Wetland Restoration Technical Information

Restoring Southern California's coastal wetlands is a difficult job. For starters, there is still much we need to need to learn about how a tidal marsh actually functions. In the words of Joy Zedler and Abbey Powell---two wetland scientists who have done extensive work in the region: "In over 20 years of observing and studying Southern California's marine-dominated wetlands, we still marvel at their complexity. . .What makes these systems complex is what makes them interesting. It's also what makes them difficult to manage and almost impossible to duplicate when we try to build them from scratch. . ."

Although we enjoy a mild climate, Southern California's coastal wetlands are subject to unusual stresses. There is great variability here in rainfall and streamflow, both seasonally and from one year to the next. Coastal wetlands may experience catastrophic floods in some years and no freshwater inflows in others. Limited rainfall can dramatically alter the dynamics of a tidal marsh, increasing sediment accumulation to such an extent that the estuary mouth silts in and tidal flushing disappears.

Wetland plant and animal communities have adapted to fluctuations in water levels, salinity, oxygen, and temperature in such a way that Southern California's coastal marshes are home to an unusually rich array of species and habitats. But because of urbanization, these wetlands face other intense pressures which will be much more difficult to accommodate: habitat fragmentation, changed hydrological conditions, and destruction of buffers and upland connections.

The following section provides links and citations to a wide variety of studies, reports and books to aid you in almost every conceivable topic relating to wetland conservation and restoration.

1. General Information

- ***Links to websites and online documents and bibliographies***

The ***California Wetlands Information System*** of the California Resources Agency offers comprehensive wetlands information at www.ceres.ca.gov/wetlands/ The site offers a compilation of public and private sector material, including maps, environmental documents, agency roles in wetlands management, restoration and mitigation activities, regulatory permitting, and wetland policies. It includes wetlands databases and inventories, information on education and research, restoration and mitigation projects, and a special section on vernal pools.

US EPA's ***An Introduction and User's Guide to Wetland Restoration, Creation and Enhancement*** is a very useful publication, which offers an overview of wetlands and their restoration, information on project planning, implementation and monitoring, and a list of resources, contacts, and funding sources. It contains an excellent bibliography on wetlands and specific wetland types, restoration, monitoring and management. The manual is available from the EPA in print as an 86-page full color booklet or it can be downloaded as a pdf file at www.nmfs.noaa.gov/habitat/habitatprotection/ pdf/Wet%20Res%20Guidance_FINAL.pdf

Although it is oriented toward the ecology of the Pacific Northwest, ***Restoring Wetlands in Washington: A Guidebook for Wetland Restoration, Planning and Implementation*** provides an excellent, concise handbook on the basic steps in planning, designing, implementing, monitoring and managing a restoration project. It can be downloaded from the Washington Department of Ecology's website at http://www.ecy.wa.gov/biblio/93017.html

Another document available on the Washington Department of Ecology's website provides a summary and synthesis of recent literature on the science and management of freshwater wetlands. ***Freshwater Wetlands in Washington State - Vol. 1: A Synthesis of the Science*** reviews research on how environmental factors control the functions of wetlands across the

landscape and at individual sites, how freshwater wetlands are classified according to these controls, what functions are performed by different classes of wetlands, how wetlands are protected and managed using common tools such as buffers and compensatory mitigation, and how cumulative effects result from the current use of these tools. It is available as a pdf file at www.ecy.wa.gov/biblio/0306016.html

The online library of the US Geological Service's **National Wetlands Research Center** (http://www.nwrc.usgs.gov/library.htm) contains an online search engine with over 11,000 documents as well as an extensive collection of digital publications that includes species profiles (life histories and environmental requirements of coastal fishes and invertebrates), a waterfowl management handbook, habitat suitability index models, ecological community profiles, biological and other technical reports on vernal pools, tidal marshes and estuarine habitats in coastal California.

The website of the **Association of State Wetland Managers** (http://www.aswm.org/) includes a number of publications that can be downloaded in pdf format, including several papers on wetlands assessment and wetlands management, as well as digital materials on wetlands science. Similarly, **Wetlands International's** website includes a publications section (http://www.wetlands.org/pubs&/wetland_pub.html) that includes online documents. They include "A Bibliography of Wetland Creation and Restoration Literature," compiled by Kevin Erwin, which includes over 1,000 citations. The bibliography offers a comprehensive listing (as of 1996) of publications useful in designing, evaluating, managing and monitoring wetland restoration and creation projects; it is downloadable in both pdf and Word formats.

Abstracts of articles from ***Wetlands***, the journal of the Society of Wetland Scientists, are available online at http://www.sws.org/wetlands/journalsearch.html. An index of articles appearing in Environmental law Institute's ***National Wetlands Newsletter*** is available at http://www2.eli.org/nwn/nwnindex.cfm. For each journal, however, access to the articles themselves requires a paid subscription.

The ***US Environmental Protection Agency's Wetlands website*** offers a series of downloadable Wetlands Fact Sheetsthat cover a wide variety of topics, from a basic wetlands primer to many technical issues: http://www.epa.gov/owow/wetlands/facts/contents.html. In addition, the EPA's Watershed Academy's online training program includes several modules on wetlands issues. The module "Wetland Functions and Values" reviews the value of wetlands to water quality, the economy, recreation, environmental health, and other areas. It includes a self-test and a printable list of every wetland function or value discussed in the module. You can access this module at http://www.epa.gov/watertrain/wetlands/

Extensive information regarding wetlands is also available on the website of the **Army Corps of Engineers Wetlands Research Program** (http://www.wes.army.mil/el/wetlands/wetlands.html). Papers on HGM assessments and other publications relating to wetlands can be downloaded at http://www.wes.army.mil/el/wetlands/wlpubs.html.

The **Society for Ecological Restoration** has published "A Primer on Ecological Restoration" and "Guidelines for Developing and Managing Ecological Restoration Projects," each of which can be downloaded from the SER's website at http://www.ser.org/reading_resources.asp.

The website of the **California Native Plant Society** (http://www.cnps.org/links/wetland_links.htm) provides numerous links to information and resources about wetlands and vernal pools. CNPS also publishes a 50-page "Wetlands Source Book 2000" which can be downloaded as a pdf file from that site.

The ***California Ecological Restoration Projects Inventory*** (http://ice.ucdavis.edu/CERPI/) is a combined private/non-profit/government effort to establish a database, accessible through the

Internet, containing information on restoration projects in California. Reference information is to includes implementation information such as the type of ecosystem restored, plant species used, soil and nutrient amendments, and erosion control measures; it also carries monitoring information, such as performance standards and monitoring data. The database is intended for use by agencies, academicians, consultants, project designers and implementers.

The Natural Resource Conservation Service of the US Department of Agriculture has adopted ***NRCS Conservation Practice Standards*** which provide guidance for applying conservation technology on the land and set the minimum level for acceptable application of the technology to NRCS projects. The standards (and Conservation Practice Information Sheets) for wetland creation, wetland enhancement, wetland restoration, and wetland wildlife habitat management are available as either pdf or Word documents at http://www.nrcs.usda.gov/technical/Standards/nhcp.html

- ***Annotated bibliography***

Azous, Amanda L., and Richard R. Horner. ***Wetlands and Urbanization: Implications for the Future*** (Lewis Publishers, Boca Raton, 2001). This book examines the impact of urban runoff on the habitat value and other natural functions of wetlands. Based on extensive research by the Puget Sound Wetlands and Stormwater Management Program Team, it draws conclusions about the effects of watershed development on wetland ecosystems in urban areas and to offer a set of comprehensive guidelines and management strategies to avoid or minimize damaging alterations to wetland structure and function from urbanization.

France, Robert Lawrence. ***Wetland Design: Principles and Practices for Landscape Architects and Land Use Planners***. (W.W. Norton & Company, New York, 2002). A primer on the principles and practices of wetland design, it covers the creation, restoration, enhancement, and construction of designed wetlands. It provides a practical guide for wetland design on a local, site-specific scale. It presents 150 key principles and practices of wetland design and planning, accompanied by detailed illustrations and case studies.

Garbisch, E.W. ***The Dos and Don'ts of Wetland Construction*** (Environmental Concern, St Louis, available through http://www.wetland.org/ecpubs.htm). Provides advice to the wetland practitioner on such issues as site selection, plans and specifications, pre-bid and pre-construction meetings, contract bidding, constructing the wetland, post-construction maintenance and success determination, and post-construction monitoring. Its “dos and don'ts” discuss correct and incorrect methods used in creating, enhancing and constructing wetlands in order to assist readers in increasing the success of their wetland construction projects.

Hammer, Donald A. ***Creating Freshwater Wetlands***. (CRC Press, Boca Raton FL, 1997). Offers step-by-step guidelines on such issues as selecting and evaluating sites, getting help, planning projects, managing construction, selecting plants, attracting wildlife, and monitoring and maintaining projects. Includes a chapter on the special considerations required for constructed wetlands.

Kusler, Jon A. and Mary E. Kentula, editors. ***Wetland Creation and Restoration: The Status of the Science*** (Washington DC: Island Press, 1990). Contains more than thirty papers from scientists and technicians, offering a compendium of hands-on information about methods of creating, restoring, and enhancing wetlands.

Lewis, William M. Jr. ***Wetlands Explained: Wetland Science, Policy, and Politics in America***. (Oxford University Press, New York, 2001). A concise and readable overview of what a wetland is (and isn’t) and how it functions.

Marble, Anne D. ***A Guide to Wetland Functional Design*** (Lewis Publishers, Boca Raton, 1991). Provides design guidance on wetland design from a functional standpoint. It addresses subjects such as wetland hydrology, nutrient removal and transformation, sediment and toxicant retention, shoreline stabilization, floodflow alteration, groundwater recharge, and wildlife habitat.

Mitsch, William J. and James G. Gosselink. ***Wetlands.*** (John Wiley & Sons, New York, 2000, third edition). The standard text and reference on wetland ecology and management. Contains an overview of wetland chemistry, biology, hydrology, as well as principles, techniques and design aspects for constructing and restoring wetlands.

National Research Council. ***Restoration of Aquatic Ecosystems*** (National Academy Press, Washington DC, 1992). Although not focused solely on wetlands, this report examines the prospects for repairing the degradation of the nation's aquatic resources and outlines a national strategy for aquatic restoration. Featuring case studies of restoration on lakes, rivers, streams and wetlands, it examines key concepts and techniques used in restoration, common factors in successful restoration efforts, and approaches to evaluation before, during and after a project.

National Research Council. ***Wetlands: Characteristics and Boundaries*** **(**National Academy Press, Washington DC,1995). Prepared by a committee drawn from academia, government, and business, this volume explores how to define wetlands and presents a scientific basis for their definition. It also discusses the diverse hydrological and ecological functions of wetlands and makes recommendations concerning riparian ecosystems, irregularly flooded sites, and agricultural wetlands.

Pacific Estuarine Research Laboratory. ***A Manual for Assessing Restored and Natural Coastal Wetlands*** (PERL, San Diego State University, 1995). The publication, with extensive examples from Southern California, is available from PERL, which also publishes "***Tidal Wetland Restoration--A Scientific Perspective and Southern California Focus."*** For ordering information, see http://www.sci.sdsu.edu/PERL/recent.html

Tiner, Ralph W. ***Wetland Indicators: A Guide to Wetland Identification, Delineation, Classification, and Mapping*****.** (Lewis Publishers, Boca Raton, 1999). Explains the use of various plant, soil and other indicators for wetland identification in the U.S., and methods for identifying, describing, classifying, and delineating wetlands. Focuses on plants, soils, and other signs of wetland hydrology in the soil, or on the surface of wetlands. Chapters on wetland mapping and photo interpretation describe the variety of plant communities associated with wetlands and some of the offsite tools to help identify them.

Vileisis, Ann. ***Discovering the Unknown Landscape: A History of America's Wetlands***. (Island Press, Washington DC, 1997). A social and environmental history of how Americans have used and thought about wetlands.

Zedler, Joy B. (Editor). ***Handbook for Restoring Tidal Wetlands*** (CRC Press, Boca Raton FL, 2000). Combining detailed examples from coastal research studies with information drawn from the literature on tidal restoration, this book contains chapters by six different scholars and experienced practitioners on topics such as hydrology and substrate, establishing vegetation, restoring invertebrates and fish communities, assessment and monitoring, and identifying and solving management problems. It offers specific, how-to-do-it advice, and contains species lists, drawings and other illustrations of salt marsh biota and restoration projects specific to Southern California. Many of the authors are associated with the Pacific Estuarine Research Lab based at San Diego State University, and the much of their discussion focuses on tidal marshes in our region.

2. Regulation and permitting in California

Cylinder, Paul D., Kenneth M. Bogdan, April I. Zohn and Joel B. Butterworth. ***Wetlands, Streams, and Other Waters: Regulation, Conservation, and Mitigation Planning*.** (Solano Press Books, Point Arena CA, 2004). This new edition of the book *Wetlands Regulation* offers an overview of the laws and regulations governing wetlands and stream restoration. It offers a very useful and user-friendly guide to federal and California state laws and permitting requirements, including those affecting the preparation of wetland conservation plans.

For more information on regulation and permitting, see also the section on that subject on this website: Legal Authority

3. Treatment wetlands

- ***Links to websites and online documents and bibliographies***

The US Environmental Protection Agency's publication, ***Guiding Principles for Constructed Treatment Wetlands: Providing for Water Quality and Wildlife Habitat*** (publication EPA 843-B-00-003) includes: guiding principles ---developed by an interagency workgroup---for siting, design, construction, operation, maintenance, and monitoring of constructed treatment wetlands; information on current agency policies, permits, regulations, and resources; and answers to common questions regarding constructed treatment wetlands. It can be downloaded at http://www.epa.gov/owow/wetlands/constructed/guide.html.

The Agricultural Research Service of the US Department of Agriculture maintains an extensive online bibliography of materials on constructed wetlands at http://www.nal.usda.gov/wqic/Constructed_Wetlands_all/index.html

Researchers at the Southern California Coastal Water Research Project have prepared a literature review of the risks, design considerations and tradeoffs associated with using wetlands to treat urban runoff. The report, prepared by Martha Sutula and Eric Stein and entitled ***Habitat Value of Natural and Constructed Wetlands Used to Treat Urban Runoff***, is available on the Coastal Conservancy's website at www.coastalconservancy.ca.gov/scwrp/index.html.

- ***Annotated bibliography***

Campbell, Craig S. and Michael Ogden. ***Constructed Wetlands in the Sustainable Landscape*** (John Wiley & Sons; New York, 1999). Written by a landscape architect and an engineer, this book integrates aesthetic design and planning issues with the technical aspects of wetlands engineering. It covers such topics as design basics (including relevant modeling formulas), pricing estimates, and habitat creation, as well as examples of systems that the authors themselves designed and installed.

Kadlec, Robert H., and Robert L. Knight. ***Treatment Wetlands*** (Lewis Publishers, Boca Raton, 1995). This book focuses on the use of wetlands for water quality treatment created by human activity. Coverage includes wetland structure and function, wetland water quality, selection of appropriate technology, project planning and design, construction guidance, system operation and maintenance, estimated construction and operation costs, and case histories.

4. Invasive species management

- ***Links to websites and online documents and bibliographies***

An online bibliography from the Coastal Conservancy's quarterly journal, ***California Coast & Ocean***, has an extensive list of links to online resources on invasive species: http://www.coastalconservancy.ca.gov/coast&ocean/summer2003/pages/one_sidebar.html

Detailed information regarding the impacts and control of ***Arundo donax*** is available on the websites for both Team Arundo del Norte (http://ceres.ca.gov/tadn/index.html) and the Santa Margarita and San Luis Rey Watersheds Weed Management Area (http://www.smslrwma.org/). The latter also includes information on other invasive species in San Diego County, such as *Retama monosperma (*bridal broom*), Vinca major (*periwinkle*),* Tamarix spp. (tamarisk, salt cedar), *Delairea odorata* (Cape or German ivy)purple loosestrife (*Lythrum salicaria)* and giant salvinia (*Salvinia molesta.*

The Nature Conservancy's Wildland Invasive Species Team maintains a website (http://tncweeds.ucdavis.edu/) with a number of downloadable resources and links regarding invasive species management.

A website developed and maintained by the National Agricultural Library for the National Invasive Species Council, ***Invasivespecies.gov,*** discusses the impacts of various invasive species and Federal programs to control them; it also includes a number of online resources that are useful for land managers.

A Survey of Non-Indigenous Aquatic Species in the Coastal and Estuarine Water of California can be downloaded at http://www.dfg.ca.gov/ospr/organizational/scientific/exotic/exotic%20report.htm

The website of the ***California Invasive Plant Council*** (http://groups.ucanr.org/ceppc/index.cfm) contains copies of the Council's monthly newsletter, proceedings from its annual symposiums, and links to various resources regarding invasive plants.

The website for the ***California Native Plant Society*** (www.cnps.org/links/exotics_links.htm) also provides numerous links to information and resources about invasive exotic plants.

NOAA maintains a website on ***caulerpa*** eradication in Southern California at http://swr.ucsd.edu/hcd/caulerad.htm. Information on the impacts and management of **spartina** in California's coastal wetlands is available at http://www.spartina.org/

The Center for Invasive Plant Management (http://www.weedcenter.org/index.html), a coalition of agencies, organizations, and individuals interested in managing invasive plants in western North America, also maintains a website that contains weed profiles, related links, education resources and research grant information.

- ***Annotated bibliography***

Bossard, Carla C., John M. Randall, and Marc C. Hoshovsky, editors. ***Invasive Plants of California's Wildlands*** (University of California Press, Berkeley, 2000). This book provides specific information about the biology and control of the 78 nonnative plant species that are listed by the California Exotic Pest Plant Council as being of greatest ecological concern in California. Contains a section on general concepts of managing invasive plant species, as well as detailed illustrations and specific discussions for each species about the colonization, resulting problems, and reproduction of each species as well as the specific physical, biological, and chemical control methods to get rid of the plant.

5. Establishing wetland plants

- ***Links to websites and online documents and bibliographies***

The California Native Plant Society's ***A Manual of California Vegetation*** is available on line at http://davisherb.ucdavis.edu/cnpsActiveServer/index.html

- ***Annotated bibliography***

Cronk, J. K., and M.S. Fennessy. ***Wetland Plants: Biology and Ecology***. (Lewis Publishers, Boca Raton, 2001). This book offers a detailed analysis of the biology and ecology of wetland plants and various applications of wetland plant science. It reviews current research about wetland plants and their ecological communities; examines their adaptation and reproduction; and explores the function, dynamics, and potential disturbances of wetland plant communities. It covers growth forms, evolution, distribution, primary production, community dynamics; the development of plant communities in newly restored or created wetlands; the use of wetland plants as indicators of ecological integrity; and adaptation to conditions, such as life in water or saturated soils, high salt or high sulfur, low light and low carbon dioxide levels.

Faber, Phyllis M. ***Common Wetland Plants of Coastal California: A Field Guide for the Layman***. (Pickleweed Press, Mill Valley CA, 1996). This book offers an excellent field guide for the identification of wetland plants. Plants are arranged according to habitat type (salt marsh, freshwater marsh). A brief introduction to each habitat is followed by full-scale photocopies of the plants themselves, accompanied by descriptions of their distribution, habitat, size, leaf and flower characteristics.

6. Creating wildlife habitat

- ***Links to websites and online documents and bibliographies***

The US Fish and Wildlife Service's ***Waterfowl Management Handbook*** (http://www.nwrc.usgs.gov/wdb/pub/wmh/foreword.html) contains a series of chapters on waterfowl ecology, population management, wetlands ecology and habitat management that can be downloaded individually from the USFWS's website. Although some of the chapters relate to migratory species and wetlands in other parts of the country, each chapter seeks to synthesize available literature and discuss management concepts and procedures in a usable way for waterfowl and refuge managers. Chapters focus on such topics as waterfowl use of wetlands complexes, waterfowl diseases, increasing waterfowl nesting success on islands and peninsulas, human disturbances of waterfowl, aquatic invertebrates important for waterfowl production, manipulating vegetation and water levels for waterfowl, and control of loosestrife, cattails and other plants.

- ***Annotated bibliography***

Keddy, Paul A H., J. B. Birks and J. A. Wiens. ***Wetland Ecology : Principles and Conservation*** (Cambridge University Press, New York, 2000). Offers a synthesis of research on wetland ecology, including wetland characteristics, key environmental factors that produce wetland community types, and unifying problems such as assembly rules, restoration, and conservation.

Morrison, Michael L. ***Wildlife Restoration: Techniques for Habitat Analysis and Animal Monitoring*** (Island Press, Washington DC, 2002). Although not focused on wetlands, this book

provides an excellent overview of ecological concepts that can be used to design restoration projects with specific goals for wildlife. It discusses how wildlife and their habitat needs can be incorporated into restoration planning, the basic tools needed for developing and implementing a rigorous monitoring program, and case histories of wildlife analysis in restoration projects

Payne, Neil F. ***Wildlife Habitat Management of Wetlands*** (Krieger Publishing Company, Melbourne FL, 1998) The book, (a reprint of *Techniques for Wildlife Habitat Management of Wetlands, originally* published by McGraw-Hill in 1992) is a guide to direct habitat management techniques for a wide variety of North American species. The author discusses methods for improving, preserving, and developing wetlands and how to implement a full range of manipulation techniques.

Allan A. Schoenherr's ***A Natural History of California*** (University of California Press, Berkeley, 1992, includes an extensive discussion (at pp 627-736) on the ecology of California's coastline. See also Z. B. Zedler, ***The Ecology of Southern California Coastal Salt Marshes: A Community Profile.*** US Fish and Wildlife Service, Biological Services Program, 1982, publication FWS/OBS-81/54.

7. Wetlands hydrology

Gilman, Kevin. ***Hydrology and Wetland Conservation***. (John Wiley & Sons, New York, 1994) Discusses important aspects of wetland hydrology that must be considered in managing or restoring wetlands. Describes both simple and complex management techniques, drawn from studies and projects in Britain.

Middleton, Beth A. ***Wetland Restoration, Flood Pulsing, and Disturbance Dynamics*** (John Wiley & Sons, New York, 1998). This book argues that wetland restoration often fails because it does not consider natural disturbances, and it offers a framework for improving projects by incorporating disturbance dynamics. It includes an extensive discussion of the life history requirements of aquatic species, including water tolerance information, seed germination, seedling recruitment and adult survivorship, with the goal of assisting wetland scientists and restoration ecologists in creating self-sustaining systems. The book contains detailed case histories of a number of diverse wetland restoration projects around the world.

8. Water Quality

Rand, Gary M. editor, **Fundamentals of Aquatic Toxicology: Effects, Environmental Fate, and Risk Assessment**. (Taylor & Francis, 1995). A comprehensive textbook on aquatic and environmental toxicology, it discusses general principles and concepts; the testing, evaluation, and interpretation of toxicity data; and the impacts of aquatic toxicology on the environment as a whole.

US Environmental Protection Agency. ***Protecting Natural Wetlands: A Guide to Stormwater Best Management Practice.*** (EPA Publication EPA-843-B-96-001, October 1996). Provides an overview of factors to consider when selecting BMPs to protect the water quality in a wetland, descriptions of specific structural and nonstructural BMPs, and case studies of how they have been used in various projects around the country

9. Wetland soils

- ***Links to websites and online documents and bibliographies***

The *Journal of the Soil Science of America* maintains an online bibliography of technical articles about wetland soils at http://soil.scijournals.org/cgi/collection/wetland_soils?page=4

The class notes from a course on wetland soils taught by M. J. Vepraskas at North Carolina State University (co-author of the book below) are also available on line and provide a good overview of various issues relating to the subject: http://www.soil.ncsu.edu/lockers/Vepraskas_M/intro1.htm

- ***Annotated bibliography***

Richardson, J.L. and M. J. Vepraskas. ***Wetland Soils: Genesis, Hydrology, Landscapes, and Classification.*** (CRC Press, Boca Raton FL, 2000). Written for scientists without a background in soil science, the book focuses on the morphology of soils that cover most types of wetlands. Part I examines basic concepts, processes, and common properties of hydric soils ; Part II covers soils in specific kinds of wetlands and the different functions they perform; and Part III emphasizes special wetlands conditions, such as soils composed of sand, organic soils in northern North America, prairie wetlands, wetlands in saline situations, dry climates, and wetlands with modified hydrology.