-4):391-403.

Abstract

Coastline mapping and coastline change detection are critical issues for safe navigation, coastal resource management, coastal environmental protection, and sustainable coastal development and planning. Changes in the shape of coastline may fundamentally affect the environment of the coastal zone. This may be caused by natural processes and/or human activities. Over the past 30 years, the coastal sites in Turkey have been under an intensive restraint associated with a population press due to the internal and external touristic demand. In addition, urbanization on the filled up areas, settlements, and the highways constructed to overcome the traffic problems and the other applications in the coastal region clearly confirm an intensive restraint. Aerial photos with medium spatial resolution and high resolution satellite imagery are ideal data sources for mapping coastal land use and monitoring their changes for a large area. This study introduces an efficient method to monitor coastline and coastal land use changes using time series aerial photos (1973 and 2002) and satellite imagery (2005) covering the same geographical area. Results show the effectiveness of the use of digital photogrammetry and remote sensing data on monitoring large area of coastal land use status. This study also showed that over 161 ha areas were filled up in the research area and along the coastal land 12.2 ha of coastal erosion is determined for the period of 1973 to 2005. Consequently, monitoring of coastal land use is thus necessary for coastal area planning in order to protecting the coastal areas from climate changes and other coastal processes.

Application of a Remote Sensing Technique to the Study of Coastal Dunes. Delgado-Fernandez, Irene, R. Davidson-Arnott, and J. Ollerhead. 2009. Journal of Coastal Research. 25(5):1160-1167.

Abstract

This paper reports on a remote sensing station specifically designed to investigate eolian processes at a beach–dune system. The monitoring station is located at Greenwich Dunes, Prince Edward Island National Park, Prince Edward Island (Canada), and it is the second, improved generation of a previous system using continuous video and photographs. The setup consists of three digital single-lens reflex cameras, a two-dimensional sonic anemometer, two safires, erosion–deposition pins, and an array of batteries and solar panels. The cameras run on a timer that takes pictures every hour. The images are rectified and analyzed using a combination of ArcMap 9.2 and PCI Geomatica software, which permits the generation of moisture maps, vegetation, ice and snow cover, shoreline position, and erosion–deposition processes. The two-dimensional sonic provides continuous wind speed and direction, and the saltation probes record the intensity of transport events. The result is a large geodatabase of a time series of factors affecting eolian processes at the beach at a variety of temporal and spatial scales. This geodatabase can be queried, and it is a valuable tool for studying the frequency and magnitude of events delivering sediment from the beach to the dune and thus for improving our knowledge of sediment transport at coastal areas. Although the remote sensing station was initially conceived as a tool to measure subaerial processes, a full year of measurements shows large potential for the system to provide information on processes at the nearshore environment and ice dynamics.

Mapping Ecosystem Functions to the Valuation of Ecosystem Services: Implications of Species–habitat Associations for Coastal Land-use Decisions. Sanchirico, James N. and P. Mumby. 2009. Theoretical Ecology. 2(2):67-77.

Abstract

Habitats and the ecosystem services they provide are part of the world's portfolio of natural capital assets. Like many components of this portfolio, it is difficult to assess the full economic value of these services, which tends to over-emphasize the value of extractive activities such as coastal development. Building on recent ecological studies of species–habitat linkages, we use a bioeconomic model to value multiple types of habitats as natural capital, using mangroves, sea grass, and coral reefs as our model system. We show how key ecological variables and processes, including obligate and facultative behaviors map into habitat values and how the valuation of these ecological processes can inform decisions regarding coastal development (habitat clearing). Our stylized modeling framework also provides a clear and concise road map for researchers interested in understanding how to make the link between ecosystem function, ecosystem service, and conservation policy decisions. Our findings also highlight the importance of additional ecological research into how species utilize habitats and that this research is not just important for ecological science, but it can and will influence ecosystem service values that, in turn, will impact coastal land-use decisions. While refining valuation methods is not necessarily going to lead to more rational coastal land-use decisions, it will improve our understanding on the ecological–economic mechanisms that contribute to the value of our natural capital assets.

Threats to Sandy Beach Ecosystems: A Review. Defeo, Omar, A. McLachlan, D.S. Schoeman, T.A. Schlacher, J. Dugan, A. Jones, M. Lastra, and F. Scapini. 2009. Estuarine, Coastal, and Shelf Science. 81(1):1-12.

Abstract

We provide a brief synopsis of the unique physical and ecological attributes of sandy beach ecosystems and review the main anthropogenic pressures acting on the world's single largest type of open shoreline. Threats to beaches arise from a range of stressors which span a spectrum of impact scales from localised effects (e.g. trampling) to a truly global reach (e.g. sea-level rise). These pressures act at multiple temporal and spatial scales, translating into ecological impacts that are manifested across several dimensions in time and space so that today almost every beach on every coastline is threatened by human activities. Press disturbances (whatever the impact source involved) are becoming increasingly common, operating on time scales of years to decades. However, long-term data sets that describe either the natural dynamics of beach systems or the human impacts on beaches are scarce and fragmentary. A top priority is to implement long-term field experiments and monitoring programmes that quantify the dynamics of key ecological attributes on sandy beaches. Because of the inertia associated with global climate change and human population growth, no realistic management scenario will alleviate these threats in the short term. The immediate priority is to avoid further development of coastal areas likely to be directly impacted by retreating shorelines. There is also scope for improvement in experimental design to better distinguish natural variability from anthropogenic impacts. Sea-level rise and other effects of global warming are expected to intensify other anthropogenic pressures, and could cause unprecedented ecological impacts. The definition of the relevant scales of analysis, which will vary according to the magnitude of the impact and the organisational level under analysis, and the recognition of a physical–biological coupling at different scales, should be included in approaches to quantify impacts. Zoning strategies and marine reserves, which have not been widely implemented in sandy beaches, could be a key tool for biodiversity conservation and should also facilitate spillover effects into adjacent beach habitats. Setback and zoning strategies need to be enforced through legislation, and all relevant stakeholders should be included in the design, implementation and institutionalisation of these initiatives. New perspectives for rational management of sandy beaches require paradigm shifts, by including not only basic ecosystem principles, but also incentives for effective governance and sharing of management roles between government and local stakeholders.

Mapping and Monitoring Intertidal Benthic Habitats: A Review of Techniques and a Proposal for a New Visual Methodology for the European Coasts. Godet , Laurent, J. Fournier, N. Toupoint, and F. Olivier. 2009. Progress in Physical Geography. 33(3):378-402.

Abstract

Mapping seafloors is a fundamental step for managing and preserving coastal zones. Moreover, in a context of current global environmental changes, new methods allowing long-term monitoring are increasingly required. Various methods have been used to map seafloors, primarily benthic macrofauna and sediment sampling along regular grids or transects, and remote sensing methods. These methods map very different things, do not have the same accuracy levels, and have different costs in time and money. Furthermore, such methods often require the competencies of highly skilled scientists and exclude non-specialists otherwise best placed to perform them. In this paper, we test a method based on Direct Field Observations ('DFO method'), which can be used by non-specialists, and assess if it is sufficient for mapping and monitoring intertidal habitats. We further compare this method with other conventional ones. The results show that such a simple method is relatively rapid and inexpensive given the results obtained. Moreover, it is particularly suitable for highly fragmented intertidal landscapes where other methods are often very limited. In consequence, in areas such as the European coasts, it can be used by non-specialists, such as protected-area managers, and because it is an inexpensive and quick method long-term monitoring is also possible.

Application of a Remote Sensing Technique to the Study of Coastal Dunes. Delgado-Fernandez, Irene, R. Davidson-Arnott, and J. Ollerhead. 2009. Journal of Coastal Research. 25(5):1160-1167.

Abstract

This paper reports on a remote sensing station specifically designed to investigate eolian processes at a beach–dune system. The monitoring station is located at Greenwich Dunes, Prince Edward Island National Park, Prince Edward Island (Canada), and it is the second, improved generation of a previous system using continuous video and photographs. The setup consists of three digital single-lens reflex cameras, a two-dimensional sonic anemometer, two safires, erosion–deposition pins, and an array of batteries and solar panels. The cameras run on a timer that takes pictures every hour. The images are rectified and analyzed using a combination of ArcMap 9.2 and PCI Geomatica software, which permits the generation of moisture maps, vegetation, ice and snow cover, shoreline position, and erosion–deposition processes. The two-dimensional sonic provides continuous wind speed and direction, and the saltation probes record the intensity of transport events. The result is a large geodatabase of a time series of factors affecting eolian processes at the beach at a variety of temporal and spatial scales. This geodatabase can be queried, and it is a valuable tool for studying the frequency and magnitude of events delivering sediment from the beach to the dune and thus for improving our knowledge of sediment transport at coastal areas. Although the remote sensing station was initially conceived as a tool to measure subaerial processes, a full year of measurements shows large potential for the system to provide information on processes at the nearshore environment and ice dynamics

Restoration

Eelgrass (Zostera marina L.) in the Chesapeake Bay Region of Mid-Atlantic Coast of the USA: Challenges in Conservation and Restoration. Orth, Robert J., S.R. Marion, K.A. Moore, and D. J. Wilcox. 2010. Estuaries and Coasts. 33(1):139-150.

Abstract

Decreases in seagrass abundance reported from numerous locations around the world suggest that seagrass are facing a global crisis. Declining water quality has been identified as the leading cause for most losses. Increased public awareness is leading to expanded efforts for conservation and restoration. Here, we report on abundance patterns and environmental issues facing eelgrass (*Zostera marina*), the dominant seagrass species in the Chesapeake Bay region in the mid-Atlantic coast of the USA, and describe efforts to promote its protection and restoration. Eelgrass beds in Chesapeake Bay and Chincoteague Bay, which had started to recover from earlier diebacks, have shown a downward trend in the last 5–10 years, while eelgrass beds in the Virginia coastal bays have substantially increased in abundance during this same time period. Declining water quality appears to be the primary reason for the decreased abundance, but a recent baywide dieback in 2005 was associated with higher than usual summer water temperatures along with poor water clarity. The success of eelgrass in the Virginia coastal bays has been attributed, in part, to slightly cooler water due to their proximity to the Atlantic Ocean. A number of policies and regulations have been adopted in this region since 1983 aimed at protecting and restoring both habitat and water quality. Eelgrass abundance is now one of the criteria for assessing attainment of water clarity goals in this region. Numerous transplant projects have been aimed at restoring eelgrass but most have not succeeded beyond 1 to 2 years. A notable exception is the large-scale restoration effort in the Virginia coastal bays, where seeds distributed beginning in 2001 has initiated an expanding recovery process. Our research on eelgrass abundance patterns in the Chesapeake Bay region and the processes contributing to these patterns have provided a scientific background for management strategies for the protection and restoration of eelgrass and insights into the causes of success and failure of restoration efforts that may have applications to other seagrass systems.

Return to Neverland: Shifting Baselines Affect Eutrophication Restoration Targets. Carlos M. Duarte, D. J. Conley, J. Carstensen, and M. Sánchez-Camacho. 2009. Estuaries and Coasts. 32(1):29-36.

Abstract

The implicit assumption of many scientific and regulatory frameworks that ecosystems impacted by human pressures may be reverted to their original condition by suppressing the pressure was tested using coastal eutrophication. The response to nutrient abatement of four thoroughly studied coastal ecosystems that received increased nutrient inputs between the 1970s and the 1980s showed that the trajectories of these ecosystems were not directly reversible. All four ecosystems displayed convoluted trajectories that failed to return to the reference status upon nutrient reduction. This failure is proposed to result from the broad changes in environmental conditions, all affecting ecosystem dynamics, that occurred over the 30 years spanning from the onset of eutrophication to the reduction of nutrient levels. Understanding ecosystem response to multiple shifting baselines is essential to set reliable targets for restoration efforts.

Reforming Watershed Restoration: Science in Need of Application and Applications in Need of Science. Palmer, Margaret A. 2009. Estuaries and Coasts. 32(1):1-17.

Abstract

Coastal and inland waters are continuing to decline in many parts of the world despite major efforts made to restore them. This is due in part to the inadequate role that ecological science has played in shaping restoration efforts. A significant amount of fundamental ecological knowledge dealing with issues such as system dynamics, state changes, context-dependency of ecological response, and diversity is both under-used by managers and practitioners and under-developed by ecologists for use in real-world applications. Some of the science that is being 'used' has not been adequately tested. Thus, restoration ecology as a science and ecological restoration as a practice are in need of reform. I identify five ways in which our ecological knowledge should be influencing restoration to a far greater extent than at present including a need to: shift the focus to restoration of process and identification of the limiting factors instead of structures and single species, add ecological insurance to all projects, identify a probabilistic range of possible outcomes instead of a reference condition, expand the spatial scale of efforts, and apply hierarchical approaches to prioritization. Prominent examples of restoration methods or approaches that are commonly used despite little evidence to support their efficacy are highlighted such as the use of only structural enhancements to restore biodiversity. There are also major gaps in scientific knowledge that are of immediate need to policy makers, managers, and restoration practitioners including: predictive frameworks to guide the restoration of ecological processes, identification of social-ecological feedbacks that constrain ecosystem recovery and data to support decisions of where and how to implement restoration projects to achieve the largest gains. I encourage ecologists to respond to the demand for their scientific input so that restoration can shift from an engineering-driven process to a more sustainable enterprise that fully integrates ecological processes and social science methods.

Potential of Restoration and Phytoremediation with Juncus roemerianus for Diesel-contaminated Coastal Wetlands. Lin, Qianxin and I.A. Mendelssohn. 2009. Ecological Engineering. 35(1):85-91.

Abstract

Oil spills may considerably damage sensitive coastal wetlands. In this study, the tolerance limits of a dominant coastal salt marsh plant, *Juncus roemerianus*, to diesel oil and its phytoremediation effectiveness in wetland environments were investigated in the greenhouse. *J. roemerianus* was transplanted into salt marsh sediment contaminated with diesel fuel at concentrations of 0, 20, 40, 80, 160, 320, and 640 mg diesel g–1 dry sediment. Plant stem density, shoot height, aboveground biomass and belowground biomass were detrimentally impacted at high oil dosages even 1 year after transplantation. Tolerance limits were estimated between 160 and 320 mg g–1 based on various plant variables. Importantly, *J. roemerianus* enhanced oil degradation; at the 40 mg/g diesel dosage, concentrations of residual total petroleum hydrocarbons (TPH) in the sediment planted with *J. roemerianus* were significantly lower than those of unplanted sediments 1 year after treatment initiation. Furthermore, concentrations of total targeted polycyclic aromatic hydrocarbons (PAHs) and n-alkanes in the *J. roemerianus* planted treatment were, respectively, about 3% and 15% of the unplanted treatment. Concentration reduction in all categories of hydrocarbons suggested that *J. roemerianus* effectively phytoremediated the diesel-contaminated wetlands.

Hydrodynamic and Ecological Assessment of Nearshore Restoration: A Modeling Study. Zhaoqing Yang, K.L. Sobocinski, D. Heatwole, T. Khangaonkar, R. Thom, and R. Fuller. 2010. Ecological Modeling. 221(7):1043-1053.

Abstract

Along the Pacific Northwest coast, much of the estuarine habitat has been lost over the last century to agricultural land use, residential and commercial development, and transportation corridors. As a result, many of the ecological processes and functions have been disrupted. To protect and improve these coastal habitats that are vital to aquatic species, many projects are currently underway to restore estuarine and coastal ecosystems through dike breaches, setbacks, and removals. Understanding site-specific information on physical processes is critical for improving the success of such restoration actions. In this study, a three-dimensional hydrodynamic model was developed to simulate estuarine processes in the Stillaguamish River estuary, where restoration of a 160-acre parcel through dike setback has been proposed. The model was calibrated to observed tide, current, and salinity data for existing conditions and applied to simulate the hydrodynamic responses to two restoration alternatives. Model results were then combined with biophysical data to predict habitat responses within the restoration footprint. Results showed that the proposed dike removal would result in desired tidal flushing and conditions that would support four habitat types on the restoration

footprint. At the estuary scale, restoration would substantially increase the proportion of area flushed with freshwater (<5 ppt) at flood tide. Potential implications of predicted changes in salinity and flow dynamics are discussed relative to the distribution of tidal marsh habitat.

Drowning of the Mississippi Delta Due to Insufficient Sediment Supply and Global Sea-level Rise. Blum, Michael D. and H.H. Roberts. 2009. Nature Geoscience. 2:488-491.

Abstract

Over the past few centuries, 25% of the deltaic wetlands associated with the Mississippi Delta have been lost to the ocean. Plans to protect and restore the coast call for diversions of the Mississippi River, and its associated sediment, to sustain and build new land. However, the sediment load of the Mississippi River has been reduced by 50% through dam construction in the Mississippi Basin, which could affect the effectiveness of diversion plans. Here we calculate the amount of sediment stored on the delta plain for the past 12,000 years, and find that mean storage rates necessary to construct the flood plain and delta over this period exceed modern Mississippi River sediment loads. We estimate that, in the absence of sediment input, an additional 10,000–13,500 km2 will be submerged by the year 2100 owing to subsidence and sea-level rise. Sustaining existing delta surface area would require 18–24 billion tons of sediment, which is significantly more than can be drawn from the Mississippi River in its current state. We conclude that significant drowning is inevitable, even if sediment loads are restored, because sea level is now rising at least three times faster than during delta-plain construction.

Wetlands and Global Climate Change: The Role of Wetland Restoration in a Changing World. Erwin, Kevin L. 2009. Wetlands Ecology and Management. 17(1):71-84.

Abstract

Global climate change is recognized as a threat to species survival and the health of natural systems. Scientists worldwide are looking at the ecological and hydrological impacts resulting from climate change. Climate change will make future efforts to restore and manage wetlands more complex. Wetland systems are vulnerable to changes in quantity and quality of their water supply, and it is expected that climate change will have a pronounced effect on wetlands through alterations in hydrological regimes with great global variability. Wetland habitat responses to climate change and the implications for restoration will be realized differently on a regional and mega-watershed level, making it important to recognize that specific restoration and management plans will require examination by habitat. Floodplains, mangroves, seagrasses, saltmarshes, arctic wetlands, peatlands, freshwater marshes and forests are very diverse habitats, with different stressors and hence different management and restoration techniques are needed. The Sundarban (Bangladesh and India), Mekong river delta (Vietnam), and southern Ontario (Canada) are examples of major wetland complexes where the effects of climate change are evolving in different ways. Thus, successful long term restoration and management of these systems will hinge on how we choose to respond to the effects of climate change. How will we choose priorities for restoration and research? Will enough water be available to rehabilitate currently damaged, water-starved wetland ecosystems? This is a policy paper originally produced at the request of the Ramsar Convention on Wetlands and incorporates opinion, interpretation and scientific-based arguments.

Restoration of Dredged Canals in Wetlands: A Comparison of Methods. Baustian, Joseph J., R.E. Turner, N.F. Walters, and D.P. Muth. 2009. Wetlands Ecology and Management. 17(5):445-453.

Abstract

A comparison of two methods for restoring dredged canals to wetlands was examined at the Jean Lafitte National Historical Park and Preserve's Barataria Preserve Unit near New Orleans, LA. Both northern and southern canals had the remnant dredged spoil material returned to the canal, but the southern canal had additional sediment pumped in from a nearby lake. The water depth in the southern canal shallowed significantly from 1.2 to 0.4 m following backfilling and sediment addition, while the depth of the northern canal (which received no additional sediment) remained unchanged following backfilling. Neither site had complete soil restoration, but the former spoil areas of the northern canal showed greater restoration than the southern canal. The vegetation on the former spoil areas of the northern canal closely resembled that of the reference marsh, while the former spoil areas of the southern canal had species indicative of spoil banks and other elevated areas. After 3 years wetland vegetation was established on approximately 65% of the former spoil areas at both sites and 20–25% of the open water areas. Sediment addition to the southern canal raised costs by a factor of eight times compared to that of the northern canal. The results of this study document the restoration potential of both methods, but also show that backfilling without supplemental sediment additions can restore abandoned canals at a fraction of the cost of other methods.

Evaluating Wildlife Response to Coastal Dune Habitat Restoration in San Francisco, California. Russell, Will, J. Shulzitski, and A. Setty. 2009. Ecological Restoration. 27(4):439-448.

Abstract

The vast dune system that once dominated the entire western half of the San Francisco peninsula in California has been reduced to a few fragments that conserve locally threatened plant and animal species. We measured the effects of ongoing restoration efforts on wildlife abundance and diversity on one of the largest of these fragments, Fort Funston in the Golden Gate National Recreation Area. Efforts included removal of non-native species, active restoration of native dune vegetation, and restricted visitor use. We collected data regarding the composition and abundance of vegetation, birds, and ground-dwelling vertebrates on four treatments including an actively restored area with restricted visitor use, an unrestored area where visitor use had been restricted for ten years, an unrestored area where visitor use had been restricted for two years, and an unrestored

area with unrestricted visitor use. Results indicated that the diversity and abundance of wildlife species, as well as the richness and cover of native plant species, were greater in the restored area than in all other sampled areas. Restricted visitor use alone had only modest positive effects on the abundance and diversity of wildlife and the richness and cover of native plant species.

Soil Recovery after Removal of the N2-fixing Invasive Acacia longifolia: Consequences for Ecosystem Restoration. Marchante, Elizabete, A. Kjøller, S. Struwe, and H. Freitas. 2009. Biological Invasions. 11(4):813-823.

Abstract

Invasion by *Acacia longifolia* alters soil characteristics and processes. The present study was conducted to determine if the changes in soil C and N pools and processes induced by *A. longifolia* persist after its removal, at the São Jacinto Dunes Nature Reserve (Portugal). Some areas had been invaded for a long time (›20 years) and others more recently (‹10 years). For each type of invasion, (i.e., long-invaded and recently invaded), three treatments were used: (1) *A. longifolia* left intact; (2) *A. longifolia* was removed; and (3) both *A. longifolia* and litter layer were removed. Soil samples were collected once a year for four and half years and analysed for chemical and microbial properties. In general, microbial parameters responded faster than C and N pools. In long-invaded areas, two and half years after removal of plants and litter, basal respiration and microbial biomass had already decreased ›30%, βglucosaminidase activity (N mineralization index) ›60% and potential nitrification ›95%. Removal of plants and litter resulted in a ›35% decrease in C and N content after four and half years. In recently invaded areas, βglucosaminidase activity and potential nitrification showed a marked decrease (›54% and ›95%, respectively) after removal of both *A. longifolia* and litter. Our results suggest that after removal of an N2-fixing invasive tree that changes ecosystem-level processes, it takes several years before soil nutrients and processes return to pre-invasion levels, but this legacy slowly diminish, suggesting that the susceptibility of native areas to (re)invasion is a function of the time elapsed since removal. Removal of the N-rich litter layer facilitates ecosystem recovery.

Assessing the Residual Effects of Carpobrotus edulis Invasion, Implications for Restoration. Conser, Christiana and E.F. Connor. 2009. Biological Invasions. 11(2):349-358.

Abstract

We examined whether the residual effects on soil caused by the invasion of *Carpobrotus edulis*, common iceplant, would inhibit the reestablishment of a native plant species. *Carpobrotus edulis* interacts both directly by suppressing the growth and establishment of other plants and indirectly by altering soil chemistry. We tested whether the residual effects of *C. edulis* resulted in lowered germination, survival, growth, and reproduction of *Gilia millefoliata*, a rare dune annual. We compared *G. millefoliata* planted in plots previously occupied by *C. edulis* to *G. millefoliata* planted in plots that previously had native vegetation. Each plot received three treatments: seed, transplant, and unplanted, and were censused every three weeks until senescence. *Carpobrotus edulis* had strong negative effects on the germination, survival, growth, and reproduction of *G. millefoliata*. *C. edulis* lowers soil pH and increases organic content due to the recalcitrance of tissue to decomposition, which may have evolved as a mechanism to facilitate recolonization and invasion.

Can Soil Seed Banks Contribute to the Restoration of Dune Slacks under Conservation Management? Plassmann, Katharina, N. Brown, M.L.M. Jones, and G. Edwards-Jones. 2009. Applied Vegetation Science. 12(2):199-210.

Abstract

Questions: Does the soil seed bank resemble the former early successional stages of a dune slack system more than the established later successional vegetation? Does it have the potential to contribute to the conservation of a highly endangered habitat?

Location: Dune slacks at Newborough Warren, UK.

Methods: The composition of the soil seed bank in two depth layers was determined using the seedling emergence method between March 2004 and April 2005. Long-term monitoring data on the floristic composition of the established vegetation were obtained from the national conservation agency, and additional monitoring was undertaken in 2003. Floristic composition, seed weights, seed longevity of component species and Ellenberg indicator values were used to compare the seed bank and established vegetation.

Results: The soil seed bank was diverse and contained typical dune slack species, species of early successional stages and species of conservation interest. A comparison between the composition of the seed bank and historical data on the composition of the established vegetation showed that the seed bank reflects earlier successional stages more closely than the current aboveground vegetation. This study increases the scarce information currently available on the seed bank ecology of several species, including two orchid species.

Conclusions: The soil seed bank can be expected to contribute to vegetation change after disturbance. Stimulation of germination from the seed bank through management may contribute to the conservation of both characteristic and threatened species typical of dune slacks.

The Ballona Wetlands Conservancy is dedicated

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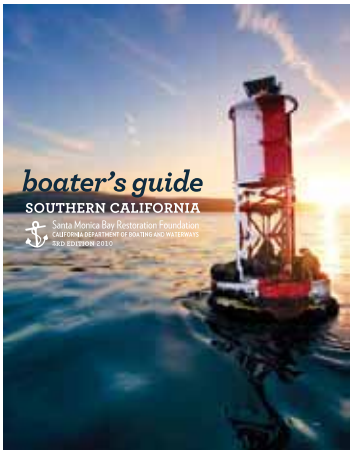

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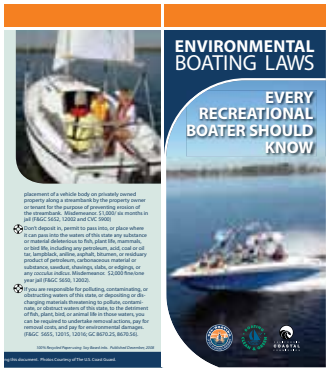

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