Wetland Restoration and Enhancement in California

Michael Josselyn, Editor

A California Sea Grant College Program Publication

NOBODY'S PERFECT!

Everyone makes typographical mistakes now and then, but in a scientific publication such as this, some typos are more forgiveable than others

To maintain this publication's technical accuracy, please take a moment to make the following corrections in the text.

Pages 1, 105:	Change the resolution number to read, "Resolution No. *28*"
Page 32:	Add the word *square* so that the sentence reads, "...cover 125 *square* miles"
Page 36:	Add the word *not* so that the sentence reads, "...when the Central Valley is *not* well flooded..."
Page 99:	Add a slash symbol (/) so that the sentence reads, "...seedlings ($75/m^2$)...($190/m^2$)..."

CALIFORNIA SEA GRANT

Wetland Restoration and Enhancement in California

Michael Josselyn, Editor
Tiburon Center for Environmental Studies
P.O. Box 855, Tiburon, CA 94920

A proceedings of a workshop held in February 1982 at the California State University, Hayward

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Invited Participants

Steven Balling
Department of Entomology
University of California
Berkeley, CA 94720

Roger Barnhart
California Cooperative Fisheries
Research Unit
Humboldt State University
Arcata, CA 95521

Milton Boyd
Department of Biology
Humboldt State University
Arcata, CA 95521

James Buchholz
Wetlands Research Associates, Inc.
4319 23rd Street
San Francisco, CA 94114

Terry Bursztynsky
Association of Bay Area Governments
Hotel Claremont
Berkeley, CA 94705

Emy Chan
Association of Bay Area Governments
Hotel Claremont
Berkeley, CA 94705

Martin Cohen
State Coastal Conservancy
1330 Broadway, Suite 1100
Oakland, CA 94612

Fran Demgen
Demgen Aquatic Biology
118 Mississippi Street
Vallejo, CA 94590

Nona Dennis
ESA/Madrone Associates
23 Pamaron Way
Novato, CA 94947

Thomas Dickert
Department of Landscape Architecture
University of California
Berkeley, CA 94720

Tomas Firle
San Diego Unified Port District
P.O. Box 488
San Diego, CA 92112

Calvin Fong
Regulatory Functions Branch
US Army Corps of Engineers
211 Main Street
San Francisco, CA 94105

Susa Gates
State Coastal Conservancy
1330 Broadway Avenue, Suite 1100
Oakland, CA 94612

H. Thomas Harvey
Department of Biological Sciences
San Jose State University
San Jose, CA 95192

Robert Holmes
Marine Sciences Institute
University of California
Santa Barbara, CA 93106

Thomas Inouye
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95801

Robert Jones
Jones and Stokes Associates, Inc.
2321 P Street
Sacramento, CA 95816

Michael Josselyn
Tiburon Center for Environmental Studies
P.O. Box 855
Tiburon, CA 94920

Steven Kaufmann
California Attorney General's Office
3580 Wilshire Blvd.
Los Angeles, CA 90010

Raymond Krone
College of Engineering
University of California
Davis, CA 95616

Scott McCreary
State Coastal Conservancy
1330 Broadway Avenue, Suite 1100
Oakland, CA 94612

Eric Metz
California Coastal Commission
631 Howard Street
San Francisco, CA 94105

Thomas Niesen
Department of Biological Sciences
San Francisco State University
San Francisco, CA 94132

John Oliver
Moss Landing Marine Laboratories
P.O. Box 233
Moss Landing, CA 95039

Chris Onuf
Marine Science Institute
University of California
Santa Barbara, CA 93106

Margaret Race
Human Biology Program
Stanford University
Stanford, CA 94305

Robert Radovich
California Department of Fish and Game
1416 9th Street
Sacramento, CA 95814

Fred Roberts
Alameda County Mosquito Abatement Dist.
3024 E. 7th Street
Oakland, CA 94604

James Schooley
Department of Biological Sciences
California State University
Hayward, CA 94542

Howard Shellhammer
Department of Biological Sciences
San Jose State University
San Jose, CA 95192

David D. Smith
David D. Smith and Associates
Box 1388
La Jolla, CA 92038

Felix Smith
US Fish and Wildlife Service
1230 N Street
Sacramento, CA 95814

Jonathan Smith
Bay Conservation and Development Comm.
30 Van Ness Avenue
San Francisco, CA 94102

Jens Sorensen
Jens Sorensen and Associates
2445 G Street
San Diego, CA 92102

Paul Springer
Wildlife Research Field Station
Humboldt State University
Arcata, CA 95521

Nancy Wakeman
Bay Conservation and Development Comm.
30 Van Ness Avenue
San Francisco, CA 94102

Phil Williams
Phil Williams and Associates
Pier 33 North
San Francisco, CA 94111

Joy Zedler
Department of Biology
San Diego State University
San Diego, CA 92182

John Zentner
State Coastal Conservancy
1330 Broadway, Suite 1100
Oakland, CA 94612

Preface

Geologically, California's wetlands are relatively recent in origin. Most estimates place the origins of present-day wetlands at 4,000 to 6,000 years ago as the rate of submergence due to a rising sea level slowed to within 1-2 m per millenium. During this period, wetlands in California expanded to cover approximately 381,000 acres. These wetlands supported abundant fish and wildlife resources in addition to an aboriginal human population. The arrival and early colonization of the California coast by Europeans brought both loss and gain to the wetland habitat. Gone were the large mammals utilizing the wetlands, the plumage birds inhabiting tidal shores, and the native American Indians who relied on the wetland flora and fauna for food. Additions to wetlands included the introductions of exotic species of wildlife, expansion of mudflats and marshes due to increased sedimentation, and development of upland areas adjacent to wetlands. Yet, none of these changes had as major an impact as the almost complete destruction of wetlands by the rapid development of California in the last 50 years.

Destruction of wetlands has not been isolated to California, but in no other state has the loss been as great, amounting to 95 percent in some regions. Only during the past decade have concerned citizens brought pressure to bear on legislators and developers to recognize the damage and to preserve and enhance the remaining habitat. Large sums of money have been invested by public and private sources to not only preserve, but to expand existing wetland habitats. Analogous to the recent geologic origin of California's wetlands, the science of wetland restoration and enhancement is young and based on a haphazard experience of success and failure.

These proceedings developed from a workshop held in February 1982 at the California State University, Hayward. The purpose of the workshop was two-fold: 1) to summarize the existing knowledge on wetland restoration and enhancement in California and, 2) to address current problems and constraints which limit our abilities to successfully restore such systems. This publication is intended to reflect the diversity and enthusiasm of the conference. Eight major presentations were given followed by comments from invited panelists who reviewed the papers. Audience comments were then solicited and included in the proceedings. A contributed poster session was also held and the abstracts printed herein. Prior to publication, each paper was critically reviewed by panel members.

The need for the workshop and these proceedings was recognized by several agencies and many interested individuals, without which the proceedings could not have been published. The California Sea Grant College Program and the California Coastal Commission acted as major sponsors of the workshop. The San Francisco Bay Conservation and Development Commission, the State Coastal Conservancy, and the California State Universities at Hayward and San Francisco were instrumental in providing needed services to complete this undertaking. An advisory committee assisted in the planning and organization of the workshop. The committee members were: Roger Barnhart (Cooperative Fisheries Research Program), Susa Gates (State Coastal Conservancy), Eric Metz (California Coastal Commission), Chris Onuf (University of California, Santa Barbara), James Schooley (California State University, Hayward), Jens Sorensen (California Sea Grant College Program), Nancy Wakeman (Bay Conservation and Development Commission), and Joy Zedler (San Diego State University). Local arrangements for the meeting were ably handled by Dr. James Schooley of California State University, Hayward with assistance provided by Nan Franceschini. I wish to extend special thanks to Dean W.G. Vandenburgh for providing a large meeting space when we realized the capacity of our original arrangements would be exceeded. Support for the research reported herein by Milton Boyd, Chris Onuf, Jens Sorensen, and Joy Zedler was supported, in part, by the California Sea Grant College Program.

The workshop was attended by 250 people and according to registration, affiliation consisted of 20 percent associated with universities, 51 percent with government agencies, 14 percent with private consulting firms, 8 percent with environmental organizations, and 7 percent as private individuals. The workshop was moderated by Joanne Sorenson of Jones and Stokes Associates, Inc. and Joe Tieger of the U.S. Fish and Wildlife Service. A keynote address was given by Dr. Hanley Smith of the Waterways Experiment Station, Vicksburg, Mississippi on "Wetlands Research and Restoration: the Corps Experience".

The proceedings were funded by the California Sea Grant College Program, the California Coastal Commission, and San Francisco State University. I am grateful to Vi Weathersby and Susan Hayes for their typing of various papers and transcripts. Kelly Anderson, Communications Coordinator for the California Sea Grant College Program, provided much helpful advice and support in completing the publication. I wish to acknowledge all the panel members for their critical review of the papers and the diligent efforts of the authors in meeting deadlines.

Michael Josselyn
November 1, 1982

Summary of Past Wetland Restoration Projects in California

Michael Josselyn, *Tiburon Center for Environmental Studies, Tiburon, CA*
James Buchholz, *Wetlands Research Associates, Inc., San Francisco, CA*

Introduction

Wetland restoration and enhancement has become a significant activity in California over the past decade. A change in public and governmental attitudes concerning wetlands has occurred due to recognition of their significant wildlife habitat value and alarm over uncontrolled bay and coastal development. The first effective governmental action taken to regulate the development of wetlands was the creation of the San Francisco Bay Conservation and Development Commission (BCDC) in 1965. The preparation of a Bay Plan and the passage of the McAteer-Petris Act of 1969 formalized the Commission's regulatory powers to guide the conservation and development of the Bay's wetlands. The result has been a rapid decrease in filling activity and a more frequent use of wetland resoration or enhancement as mitigation for shore zone development. State-wide efforts to control development in wetlands began with the passage of the California Coastal Act of 1976 and the formation of the California Coastal Commission (CCC). In exercising its permit granting authority, the CCC receives advisement and policy direction from the Resources Agency Wetland Policy (1977), Senate Concurrent Resolution No. 29 (1979), and various state and federal agencies with jurisdiction or expertise in wetland habitats. The CCC has recently adopted (1981) its own Statewide Interpretive Guidelines for Wetlands. State policy towards wetlands was changed from a regulatory role to active participation in restoration and enhancement with the formation of the State Coastal Conservancy in 1976. Coupled with increasing federal responsibility in wetland protection, state and regional agencies, often encouraged by local and national citizen groups, are now pursuing a wide range of alternatives to preserve remaining wetlands and to recreate habitats degraded by development (Environ. Law Inst., 1981).

With the advent of a permitting system, records of proposed wetland restoration projects have accumulated at various state agencies. Many of these projects have been completed, others are in progress, while still others have not been undertaken. Project sizes have ranged from less than an acre to over 200 acres and have included designs ranging from small scale vegetation planting to earthmoving and tidal restoration. The planning documents, designs, and technical reports on these projects have great potential value to individuals and agencies undertaking new projects. Unfortunately, those desiring information are often confronted with great difficulty in locating pertinent documents and individuals knowledgeable about specific projects. Our goals in writing this paper are to present a definitive listing of completed projects in California and to provide bibliographic data to direct individuals to appropriate sources. A by-product of our search is the development of recommendations to improve information transfer from these sources to agencies and groups planning future projects.

Methodology and Limitations

This inventory lists projects undertaken to restore or enhance wetland habitats within the coastal zone (as defined by the Coastal Act of 1976) and San Francisco Bay (excluding the Delta region). These enhancement and restoration projects usually involve a complete or partial establishment of tidal and/or freshwater flows to stimulate the growth and establishment of wetland vegetation and associated wildlife habitat (channels, mudflats, plant cover). We excluded projects whose primary goal was to create open water habitat.

Data for the projects came primarily from permit files at the San Francisco Bay Conservation and Development Commission, the California Coastal Commission, the State Coastal Conservancy, and the U.S. Army Corps of Engineers. Additional project information was obtained through contact with persons responsible for wetlands in the California Department of Fish and Game, various local public works and park districts, and private consulting firms. In some cases, published reports in the scientific literature provided detailed information not found elsewhere. Our inquiry was conducted from September, 1981 to January, 1982; projects initiated after this date are not included.

We limited our listing to projects in which permits

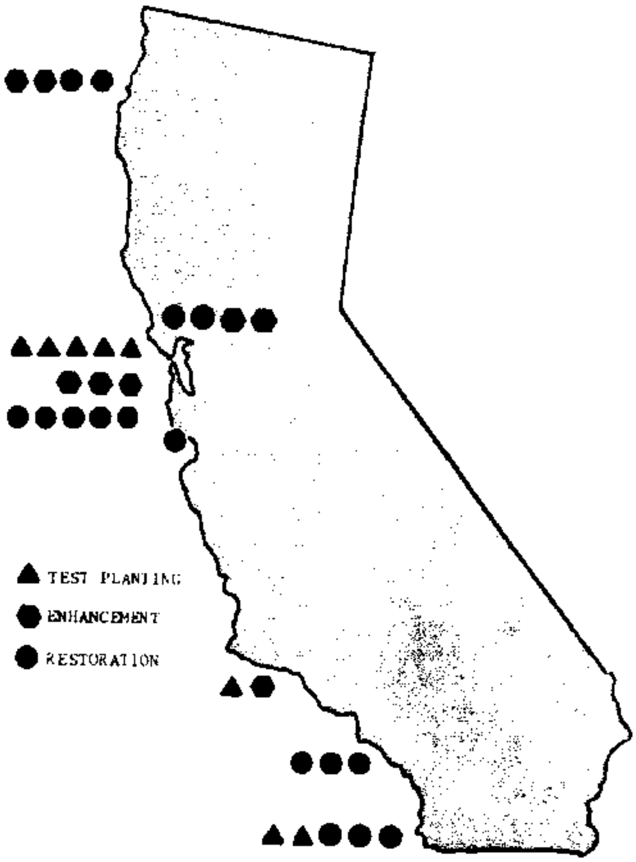

Figure 1: *Location of completed wetland restoration and enhancement projects in California as of 1981.*

had been authorized and construction or planting activity had begun. We discovered that permit authorization did not necessarily lead to wetland restoration as projects were stopped, goals changed, or legal challenges were outstanding. Listing such projects would create an over-estimation of actual acreage involved in wetland restoration. Non-permit activity which resulted in new wetland habitats was not always included due to the difficulty of compiling accurate information. For example, dike failure due to lack of maintenance could result in the establishment expansion of wetland vegetation. Such events might be accidental or represent benign neglect on the part of responsible agencies. Other non-permit activity includes expansion of wetlands due to sedimentation caused by upland activity or shoreline construction. The only non-permited restoration activity we considered were experimental plantings documented in published literature.

We categorized projects into three areas: 1) experimental plantings, 2) enhancement projects involving only dike breaching or tide gate construction and, 3) restoration projects involving both dike breaching and substrate alteration (dredge spoil disposal; earthmoving).

Project Listings

Table 1 illustrates the difficulty in compiling information on wetland restorations using available summary listings. Synonyms for various projects abound and criteria used to list various projects are usually not given. Surveys completed at later dates do not include those listed earlier which questions the validity of previous lists. As a result, there is no clear idea about the status of wetland restorations and their success or failure.

Based on our criteria given above, 33 wetland restoration projects have been completed or, at least partially completed in the California coastal zone and San Francisco Bay (Figure 1). The majority of the projects have been completed in San Francisco Bay. Humboldt Bay and San Diego Bay have four and three projects, respectively. Our summaries for these projects are given in Tables 2, 3, and 4.

Experimental plantings (Table 2) have largely focused on the establishment of *Spartina foliosa* on dredge spoils. Much of this work has been done in San Francisco and San Diego Bays. Universities and consulting firms are principally involved in these efforts toward improving planting techniques and developing cost estimates for larger projects. The results of these plantings have been given in several technical reports and have recently been summarized for the San Francisco Bay region and southern California by Harvey *et al.* (1982) and Zedler (1982), respectively. Since any marsh planting may be considered experimental due to a lack of experience with large scale restorations, we expect that monitoring programs will provide new information on successful techniques in establishing wetland vegetation.

Table 1: *Restoration projects for San Francisco Bay listed by various reports.*

	Yudelson & Tallant, 1976	Jones & Stokes *et al.*, 1979	Harvey *et al.*, 1981	BCDC unpubl. survey, 1981	Not listed elsewhere or synonyms
1	Marin Country Day School	Marin Country Day School	—	—	—
2	Muzzi	Muzzi	Muzzi	Larkspur Ferry Terminal	—
3	Martinez Wastewater	—	—	—	Mt. View
4	Creekside Park	Creekside Park	Creekside Park	—	—
5	Alameda Creek	Alameda Creek	—	—	—
6	Marsh Road Bay Front	—	—	Marsh Rd. Sanitary Ldfl	—
7	Palo Alto Flood Basin	—	—	—	—
8	SF Bay Res. Center	—	—	—	—
9	—	Bay Bridge Approach	—	—	—
10	-	Faber Tract	Faber Tract	Palo Alto Yacht Harbor	—
11	Anza Pacific Lagoon	—	—	—	—
12	—	Pond 3	Pond 3	Coyote Hills Slough	—
13	—	Westside, Alameda Is.	—	—	—
14	—	Green Bay	—	—	Greenwood Bay
15	—	Pinole, Foster City, Nwk.	—	—	Bank Stabilization
16	—	—	Mill Vly Middle School	—	—
	—	—			
18	—	—	Palo Alto Lagoon	—	—
19	—	—	Johnson Landing	Dumbarton Bridge	Hayward Regional Shln.
20	—	—	Palo Alto Flood Basin	—	—
21	—	—	—	Point Edith	—
22	—	—	—	San Pedro Cove	—
23	—	—	—	Vallejo Mini Property	Napa River marsh
24	—	—	—	Benicia Marina	—
25	—	—	—	North Harbor Basin	Inner Harbor Basin
26	—	—	—	Charleston Slough	—
27	—	—	—	Deak Office Park	—
28	—	—	—	Shoreline Center	—
29	—	—	—	—	Martinez Wharf
30	—	—	—	—	Suisun marsh
31	—	—	—	—	Bair Island
32	—	—	—	—	Village Shopping Center
33	—	—	—	—	Ravenswood Triangle
34	—	—	—	—	Alameda Fld Ctl Basin
35	—	—	—	—	Coyote Hills freshwater

PROJECT NAME	DATE	LOCATION	ORGANIZATION
Bank Stablization Study using *Spartina foliosa*	5/76 - 1/78	Point Pinole, Foster City, Alameda Flood Control Channel, San Francisco Bay	San Francisco Bay Marine Research Center (C. Newcombe)
Marin Country Day School	1974	Marin Cty.	Madrone Assoc. (P. Faber)
Bay Bridge Approach, Oakland	1969-71	Oakland, Alameda Cty.	San Jose State (H.T. Harvey)
Anza Pacific Lagoon	1974	Burlingame, San Mateo Cty.	San Jose State (H.T. Harvey)
Alameda Creek Channel, Newark	1974-76	Alameda Cty.	San Jose State (H.T. Harvey)
San Diego River Flood Control Channel	1979	San Diego, San Diego Cty.	San Diego State (J. Zedler)
Tijuana Estuary Lagoon	1979	San Diego Cty.	San Diego State (J. Zedler)
San Diego Bay Wildlife Reserve	1981	Chula Vista, San Diego Cty.	San Diego State
Mugu Lagoon	1981	Pacific Missle Test Center, Ventura Cty.	U.S. Navy (Ron Dow) USFWS (John Wolf)

Table 2: *Experimental plantings in California wetlands.*

SPECIES PLANTED	REPORTS	REMARKS
Spartina foliosa: Seeds, Sprigs, Plugs, and Bio-constructs	Newcombe et al. (1979) & Newcombe (1978)	Test of various means to control erosion by vegetation.
Spartina foliosa: Plugs	Kingsley and Boerger (1976)	Planting was done by students; pilot work for Muzzi Marsh.
Spartina foliosa		
Spartina foliosa		
Spartina foliosa		
Spartina foliosa: Sprigs; competition/ grazer manipulation	Zedler (1981a) & Zedler (1981b)	Determine limiting factors for successful transplantation.
Spartina foliosa	Zedler (1981c)	Factors controlling distribution of Spartina.
Spartina foliosa Salicornia virginica Suaeda fruticosa Salicornia bigelovii Batis maritima	SDUPD (1981)	Pilot plantings on dredge spoils.
Zostera marina		Transplantation to area previously degraded.

PROJECT NAME	DATE CONST'D	TIDE GATE / DIKE BREACH	LOCATION	SIZE (A)	PERMIT	OBJECTIVES: WILDLIFE HABITAT	FLOOD CONTROL	PUBLIC ACCESS	MITIGATION	RESEARCH	OTHER
Doolittle Pond	1980	DB	Oakland, Alameda Cty.	18	BCDC (13-77)	●		●			
Charleston Slough	1981	TG	Mt. View, Santa Clara Cty	110	BCDC (2-78)	●	●	●	●		
Park Street	1979	DB	Humboldt Cty.	9.5		●			●	●	Open Space
Palo Alto Flood Basin	1981	TG	Palo Alto, Santa Clara Cty	525			●				
Elk River	1980	DB	Eureka, Humboldt Cty.	20					●	●	Open Space
Suisun	1979-1980	TG	Solano Cty.	550	BCDC (M78-144)	●		●			
Mugu Lagoon	1977-1979	DB	Pacific Missle Test Center, Ventura Cty	275	ACE	●					
Port Chicago	1980-1981	DB	Naval Weapons Station, Port Chicago	325	ACE (13014-59)	●					Mosquito Control

Table 3: *Wetland enhancement projects involving dike breaching and/or construction of tidal gates and culverts. Total costs include both actual and estimated costs for planning, design, construction, planting and management. In many cases, planning and management costs are borne by public agencies.*

PLANNING	PRIMARY RESOURCE INDIVIDUAL	HABITATS CREATED: MUDFLAT	ISLANDS	LAGOON	MARSH	OTHER	TOTAL COSTS (000)	PROJECT MONITORING	REMARKS
East Bay Reg. Park Dist.	Paul Covel, Native Plant Society		●	●			6	No formal plan.	Dredge spoils used to create islands.
Ruth and Going, Inc.	Richard Haughey, DPW, Mt. View	●		●	●		300	Begins 7/84; every 3 years for 9 years. Monitor vegetation and tidal fluctuation.	
Winzler & Kelly, Engineers	Paul Springer, Roger Barnhart, Humbolt State University	●			●		28	Extensive monitoring by staff at Humboldt. Funded by HSU, USFWS, and Sea Grant.	Mitigation for Woodley Island Marina.
	Emy Chan, ABAG	●			●				
CALTRANS	Dana Base, HSU; Joe Thorne, CALTRANS	●			●			Dana Base: birds; Mark Stopher, Gail Newton: vegetation	
California Dept. Fish and Game	Dennis Becker, California Dept. Fish and Game						500	No formal plan. Natural colonization expected.	Of total, 170 acres completed.
U.S. Fish and Wildlife Service	Ron Dow, U.S. Navy	●		●			250	No formal plan	Increased tidal activity by replacing roadfill with bridge.
USFWS, U.S. Navy, ACE	Dave Sikes, U.S. Navy		●		●		14	Site included in U.S. Navy Natural Resource Survey.	Mitigation for dredge spoils disposal; two sites in project-P161

Diked lands containing wetland vegetation can be restored to complete or partial tidal flows as a means of restoring these areas to their former state. The increased tidal action usually results in the re-establishment of natural intertidal zonation patterns. We have listed eight projects, ranging in size from 10 to 525 acres (Table 3). Because most of these projects were designed to improve circulation in areas where wetlands were still present, only minimal monitoring has been conducted except for the Park Street project in Humboldt County. The Palo Alto Flood Basin is a multipurpose project to create wetland habitat and to control and partially treat urban runoff (ABAG, 1979). The cost of these projects varies considerably, but are less than projects involving major earthwork or excavation (see Table 4). The construction of tide gates and other water control structures make up the largest proportion of the cost.

Most restoration projects involve changes in the substrate of the site prior to re-establishment of tidal flows (Table 4). Ground subsidence and erosion of land behind dikes requires fill to recreate elevations suitable for marsh plants. On the other hand, sedimentation or fill on former tide lands necessitates the construction of channels and/or embayments to restore intertidal habitat. Once new land contours have been established, marsh planting is often undertaken to accelerate the regrowth of wetland vegetation. These projects require extensive engineering plans, careful biological considerations, and large budgets. Because of the costs, they are usually funded by public agencies as part of a mitigation plan for public facilities, *i.e.* harbor dredging to create open space and public access to the shore. The documentation on these projects is extensive and includes feasibility studies, impact statements, permit recommendations, and technical reports on specific aspects. Unfortunately, most documents are of limited distribution and quickly lost in a mass of literature. It is usually necessary to contact the individuals directly involved in supervising or planning the project (Table 5).

Recommendations

In reviewing the literature and through discussions with resource individuals, we discovered two major weaknesses in the planning process. First, the objectives of a project are usually very general and not stated clearly in the planning documents. Most frequently, mitigation or creation of wildlife habitat are the stated objectives. Aside from describing attributes of wetland habitats, little effort is focused on the specific needs of the area and the reasons for creating mudflats, ponds, or upland vegeta-

Table 4: *Wetland restorations involving major substrate alterations. Date of construction refers to initial construction activity. Objectives determined from permit or planning documents. Additional reports refer to documents separate from initial planning and EIR reports. Total costs include both actual and estimated for planning, design, construction, planting, and monitoring. In-house costs borne by government agencies and land acquisition costs not included.*

PROJECT NAME	DATE	LOCATION	SIZE (A)	PERMIT
Faber Tract	1965-1971	Palo Alto, Santa Clara Cty	95	BCDC 4-68
Mt View Freshwater	1974	Contra Costa Cty	20	no juris.
Pond 3	1975	Hayward, Alameda Cty	110	---
Muzzi	1975	Corte Madera, Marin Cty	125	BCDC 22-73
Creekside Park	1976	Kentfield, Marin Cty	16	NA
Benicia Marina	1976	Benicia, Solano Cty	19	BCDC 5-77
Bolsa Chica	1978	Huntington Beach, Orange Cty	150	ACE
Arcata Freshwater	1979	Arcata, Humboldt Cty	37	CCC CP-1-79
San Diego Bay Wildlife Reserve	1979-1981	Chula Vista, San Diego Cty	100	CCC 1976 CE 1977
Hayward Regional Shoreline	1980	Hayward, Alameda Cty	225	BCDC 20-73 CE 12488-49
Moran Lake Resource Enhancement	1980	Live Oaks, Santa Cruz Cty.	13	CCC: CP-4-80
Bracut	1981	Humboldt Cty	6	CCC: CP-10-80
Big Canyon	1981	Newport Beach, Orange Cty	15	CCC: 91-81
San Elijo Lagoon, East Basin	1979-1981	San Diego Cty.	155	CCC ACE
Seal Beach National Wildlife Refuge	1978-1982	Orange Cty.	220	CCC ACE
Santa Margarita River Estuary	1971-present	Camp Pendleton, San Diego Cty.	92	

OBJECTIVES: Mitigation	OBJECTIVES: Wildlife Habitat	OBJECTIVES: Research	OBJECTIVES: Sewage Treatment	OBJECTIVES: Public Access	OBJECTIVES: Other	PLANNING (FEASIBILITY/EIR)	ADDITIONAL REPORTS: Hydrology/Sediments	ADDITIONAL REPORTS: Flora	ADDITIONAL REPORTS: Fauna	PRIMARY RESOURCE INDIVIDUAL	RESTORATION METHODS: Dredge Spoil	RESTORATION METHODS: Regrading/Excavation	RESTORATION METHODS: Dike Breaching	RESTORATION METHODS: Planting	RESTORATION METHODS: Other	TOTAL COST (000)	PROJECT MONITORING	REMARKS
●						---	●	●		H.T. Harvey, Harvey & Stanley Assoc, J.A. Alpin	●			●		120	Unspecified monitoring.	Primarily dredge spoil disposal, with some planting done.
	●					J.Warren Nute, Inc. (1978)				Fran Demgen, Demgen Aquatic Biol.		●		●		80	Mt. View Sanitation District, Demgen (1979)	
		●				Harvey (1972)	●	●		P. Knutsen, USACE	●	●	●	●		1070	USACE (Appendix K), 1976; Morris et al., 1978: vegetation.	10% of area planted.
●	●			●		GG Bridge High. Trans. Dist. (1973); Madrone Assoc.	●	●		Gene Rexrode, GGBHTD	●	●	●	●		1234	Faber (1979, 80a, 80b), monitor vegetation for first 4 years.	Planting and public access planned, 1982-1983.
	●			●		Royston, Hanamoto, Allan, & Abbey (1975)				Brian Whittenkeller, Private Consult.	●			●	Culvert	226	No monitoring.	Limited test planting.
	●				Improve Water Quality	Sentina and Thompson (1975)	●	●		R.C. Carter CSO Intl., Inc.		●			Tide Gate		Unspecified monitoring.	Marsh proposed as a "treatment system".
	●			●		Cal. Fish and Game (1974)	●	●	●	B. Novick, Fish & Game		●			Tide Gates	546	Cal. Fish and Game have responsibility, unspecified.	Phase 1 completed.
	●	●	●	●	Aquaculture	Envir. Analysts Inc. City of Arcata (1979) Tertascan (1979)				Frank Klopp, Public Works City of Arcata		●	●	●		789	Unspecified monitoring.	Upland planting done, marsh planting not done.
●	●					SDUnified Port Dist. (1976); Smith <u>et al.</u> (1975); David D. Smith & Assoc.	●		●	T. Fiile, SDUPD	●			●		2610	Unspecified annual reports to California Coastal Commission.	Planting not started, some pilot planting.
●	●			●		East Bay Reg. Park Dist.; Madrone Assoc. (1978); W&E, Inc. (1978)	●	●		P. Koos, EBRPD H. Cogswell, EBRPD		●	●	●		902	Niesen, Josselyn (1981), monitor fish, inverts., soils, vegetation for first 12 months.	Planting planned for 1983.
	●			●	Improve Water Quality	Santa Cruz Cty (1976)				Ray Holmberg, County of Santa Cruz		●		●	Tide Gate	421	Visual monitoring by County of Santa Cruz.	Upland planting completed, some pilot marsh planting.
●	●	●		●		Winzler & Kelly Eng. (1980); Camp, Dresser McKee Inc. and Madrone Assoc (1980)				Herb Pierce, Cal. Fish & Game Frank Klopp, Public Works, City of Arcata		●	●	●		164	Unspecified monitoring by graduate student(s), no written documentation	Further earthwork needed, no planting completed.
●	●			●	Clapper Rail	EDAW, Inc.; Orange County Sanitation District #5				Carl Wilcox, Cal. Fish & Game		●		●		270	Cal. Fish and Game bird surveys.	Flooding problems. Uplands planted, no marsh planting.
	●			●	Improve Water Quality; Mosquito Control	Cal. Fish and Game; Lagoon Tech. Comm.; San Elijo Alliance	●			Earl Lauppe, Cal. Fish and Game		●			Water Control Struct.	400	Unspecified monitoring	Control structures to increase freshwater retention.
	●				Mosquito Control	U.S. Fish and Wildlife Service				Tom Charmley, USFWS		●			Removed Vehicle Access	160	Planned but not funded	Ponds and islands created.
	●					U.S. Fish and Wildlife Service				Linda Belluomini, Camp Pendleton		●				N/A	No monitoring	Preliminary work only, not part of USFWS Enhancement Plan.

tion. Whereas the engineer has formulas to calculate flows and tidal heights, the ecologist has not developed similar criteria to evaluate the size and configuration of specific habitats. The result is a plan developed to meet engineering criteria and not ecological function. Second, project monitoring should be included at the planning stage so that funds and personnel can be dedicated to evaluating the success of the project. Restoring a major ecosystem is not a simple task, but requires careful observation once construction is completed and tidal action restored. We found that monitoring was usually given low priority and often not considered until after the project was completed. Only one project, Muzzi marsh, had a monitoring program longer than two years. It is essential to assure the public that its money is well spent and to improve on future projects that more effort be placed on monitoring.

We also feel that greater effort should be made by the permitting agencies to develop standard reporting forms for their projects. There is a wealth of information contained in documents and permit applications filed during the planning process which are invaluable to other agencies. It seems each new project "reinvents the wheel" instead of building on past documentation. Careful cost analysis would also be useful to those planning new projects. We recognize that complex acquisition schemes and site specific problems make each project different, but at present a great deal can be learned from past experience. Both this paper and the workshop were planned to initiate a more concerted effort to bring together needed data to improve the planning, implementation, and success of wetland restoration.

Table 5: *Names and addresses of primary resource individuals listed in Tables 3 and 4 for various wetland restoration and enhancement projects.*

Barnhart, Roger
Cal. Cooperative Research Unit
Humboldt State University
Arcata, CA 95521

Base, Dana
2128 Quaker Street
Eureka, CA 95501

Becker, Dennis
Cal. Dept. Fish and Game
PO Box 47
Yountville, CA 94595

Belluomini, Linda
Base Director of Natural Resources
Marine Corps Base
Camp Pendleton, CA 92055

Carter, Ralf
Tideline Marine Co.
2130 Madeline
Oakland, CA 94602

Chan, Emy
Assoc. Bay Area Governments
Hotel Claremont
Berkeley, CA 94705

Charmley, Thomas
Seal Beach National Wildlife Refuge
Box 219
Delano, CA 93216

Cogswell, Howard
Biological Sciences
California State University
Hayward, CA 94542

Covel, Paul
Cal. Native Plant Society
2380 Ellsworth Street
Berkeley, CA 94704

Demgen, Fran
Demgen Aquatic Biology
118 Mississippi Street
Vallejo, CA 94590

Dow, Ron
Point Mugu Naval Air Station
Code 6230-2
Point Mugu, CA 93042

Firle, Tomas
San Diego Unified Port District
PO Box 488
San Diego, CA 92112

Harvey, H. Thomas
Department of Biological Sciences
San Jose State University
San Jose, CA 95192

Haughey, Richard
Department of Public Works
City of Mountain View
Mountain View, CA 94040

Holmberg, Ray
Department of Public Works
County of Santa Cruz
Santa Cruz, CA 95061

Klopp, Frank
Dept. Public Works
736 F Street
Arcata, CA 95521

Knutson, Paul
Coastal Engineering Res. Center
Kingman Building
Ft. Belvoir, VA 22060

Koos, Peter
East Bay Regional Park District
11500 Skyline Blvd.
Oakland, CA 94619

Lauppe, Earl
Cal. Dept. Fish and Game
350 Golden Shore
Long Beach, CA 90802

Novick, Harold
Cal. Dept. Fish and Game
8671 Viceroy Circle
Huntington Beach, CA 92647

Pierce, Herb
Cal. Dept. Fish and Game
Eureka, CA 95501

Rexrode, Gene
GGBHTD Box 9000
Presidio Station
San Francisco, CA 94129

Sikes, David
Concord Naval Weapons Station
Public Works Engineer
Concord, CA 94524

Springer, Paul
Wildlife Research Center
US Fish and Wildlife Service
Humboldt State University
Arcata, CA 95521

Wilcox, Carl
Cal. Dept. Fish and Game
1013 W. Bay Avenue
Newport Beach, CA 92661

Wittenkeller, Brian
69 Lincoln Avenue
San Anselmo, CA 94960

An Inventory of California Coastal Wetlands with a Potential for Restoration and Enhancement

Susa Gates, *State Coastal Conservancy, Oakland, CA*

Preface

In late 1981, the State Coastal Conservancy was preparing an inventory of coastal wetlands jointly with the Department of Fish and Game (DFG). The inventory was to be based on a preliminary survey completed by the State Coastal Conservancy with the assistance of the DFG wetland staff (State Coastal Conservancy 1980). It was intended that this survey would be refined and include detailed descriptions of individual wetland habitat types, restoration and enhancement needs, and habitat maps. Due to budget cuts, the inventory was discontinued by both agencies. The importance of a comprehensive inventory of potential coastal wetland restoration needs will hopefully prevail allowing the continuation of the inventory in the future.

Introduction

An assessment of the coastal and San Francisco Bay wetland resources is critical in focusing institutional, political, and financial resources on those wetlands needing restoration. The goal to maintain and restore the remaining habitats while retaining the diversity of wetland habitats can only be achieved if those institutions and individuals concerned with natural resource protection, are aware of the wetland sites where the habitat value is diminishing or currently have high wildlife value and therefore deserve special protection. This paper defines "potential for restoration" in two ways. The first definition is an identification of those wetlands which due to artificial modifications, high floral or faunal value, or other unique attributes, have a higher priority for preservation and restoration (Table 1). These wetlands should have a greater potential for restoration because of the special biological importance and/or critical threat that has been identified for these sites. However, this analysis is not meant to imply that 1) other wetlands should or will be excluded because they are not identified in the existing survey, 2) any of the surveys are definitive, for many wetlands there is little information on the quality and type of environmental resources.

The second definition used to describe wetlands with a "potential for restoration" refers to those projects (as of July 1, 1982) which are being planned by an agency/organization where restoration is imminent (Table 2). Many of these agencies/organizations are obtaining permits, final engineering drawings, or other requirements necessary for project construction. Clearly these projects have a very high potential for restoration.

The first section of the paper presents a compilation of wetlands requiring restoration. In the second section, a list of projects under active planning is given. In the final section, various projects which may receive funding preference are described, *i.e.* wetlands that fall into these categories are more likely to be restored due to current institutional or political funding priorities.

Wetlands Identified for Preservation and Enhancement

Substantial portions of many wetland systems, and in a few cases, entire wetland systems have been destroyed. Many of the remnant systems are subject to ongoing artificial disturbances which have diminished or are threatening unique wildlife values. It has been suggested that an evaluation of disturbed and modified wetlands should distinguish between alterations that have resulted from natural causes and those accelerated by man-made influences. Unfortunately, such a distinction is not easy. Certain impacts such as sedimentation are difficult to distinguish between natural and man-made causes because little documentation is available on natural geologic processes within specific wetland systems. Secondly, wetland dynamics which would have accommodated natural alterations have been disrupted. The diminished capacity of the wetland system to respond to detrimental conditions, either natural or man-made, may make it more difficult for a system to recover. Largely due to the lack of consistent site-by-site data, this paper combines natural and man-made alterations in their effect of degrading wetlands.

The four surveys given below were used to identify wetlands with a potential for preservation and enhancement among the 150 identified wetlands on the coast and in San Francisco Bay. Current efforts in wetland restoration will improve the status of several wetlands and more wetland systems should be added to the list. Several wetlands have been identified only for acquisition. These wetlands are included in the matrix because 1) the objective of several surveys was to prepare an acquisition priority list with a subsequent assessment of restoration needs and 2) valuable wetlands already in public ownership have a greater potential for restoration than wetlands where acquisition is necessary.

A survey undertaken by the Coastal Conservancy (1980) identified those wetland systems that had been artificially impaired and required enhancement. At this time, about 44 percent of the remnant coastal wetlands have been so severely disturbed and impaired that they need restoration. These wetlands have been disturbed by land use and management conflicts with the natural processes of the wetland. The criteria used to select wetland areas where restoration is both possible and desirable were based on the type and degree of artificial alteration that affected the habitat including:

1. Reshaping of coastal water basins by channelization and dredging for harbors, ports and marinas.
2. Diking of wetlands.
3. Filling of wetlands.
4. Restriction of tidal flow by roads, railroad crossing, channels or other structures in the wetland.
5. Reduction of tidal flow by roads, railroad crossings, channels or other structures in the wetland.
6. Water pollution from point and non-point sources.
7. Accelerated sedimentation.
8. Excessive human use of the wetland.
9. Degradation or loss of supporting upland vegetation.

From the criteria enumerated above, it is clear that many problems affecting coastal wetlands are not unique to an individual wetland system. Typically, wetland mod-

Table 1: *List of potential acquisition or restoration projects for wetland habitats in California. Abbreviations: R—recommended for restoration; A—recommended for acquisition; P—in private ownership; PU—in public ownership; P/PU—in partial private and public ownership; U—ownership unknown at this time.*

Wetland	SCC (1980)	USFWS (1979)	DFG (1976)	DFG (1970-1978)	USFWS (1980)	Ownership
Del Norte						
Smith River Estuary Yontocket Slough	R			R		P
Lakes Earl & Talawa		A		R		P/PU
Crescent City Marshes	R					P
Lagoon Creek Marsh	R					U
Klamath River	R					P/PU
Humboldt						
Redwood Creek Estuary	R					P/PU
Stone Lagoon & Lagoon	R				R	PU
Big Lagoon	R				R	PL
Little River Estuary	R					U
Mad River Estuary	R	R				U
Humboldt Bay		R		R		P/PL
Eel River Delta	R	R		R		P
Bear River	R					P
Mattole River	R					P
Mendocino						
Seaside Creek						P
Pudding Creek	R					U
Big River Estuary	R		A		R	P
Albion Creek	R					U
Sonoma						
Gualala River	R					U
Lake Oliver	R					P
Bodega Bay	R		A	R		P/PU
Marin						
Estero Americano	R		A			P
Estero de San Antonio						
Tomales Bay	R	R				P/PU
Bolinas Lagoon				R		P/PU
Napa						
Napa Marshes	R					U
Marin						
Petaluma Marsh	R					P/PU
Gallinas Creek Marsh	R					
Novato Creek Marsh	R					U
San Rafael Creek Marsh	R					U
West Marin Island					R	U
Contra Costa						
North Richmond Marsh	R					U
Alameda						
Emeryville Crescent					R	P
San Mateo						
Pillar Point Marsh (Princeton Marsh)	R					P/PU
Pescadero Marsh	R			R		P/PU
Franklin Point Dune Marsh	R					P
Santa Cruz						
Wilder Creek	R					PU
Neary's Lagoon	R					P/PU
San Lorenzo River						
Woods Lagoon & Arana Marsh	R					U
Corcoran Lagoon	R					P
Watsonville Slough	R				R	PU

ifications are the result of a single land use conflict or a combination of land use conflicts, e.g., timber harvest, urban development. Frequently, these conflicts occur throughout a region rather than occurring as specific problems to individual wetland systems. Major statewide threats to wetlands also occur such as water diversion.

In 1979, the U.S. Fish and Wildlife Service (FWS) prepared the *Concept Plan for Wintering Waterfowl Habitat Preservation* in which 23 wetlands were identified that required preservation and restoration. The report surveyed important habitats for wintering waterfowl that were presently unprotected, tidal wetlands, and habitats that were unique or supported endangered species.

The Department of Fish and Game (1976) has identified 19 wetlands in the report, *Acquisition Priorities for the Coastal Wetlands of California*. These wetlands were listed because they represented several wetlands with high resource values that were threatened. The DFG also wrote in-depth reports on 20 coastal wetlands (DFG, 1970-8). The wetland series (*e.g. The Natural Resources of Morro Bay*) identified the restoration needs of each system.

The USFWS (1980) identified 7 coastal or Bay wetland areas that needed to be preserved because of their high floral and faunal value and the threatened status. Criteria for selection of these areas were:

1. the full compliment of animals, plans and physical features thought to represent an ecosystem.
2. Areas where sensitive species still occur and are concentrated.

These surveys have been compiled in a matrix (Table 1) to give the reader an overview of those wetland areas which have been identified as needing preservation through acquisition or regulation and/or enhancement to protect or restore resource values. Information is also indicated to distinguish if the wetland is in public or private ownership.

Current Wetland Enhancement Projects

Several projects are underway to protect and enhance wetlands (Table 2). Several of these projects are primarily acquisition or dedication projects to protect the habitat or preserve the opportunity for restoration in the future. Other projects have restoration or enhancement plans being developed to restore wetlands on public or private lands to be acquired or dedicated to a public agency.

Wetland	SCC (1980)	USFWS (1979)	DFG (1976)	DFG (1970-1978)	USFWS (1980)	Ownership
Monterey						
McClosky Slough		R				P
Elkhorn Slough - Bennett Slough	R		A	R		P/PU
Moro Cojo Slough		R				P
Old Salinas River Slough		R				P
Salinas River Estuary	R					L
Marina Ponds	R					U
Roberts Lake—Laguna Grande	R					P/PL
Del Monte Lakes	R					PU
El Estero	R					U
Carmel River	R					P/PU
San Luis Obispo						
Pico Creek	R					U
Santa Rosa Creek	R					P
Morro Bay	R		A	R		P/PU
Pismo Lake	R			R		PU
Dunes Lakes	R	A		R	R	P
Oso Flaco Lakes	R	A		R		P
Santa Maria River	R	A	A	R		P
Santa Barbara						
Santa Inez River	R					PU
Isla Vista Vernal Pools	R					P/PU
Goleta Slough	R			R		P/PU
Carpinteria Marsh	R		A	R		P/PU
Ventura						
Ventura River Estuary	R					P/PU
Ormond Beach Marsh	R					P
Mugu Lagoon	R	A		R		PU
Los Angeles						
Ballona Wetlands	R					P
Ballona Lagoon	R					P
Del Rey Lagoon	R					P
Los Cerritos Wetlands	R					P
Orange						
Seal Beach Wetlands (Hellman Prop.)	R					P
Anaheim Bay	R	R			R	PU
Bolsa Chica Wetlands	R	R			R	P
Huntington Beach Wetlands	R	R				P
Santa Ana River Mouth	R	R				P/PU
Upper Newport Bay	R		A	R		P/PU
San Diego						
Buena Vista Lagoon	R					PU
Aqua Hedionda Lagoon	R		A	R		P/PU
Batiquitos Lagoon	R		A	R		P/PU
San Elijo Lagoon	R		A	R		P/PU
San Dieguito Lagoon	R		A	R		P/PU
Los Penasquitos Lagoon	R		A	R		P/PU
Famosa Slough	R					P/PU
South San Diego Bay Wetlands			A	R		P/PU
Tijuana River Estuary			A			P/PU

Wetlands with Future Restoration Potential

The majority of future wetland restoration projects will fall under one of the following categories. In the future, fewer projects will be partially funded by the local government as San Elijo Lagoon restoration has been. Even fewer wetlands will be restored by hustling money, government manpower, colleagues and friends as the current pilot restoration project in Elkhorn Slough. Several restoration projects will be the result of mitigation for development permits. Projects which have multiple values such as protecting wildlife resources and providing wastewater treatment or providing aquaculture facilities will have wider appeal and provide greater incentive to be planned and funded.

Listed below are examples of ongoing projects or identified pootential restoration projects which fit under one of these categories. Several of these wetlands are not indicated on the surveys as wetlands in need of restoration, but have a greater potential of being restored because of secondary values such as wastewater treatment.

- Mitigation for a development permit
  - Ormand Beach marshes
  - Seal Beach Wetlands
  - Ballona Wetlands
  - Bolsa Chica Wetlands
  - Los Cerritos Wetlands
- Landbanking and enhancement
  - Bracut marsh
  - Belmont Keyes
  - Pt. Edith, San Francisco Bay
- Waste water treatment and wetland enhancement
  - Batiquitos Lagoon
  - San Joaquin Marsh
  - Salinas River
  - Andree Clark Bird Refuge
- Flood Control projects and wetland enhancement
  - Santa Ana River Mouth
  - Klamath River estuary
  - Carpinteria Marsh
  - Smith River estuary
- Harbor dredging
  - Bodega Harbor
  - Morro Bay
- Aquaculture
  - Arcata Freshwater Marsh
  - Tomales Bay
  - Elkhorn Slough
- Grants to implement the LCP
  - Carpinteria Marsh (Ash Street Marsh)
- Potential park development area
  - McGrath Lake
  - Big Lagoon
- Local land trusts for wetland enhancement
  - Antonelli Pond
  - Buena Vista Lagoon
  - Tijuana Estuary

Conclusions and Recommendations

Wetland restoration goals have been defined by biogeographical regions along the coast (Zentner, 1982). It may also be useful for wetland restoration experts to view restorations and management problems from a region-wide perspective. The objective of viewing restoration problems from a regional perspective would be to provide a broader perspective for developing and combining problem solving techniques and strategies (e.g. timber harvesting near wetlands in the north coast to control erosion or highway reconstruction plans in the central coast to improve circulation.)

Many problems that need to be addressed in order to restore wetlands are broader regional problems. Restoration regions could be defined by the major factors causing wetland degradation, the types and intensity of surrounding land uses and the future potential for wetland restoration. Clearly, along the coast there is considerable variation in the predominate land use types and their concentration in certain areas, for example, Los Angeles/Orange Counties vs. Del Norte/Humboldt/Mendocino Counties. Each region demonstrates common management problems that have resulted in many of the restoration needs.

There are also apparent areas with greater potential for change in the land use types. The most critical land use that negatively affects wetlands is intensive urban development because it results not only in a variety of detrimental environmental impacts but is also a long term commitment of the resources which translates into a lost opportunity for wetland restoration. For example, relatively little change would be expected in the land uses in coastal Los Angeles County because it is totally urbanized. Similarly, significant increases in urban development and loss of wetland restoration opportunities in Humboldt County would not be expected in the near future because of the depressed regional economy. However, sections of the Santa Cruz County coastline have tremendous urban development potential, therefore, greater risk of losing restoration opportunities.

Although ongoing degradation of wetland habitat is a critical concern, the diminishing opportunity to restore the habitat is even more important in some regions. In several areas along the coast, there is little remaining opportunity to restore even the semi-typical wetland system for that biogeographical region. In Los Angeles and Orange Counties, most opportunities for wetland restoration have been lost because of the long term commitment of the historic wetland to building pads. In the north coast, where many wetlands continue to be used for agricultural production, the opportunity to restore the historic wetland habitat may still exist because no irreversible commitment of the resource has been made. In the San Diego County area, a few opportunities remain to expand the wetland, but intensive urban development pressure

Table 2: *Status and future actions on wetland restoration projects in California.*

COASTAL WETLANDS

PROJECT	PROJECT DESCRIPTION	AGENCY	PROJECT STATUS	FUTURE ACTIONS
Lake Earl/ Tawala, Del Norte	Complete acquisition of Lake Earl/Tawala	WCB	Negotiating for additional land acquisition	Unknown
McDonald Creek Humboldt	Restoration of riparian vegetation by acquisition of a conservation easement, planting riparian species, and fencing the area	SCC	In review process	Implementation in November 1982
Dry Lagoon/ Big Lagoon/ Stone Lagoon Humboldt	Complete acquisitions at Big Lagoon	DFG	Acquisition complete in January 1982	Develop general plan for all three lagoons including restoration as necessary
Elk River Humboldt	Elk River Restoration Plan—Restoration as part of a wastewater treatment project which allows expansion of the Eureka sewage treatment plant	City of Eureka/ DFG	In review process	Restoration anticipated in next few years
Tomales Bay Marin	Funding to run a series of citizens workshops to develop a watershed management program	SCC	In review process	Implementation in November 1982
Pescadero Marsh San Mateo	Acquisition of additional wetland areas in private ownership	DFG	Negotiating the acquisition	Unknown
Wilder Creek Santa Cruz	Designation of the creek already in public ownership as a nature preserve for snowy plover nesting. Acquisition of uplands around creek.	DFG	Negotiating the acquisition	Develop park facilities
Hills Ranch	Dedication of an easement to protect riparian vegetation as part of a coastal permit	SCC	To be completed	None
Laguna Grande/ Roberts Lake Monterey	Watershed management and park improvement/wetland restoration plan	Cities of Monterey & Seaside	Developing the plan	Plan completion and implementation
Elkhorn Slough Monterey	(a) Acquisition of additional uplands surrounding the estuary as part of the estuarine sanctuary program	DFG	Negotiating the acquisition	Inclusion in the sanctuary
	(b) Restoration and ongoing monitoring of a diked agricultural area	Researchers at Moss Landing Marine Labs	Construction started August 1981	Ongoing construction and research
Watsonville/ Pajaro Slough Santa Cruz	Land dedication to protect wetland from encroaching development	DFG	Negotiating the dedication	Unknown
Little Sur River Monterey	Acquisition of the lower river and floodplain and designation as a state reserve or natural preserve in State Park	DFG	Unknown	Unknown
Sweetsprings Marsh San Luis Obispo	Dedication or bargain sale of the marsh and surrounding uplands	SCC	Negotiating the acquisition	Development of a restoration plan
Pismo Lake and Ecological Reserve San Luis Obispo	Lawsuit against upstream developers for accumulated sediments in Lake	DFG	Ongoing	Unknown
Isla Vista Vernal Pools, Santa Barbara	Acquisition and enhancement of vernal pools and development of an educational program and preserve system for future acquisition/ dedication of vernal pools in the area	SCC & Isla Vista Parks & Rec. Dept.	Plan completed and funding allocated. Land negotiations in progress	Implementation of restoration plan.

WCB	— Wildlife Conservation Board	CCC	— California Coastal Commission
SCC	— State Coastal Conservancy	USFWS	— U.S. Fish and Wildlife Service
DFG	— Department of Fish and Game	RWQCB	— Regional Water Quality Control Board

PROJECT	PROJECT DESCRIPTION	AGENCY	PROJECT STATUS	FUTURE ACTIONS
Carpinteria Marsh Santa Barbara	(a) Flood control project which will dredge channels and increase	Soil Conservation & Santa Barbara County	Plans completed but subject to review by CCC	Application for CCC permit in the next few months
	(b) Acquisition and restoration of historic wetland	SCC	Negotiating acquisition and developing plans	Completion of a restoration plan
Devreux Slough Santa Barbara	Restoration including methods to periodically or permanently breach mouth and control of upstream erosion	UCSB, DFG, USFWS	Developing the plan	Unknown
Goleta Slough Santa Barbara	Early planning stages of marsh restoration considerations and possible designation as an Ecological Reserve	DFG, City of Santa Barbara, SCC, UCSB	Under discussion	Unknown
McGrath Lake Ventura	Acquisition of dunes and uplands around lake	DFG	Partially funded	Unknown
Ormand Beach Ventura	Restoration and dedication as part of a coastal permit	Landowner or public agency	Under discussion	Application for CCC permit
Mugu Lagoon Ventura	Improvements to water circulation	Navy, USFWS	Restoration Plan complete but not funded	Unknown
Malibu Lagoon Los Angeles City	Restoration and expansion of salt water marsh	DFG	Restoration Plan complete and funding available. Delayed due to lawsuit.	Construction upon resolution of lawsuit
Los Cerritos Wetlands Los Angeles Cty.	Consolidation and enhancement of 130 acres of scattered degraded wetland	SCC	Site plan development	Implementation of a restoration plan as part of a development permit in the next 10-20 years
Seal Beach Wetlands Orange Cty.	Restoration of the scattered degraded wetlands onsite	SCC	Under review	Site plan development and implementation
Anaheim Bay Orange Cty.	Restoration of historic wetland to tidal marsh and improving circulation to existing wetland	USFWS	Under construction	None
Santa Ana River Mouth Orange Cty.	Acquire the tidal salt marsh and improve water circulation as mitigation for a flood control project	COE	Plan complete	Implementation will be at least 1986
Upper Newport Bay Orange Cty.	Restoration including dredging to remove sediment and upstream sediment basins	DFG	Plan complete and partially funded	Unknown
Los Penasquitos Lagoon San Diego Cty.	Develop plan to periodically breach the lagoon mouth	SCC, Sandag	Developing the plan	Implementation Summer 1982
Buena Vista Creek & Lagoon San Diego Cty.	Development of a plan to preserve and enhance the wetlands and riparian resources including legal instruments, a watershed management plan, a financing plan and acquisition of additional wetland	SCC, DFG	Watershed management plan under way and restoration plan being developed.	Implementation of watershed management plan
Batiquitos Lagoon San Diego Cty.	Acquisition of additional wetland	WCB	Negotiating the acquisition	Unknown

PROJECT	PROJECT DESCRIPTION	AGENCY	PROJECT STATUS	FUTURE ACTIONS
San Elijo Lagoon San Diego Cty.	Acquisition and restoration by recontouring basins, installation of water control devices, supplementing freshwater with treated waste water and dike construction	San Diego County, DFG, RWQCB	Construction started Fall 1981	To be completed in 1982
San Dieguito Lagoon San Diego Cty.	Acquisition and restoration of fresh and tidal saltwater marsh by dredging remaining dikes, pumping groundwater	SCC, City of Del Mar, DFG	Plan complete, negotiating the acquisition	Implementation of part (if acquisitions are not successful) or all of the plan
Famosa Slough San Diego Cty.	Preparation of hydrologic studies in order to prepare restoration plan	SCC, City of San Diego	Hydrologic study to start in February	Determine method to protect wetland through
Tiajuana River National Estuarine Sanctuary San Diego Cty.	Acquisition and implementation of the Estuarine Sanctuary program for Tiajuana Estuary including interpretive center	OCZM, SCC, CCC	Land appraisals in process	Land negotiation and plans for interpretive center

SAN FRANCISCO BAY

PROJECT	PROJECT DESCRIPTION	AGENCY	PROJECT STATUS	FUTURE ACTIONS
Marsh Rd. Bayfront Park, San Mateo Cty.	Performed in conjunction with sanitary land fill; eventual restoration of 150 acres	City of Menlo Park	Some regrading, but no tidal activity; BCDC: 18-70	Site to be restored adjacent to planned Bayfront Park
San Pedro Cove	1.5 acre mitigation for San Rafael, Marin Cty.	Private condominiums	No work done; landowner	— BCDC: 27-77
Shoreline Center, Marin Cty.	0.19 acre mitigation for construction of office complex	Private landowner	Entire project delayed; BCDC: 35-79	May not be completed
Village Shopping Center, Marin Cty.	Mitigation for shopping center; multiple use as flood basin; improve water quality, and create habitat. 34 acres	Private landowner	Planning completed.	Construction anticipated in 1982
Coyote Hills marsh/treatment facility, Alameda Cty.	Test facility to demonstrate use of wetlands to treat urban runoff	ABAG (EPA 208)	Planning completed in cooperation with EBRPD	Construction underway
Pt. Edith, Contra Costa Cty.	Mitigation for fill; requires restoration of 20 acres in Carquinez Straits	DFG, SLC	Restoration not begun; BCDC: 15-79	Will participate as part of larger land bank
Ravenswood Triangle, San Mateo Cty.	Mitigation for Dumbarton Bridge construction.	Mid-Peninsula Open Space Dist.	$350,000 allocated	Planning, permits, and implementation
Inner Harbor Basin marsh, Contra Costa Cty.	Involves dredging, dike-breach, and planting for a 4.03 acre restoration	Richmond Redevelopment Agency	Planning completed BCDC: 11-78	Construction in conjunction with marina development
Coyote Creek Slough, Alameda Cty.	Mitigation for industrial park to create 265 acre lagoon/marsh system	Private landowner	Planning completed; BCDC:	Project to be completed over several years; initial site to be used as borrow pit.
Hayward fresh-water marsh, Alameda Cty.	Creation of 125 acre fresh-water marsh on former salt evaporators. Will use treated effluent as freshwater source	EBRPD	Planning and permit process in progress	Awaiting SCC funding and final permits

makes reservation of the land increasingly difficult. Combining the criteria developed from the most significant artificial causes of wetland degradation, existing land uses, and areas where the opportunity for restoration may be lost, regionwide problems become apparent. Land uses adjacent to or in watersheds of wetlands such as: timber harvesting, agricultural production, and urbanization typically *influence* the wetland system resulting in slow and sometimes subtle habitat or species loss. Protection of the existing wetland area by regulation or acquisition will not ensure that habitats will be provided for the Beldings Savannah sparrow or the cinnamon teal in the future. It is critical that a simultaneous process be undertaken along with habitat restoration to manage these sources of detrimental pacts.

Panel Discussion

Eric Metz, *California Coastal Commission, San Francisco, CA:*

To my knowledge, this paper is the first time anything has been attempted to put together in one place a list of all potential projects for wetlands. It's a very difficult task because it involves both an accurate inventory of potential and existing projects and inevitably involves the question of restoration goals.

It's difficult to think about how to restore an individual wetland until you have a perspective about the value of that region in relation to others and whether there are any unique opportunities or special constraints. I'd prefer to see the discussion focused on generic types of wetland projects. For example, ones that require increased tidal circulation, restore open water systems, or create mudflats and why.

Secondly, I'd like to comment on the Coastal Act. The Coastal Act specifically enumerates projects which are allowed. Despite that constraint, there are some relatively innovative ways in which a developer could seek to restore degraded wetlands, as determined by Fish and Game, as well as providing for some development. Susa alluded to that when she mentioned the consolidation of fill area and the philosophy that in degraded wetland ecosystems, there may be certain areas which contain fill that can be consolidated on one portion of the site for development, and restoration of the remainder to wetland.

The question that will always come to mind, and where we're seeking guidance, is: what are the values on site that we're trying to preserve? Secondly, is it possible, and I think in most cases not, to assume that those values can be transferred off the site. And that's where the regional goals would be useful. It's difficult enough to attempt to replicate what's on site much less thinking about going off site. We have to be aware and careful that any time we're trying to play God with a natural system, there's bound to be trade-offs. The Coastal Commission is seeking as precise guidance as possible in this regard.

Calvin Fong, *U.S. Army Corps of Engineers, San Francisco, CA:*

I'm glad to see that there is a start in trying to inventory the coastal wetlands in California. Because the paper is general, it's difficult to give specific comments. I would like to know the criteria that were used in coming up with the list of 150 or so wetlands and how these wetlands are degraded. Other than that, it's very difficult to argue with an inventory. You either add or delete from the list based on the criteria used to create it. From the Corps' point of view, we can probably add to this list as a result of our regulatory program.

Basically, we have two programs in the Corps. One is the Water Resources Development Program which handles our flood control and navigation missions. We also have the Regulatory Program which deals with permits. The other day I went through the list of the permits we've issued in the last 12 months and I counted 25 restorative-type projects the Corps is involved in through permit actions. One is in Humboldt Bay and most are in the San Francisco Bay ranging in size from 0.17 acres to several hundred acres. The latter is about 290 or so acres in Fremont, which Tom Harvey and Phil Williams have been designing and developing. I think the Corps can help in coming up with a more comprehensive list of the type of wetlands being restored in California.

Felix E. Smith, *U.S. Fish and Wildlife Service, Sacramento, CA:*

The first thing we should do is protect existing wetlands. Let's not lose them in the first place. The next items are what and when do we restore something? What do you want to restore and what should it look like? For example, should the restoration stress ecosystem development or be aimed at the needs of selected species or a group of species? After we have restored an area, the next step would be to monitor what happens. Did the restoration/development work produce the desired results? Did the values, resources or uses occur in the area? In all too many instances we have not adequately monitored the final product over a long term.

As we restore marshlands, there are a couple of items I would like to stress in the area of environmental management. One is environmental safety factors. We don't seem to have the same safety factors in environmental planning as we see the structural engineers using. They build buildings, bridges, and highways with safety factors three, four or more above the design factor. This is the engineering point of view. It also protects financial investments, protects against the loss of life and property, and provides protection against unknown stresses. In the environmental planning area, we don't have safety factors. We must incorporate safety factors or similar concepts into environmental land and water use planning. This may be an area where consultants could do the job better than the agencies. If environmental safety factors are incorporated into planning, many of the concerns Susa was talking about regarding upland management will be resolved.

Another factor in environmental management is land use practices. I think most everyone realizes that estuaries or mouths of rivers or creeks are the sediment basins for the total watershed. When sediment builds up at the mouth of the river entering the open ocean, the actual impacts of sediment deposition are masked by storms, waves, currents. However, if one looks at sediment build-up in a confined embayment or lagoon, the impacts are quite drastic. One only has to look at Big Lagoon in Humboldt County or Upper Newport in Orange County to see the impact of very poor land management practices. Not only can we all see that happened on a very small scale, but I think the public and resource agencies have a responsibility to point a finger at the responsible party and request that corrective action be undertaken.

I would like to discuss a couple of wetland development potentials, particularly around San Francisco Bay. First, is the restoration of complete marshland ecosystems. Some dredge spoil could be used in this effort. The effort would not just develop wetlands, but build an ecosystem. For example, if we suddenly restored a salt evaporation pond to tidal action we would get more tide flat. I believe we should restore such areas to a complex of open water, channels, tide falts, marshlands and vegetated-unvegetated uplands to provide habitat diversity. The uplands around the Bay are a buffer zone. At the moment, the only uplands around the Bay are debris and levees and at high water everything comes crawling out looking for a place to seek refuge from the rising water.

Another potential for marshland restoration is using reclaimed urban wastewater. If we can find a way of using such wastewater to develop wetlands within the concerns of public health and vector control interests we can turn a waste product and problem into a beneficial product and use. I also think using such wastewater can provide the opportunity to undertake investigations to determine other uses of this wastewater. For example, can we restore or recapture some of salmonid resource that has been lost to water development both in the Coast Range and in the Sierra? An integrated wastewater treatment system consisting of a traditional waste treatment plant and a marsh ecosystem could benefit local communities, meet waste management objectives, and provide open space, wildlife, recreational opportunities, and natural resource development.

I support the assessment idea of Susa Gates. I believe that with today's knowledge, coupled with a little imagination and inventiveness, the preceding ideas for ecosystem protection and wetland restoration are accomplishable. They can be modified to fit the situation at hand.

Planning rules to keep in mind: (1) assess what is there; (2) protect the renewability of ecosystems; (3) stop, reduce or correct activities which degrade system renewability; (4) restore degraded ecosystems to some preceived standard of renewability; (5) monitor what happens.

Robert Radovich, *California Department of Fish and Game, Sacramento, CA:*

I want to emphasize that the Department did not formally review the paper presented here today.

I have a number of concerns regarding some of the technical statements in the document and I have indicated these to Susa Gates. Rather than enumerate all these concerns I want to emphasize some significant omissions.

One is that the Department should be recognized as the agency that is responsible for determining what wetlands are degraded, what wetlands are not degraded, and whether restoration is feasible. The Department has not, nor does it intend to list all the wetlands which are discussed today as degraded wetlands pursuant to the Coastal Act. There are a number of reasons for that which revolve around specific applications to certain sections of the Coastal Act. Another item which needs clarification is that in addition to improving the aquatic portion of a wetland system, it's necessary to maintain and improve upland values as well. Lastly, it's good and probably wise to mention that wetlands, by their nature, are temporary in their character. Under perfectly natural conditions, for example, Los Penasquitos Lagoon has changed from a deep water embayment to a relatively shallow wetland in a couple hundred years. The Spanish explorers indicated that it was a deep water embayment, with lobster present, and now it's essentially a high salt marsh. True, watershed development has resulted in increasing sedimentation rates, but even by the 1930's, the Penasquitos Lagoon was well on its way to being a high to medium elevation salt marsh. The point is that we can no longer allow our rivers to wander back and forth across flood plains, to fill up a given wetland area and then wander north or south and create another wetland area, as the Santa Ana River and various other rivers have done in the past. We have very finite systems that we have to manage, and we have to manage them sensitively. If we don't we're going to lose them, especially in Southern California, in the next 50 years.

Audience Participation

DR. JOY ZEDLER (San Diego State University): Although the paper is general in its range of wetland studies, it is very specific in the recommendations that were made for individual wetlands and I think there needs to be a rationale for each of the recommendations. What do you fall back upon to tell us that every wetland should have a mudflat, an upper marsh, or whatever? Why should some wetlands have more tidal circulation? We need more of a regional viewpoint and a discussion within that region on which wetlands are most suitable.

SUSA GATES: The written paper will include more information on the regional problems and rationale for saying that there needs to be watershed management or greater circulation or whatever. It's also something that would be interfaced with what John Zentner will be presenting as far as by geographical regions.

DR. JENS SORENSEN (Jens Sorensen and Associates): Has consideration been given to setting up some systematic information system given the fact we have at least 110 coastal wetlands, depending on how you define San Francisco Bay, plus a myriad of institutions, plus the literature that's been developed, et cetera? One of the problems we have is information overload and gaps in the information source. We don't have any systematic framework for bringing that information together on an interagency basis, to minimize duplication of effort and focus our attentions more effectively and efficiently.

SUSA GATES: That is a good suggestion, if you can set it up. At one point we did try to set up a system of taking each wetland and developing a bibliography for it and putting it on a computer, which as far as I know, has never gotten off the ground. It was also a very expensive idea to keep going.

PHYLLIS FABER (California Wetland Coalition): I wonder how closely you're pursuing the local coastal programs as they are being developed, because there will be opportunities for projects that should be included on your list and then there would be a network to key into those projects.

SUSA GATES: Yes. From this first-cut survey, we wish to develop a more detailed inventory. It appears that these wetlands really need restoration now but not to the exclusion of other wetlands—there may be other opportunities to restore a wetland through permits or the LCP.

ERIC METZ: The Commission, is trying to come up with some regional restoration goals, through the assistance of all of you in reviewing John Zentner's paper. If we are able to establish some goals in which there is a degree of consensus, I think that those could form a basis for framing some potential projects.

JOHN ZENTNER (California Coastal Commission): I have a question for Mr. Radovich. Bob, I thought your statement was very good in the sense it applied to intensive management for the wetlands in the future. I think we're essentially saying we're creating and managing these wetlands but we're also creating separate parks in the larger sense. That, to me, implies a lot of restoration—and I hope, as I imagine you all do—we can get the money. But if we are going to have a massive restoration effort, your opening statement puzzled me because you felt these wetlands were in no way degraded, to a large extent. Could you explain that a little further?

ROBERT RADOVICH: Yes, I could. I'm saying that some of the wetlands, not all of them, that were listed by Susa have not been declared to be severely degraded nor have they been identified as being degraded by the Department. For instance, I don't think we call Upper Newport Bay a severely degraded wetland, given the context of the Coastal Act. You have to remember we're dealing with the law. That was the point I was making. I didn't want it construed by anyone that the Department views degraded wetlands, in the same way Susa used the term.

SUSA GATES: Let me clarify that. Degradation as defined by the Coastal Act has certain meanings in carrying out projects and coastal permits. What I was discussing are wetlands that are disturbed; that are being degraded, but not using the legal words.

DR. MARGARET RACE (Stanford University): Is it possible to incorporate within the area of management, the idea of static versus dynamic nature of a marsh. Are we restoring marshes to insure that there will be a marsh there in perpetuity? Or are we managing these marshes to allow for the dynamic processes that go on? With that in mind, your discussion of algae blooms or sedimentation as a disturbance may be better off put in a category of aesthetics. Up to some point they are natural processes. Beyond that point, they tend to contribute to the degradation of the marsh. Have you developed any criteria that would allow you to distinguish between these two categories of management?

SUSA GATES: That distinction was used to indicate that these projects need restoration. Those in the North Coast have timber harvesting which does increase the accretion of sediments. Hopefully, I can clarify that in the paper.

ALLEN PAKIN: Several times in your presentation you suggested that marsh restoration needed management of the watershed or changing of watershed land use. Can you offer a precedent for undertaking these things and what laws enable you to do this and examples where you have done it?

SUSA GATES: Santa Cruz County has a watershed management program that regulates instream flows, that has setbacks from the stream bed itself, that deals with actually replanting some of the restoration area. Also, on the San Lorenzo River there are a number of dams and part of the watershed management program regulates the release of the water. So there are programs that do take a comprehensive look at watershed management.

I agree it's difficult. In those areas around Big Lagoon, the watershed needs to be addressed in order to maintain the lagoon. If you are going to restore that and you don't address the watershed problems, then you are looking at the need to restore it again in 50 years.

CINDY RICKS (Redwood National Park): I have something to add about this problem of watershed sedimentation and what's a natural rate and what is obviously an increased rate. I think that in some areas you might have an increase of sedimentation, but the sediment does not reside in the estuary or marshland. So you really do have to make a distinction. In the area I work in, increased sedimentation is not sediment coming down out of the basin, but it has more to do with the marine conditions at the time of the flood. It also has to do with where the channel goes across the flood line. I don't think you can say the whole North Coast is impacted by timber harvesting. Could I make one other question to Calvin? Do you have a problem with the difference in your two divisions—you have one that's responsible for flood control and one that's responsible for permitting. On one hand you have people that want to restore riparian vegetation and on the other hand you have people that want to rip the vegetation out to mantain flood control.

CALVIN FONG: Well, as far as our flood control projects are concerned, I think I can safely way, as a general statement for the Corps of Engineers, that any flood control project under planning now, or even beginning to get into construction, will have mitigation for altered habitats as a result of the planning process and large input from the various fish and wildlife agencies. These mitigations would include some kind of enhancement or restoration projects.

As far as the coast of California, I can think of two—both in Southern California—one, the Sweetwater River Flood Control Channel and the Santa Ana River Flood Control Channel. Both involve alteration of some wetlands and as a result there is mitigation, which encompasses enhancement. So I think within the last ten years or so, the Corps agrees that riparian areas are certainly sensitive areas, part of the overall ecosystem, and should be maintained.

Development of Regional Wetland Restoration Goals: Coastal Wetlands

John Zentner, *California Coastal Commission, San Francisco, CA*

Introduction

Wetlands and Restoration in California's Coastal Zone

Prior to 1900, coastal wetlands in California (including San Francisco Bay) covered about 381,000 acres (US FWS 1979). Today, the same area contains about 105,000 acres (*ibid*). Southern California has seen the greatest reduction; only about 25 percent of the coastal wetland acreage which existed in 1900 remains today. In addition, of the presently remaining state coastal wetlands acreage, 62 percent has been subjected to "severe damage" (California Coastal Zone Conservation Commission 1975).

Responding to this loss, the California Legislature declared, in the 1976 Coastal Act, that wetlands be restored wherever feasible. The Legislature also resolved in 1979 that, within the next twenty years, an additional 50 percent more wetlands should be created (Senate Concurrent Resolution 29). Acordingly, many state and local agencies and private interests are developing or planning restoration projects.

Unfortunately, wetland restoration is neither a simple nor inexpensive process. The restoration of an 88-acre portion of the San Dieguito Lagoon, for example, has taken almost a decade of planning and preparation and will cost almost $2 million, including acquisition costs (State Coastal Conservancy 1982c). Other restoration projects have similar costs in effort and money and have not always been successful. Not surprisingly, a California Coastal Commission (1982) report concluded that wetland restoration is presently "more art than science."

Wetland Restoration Goals

A preliminary examination of several restoration plans completed in California indicates that one reason restoration projects may be unsuccessful is that the restoration goals are unrealistic. Goals statements are often either conflicting or based on a poor understanding of wetland functions. For example, one goal common to several restoration projeects is to "maximize habitat diversity." Project goals must, at least, specify the types and extent of the different habitat types which are to be created. As space and budgets are limited, goals development will require trade-offs between different habitat types, *e.g.*, a project cannot maximize cordgrass without losing an opportunity for more pickleweed. These kinds of decisions should be based on an understanding of what types of habitat are necessary or desired in the restored wetland. Therefore, a restoration plan must determine what types and how much of particular habitats are most needed, or valuable, for a particular restoration project.

An argument can be made that restoration goals should duplicate the mix of habitats which characterized the wetlands of the past. Goals would be based on an analysis of what had been on site previously and focus on re-creating the former wetlands. In most cases this is not possible. First, the acreage is not available as much of the California coastline is developed. Secondly, the historic wetland habitat mixes, circulation patterns or other characteristics are rarely known. Finally, the supplies of freshwater which once made many areas, especially in southern California, attractive to wildlife, have been diverted for other uses.

However, even in cases where historic conditions can be restored, it is not always considered desirable to replace the lost wetland type, but instead to create another type of wetlands. The creation of salt marsh to replace sub-tidal habitat has been suggested (Smith *et al.* 1975). Economics have also played an important role in determining the type of wetland to be restored. The high cost of providing freshwater in some areas, coupled with the expense of dredging and spoils disposal makes freshwater or subtidal/submerged wetlands expensive to create and salt marsh creation more attractive.

Restoration Goals and Wetland Values

If the re-creation of filled wetlands is not always the most desirable or feasible priority, it is necessary to develop some standards or criteria by which to form restoration goals. Generally, it has been accepted that coastal wetlands have a set of values, with each value defined as some characteristic with a recognized utility, either economic or non-economic. Because these values are of demonstrated importance or utility, it seems logical that these should determine the design of a restoration project. For example, the idea that the high productivity of salt marshes is important to commercial fish and shellfish stocks leads to proposals for the creation of salt marshes (as opposed to the creation of mudflats) (LaRoe 1974). Values which have been given for coastal wetlands include high primary productivity, exceptional wildlife habitat, nursery or breeding ground for commercially important fish and shellfish, natural (*i.e.* free) wastewater treatment, flood control, shoreline protection, groundwater recharge, and important social or cultural values (Reppert *et al.* 1979, Conservation Foundation 1972).

This list of values is based on research done mostly on the Atlantic Coast. Recent work on the Pacific Coast indicates these values may not be applicable in the same way to coastal California wetlands (Onuf *et al.* 1978, Zedler *et al.* 1978). This paper will survey available research on coastal wetlands in California (excluding those of San Francisco Bay) and examine the above-noted values in order to determine their validity as state-wide restoration goals. Of course, as these values change over the coastline, then the restoration goals will change. Therefore, this paper also includes a preliminary discussion of regional restoration goals. However, it is this author's opinion that specific regional goals should be developed in conjunction with local community support. State offices can develop state-wide goals and gain a better understanding of state-wide needs but restoration projects must be locally supported or no constituency will develop for continued restoration and maintenance of existing restoration. Therefore, these regional goals are offered as preliminary guides in the hopes that they can be a useful starting point for further work.

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Wetland Values and Restoration Goals

A group of eight values are cited most often as representing the values of wetlands: high primary productivity, shoreline protection, wildlife habitat, water purification, groundwater recharge, flood protection, habitat for commercially important fish and shellfish species, and cultural values which generally include recreation and education. In this first section, these values are discussed and their relevance as restoration goals for California coastal wetlands examined. Where these values are considered relevant, specific restoration goals are considered. These goals focus on the creation of specific wetland types, that is, if the goal of enhancing marsh vascular plant production is considered relevant, then the appropriate restoration goal is the creation of high intertidal marsh areas.

Primary Productivity

Wetland primary producers generally have a high productivity compared to other areas (Gosselink *et al.* 1973). Typical primary producers within a wetland include phytoplankton, such as free-floating diatoms and blue-green algae; attached micro- and macro-algae, such as *Enteromorpha* and *Ulva;* submergent vascular plants, such as eelgrass; and emergent vascular plants, such as *Spartina* and *Salicornia.*

Much of the research on wetland primary productivity has been done on emergent vascular plants of the Atlantic and Gulf Coasts. For example, Gosselink *et al.* (1973) reported a range of 1000 to 3000 $gC/m^2/yr$ as conservative estimates for primary productivity in Louisiana and Georgia *Spartina alterniflora* marshes. Other reports (Kirby and Gosselink 1976, Hopkinson *et al.* 1978) confirm these production rates. Primary production rates are not as well studied at coastal California wetlands. Onuf *et al.* (1978), Winfield (1980), and Zedler *et al.* (1980), found that wetland vascular plants of southern and central California generally had a lower primary productivity than wetland vascular plants at a similar latitude on the Atlantic Coast. They reported productivity rates up to about 1000 gC m^2/yr. Zedler (1982) concluded that this relatively lower productivity was due to the hypersaline soils present in southern California marshes.

Primary production rates for non-vascular plants are not well known for either Atlantic or Pacific Coast wetlands. Onuf *et al.* (1978) and Zedler *et al.* (1980) found that primary productivity of epibenthic algae in southern and central California wetlands is apparently higher than algae production on the Atlantic Coast wetlands. About half of total marsh primary productivity in southern California may be derived from attached algae (Zedler 1980). Algae may be a higher quality food source than marsh succulents (Zedler 1982).

The utilization of wetland primary production by wildlife is uncertain, but can take place either by direct grazing or by the breakdown of plant material by bacteria and fungi to detritus which is then eaten by higher organisms. Utilization by the grazing food chain has been discounted in the past. Odum *et al.* (1972) reported that, in Georgia, direct grazing amounts to 5 percent of total salt marsh primary production. It has been accepted that the detrital food chain is the most common energy pathway feeding marsh wildlife. However, observations on the high primary and secondary productivity of nearshore waters adjacent to coastal marshes led to the additional theory that marsh detritus was exported from the marsh and contributed significantly to nearshore production of fish and shellfish (Teal 1962). This outward flux of marsh detritus was labelled "outwelling" and efforts to determine the characteristics of this flux focused on the movement of carbon, nitrogen, and phosphorus from the marsh to nearshore waters.

Summarizing two decades of research on marsh chemical fluxes, Nixon (1980) reported that marshes could export 100 to 200 $gC/m^2/yr$ but that there was not clear correlation between the net aerial primary production of marsh areas with this export figure. Further, when examining the open water of Chesapeake Bay, he found that the exported organic carbon production from marshes ranged from 3.8 to 7.7 $gC/m^2/yr$ of open water but that phytoplankton production in the Bay ranged from 80 to 160 $gC/m^2/yr$. Therefore, the amount of carbon exported from the marsh to the open water of the Bay was minor compared to the contribution by phytoplankton. This observation is supported by Haines (1979), who compared $^{13}C/^{12}C$ ratios of suspended organic matter in estuarine and nearshore waters with the $^{13}C/^{12}C$ ratios of marsh *Spartina* and marine phytoplankton. Her results show that most (60 to 90 percent) of the organic carbon in the nearshore and estuarine waters of Georgia come from algal production, not from *Spartina* detritus. Other recent data, from Tijuana Estuary, indicate that marshes can be net *importers* of particulate carbon (Winfield 1980). Clearly, the case for a significant export of organic carbon by coastal marshes has not been established. In reviewing the nitrogen flux (composed of particulate nitrogen, dissolved organic nitrogen, ammonia, nitrite and nitrate), Nixon (1980) found that marshes often import dissolved oxidized nitrogen (nitrite and nitrate) and export dissolved and particulate nitrogen in reduced forms. The magnitude of that export, at least for Chesapeake Bay, was determined to be less than 2 percent of estimated nitrogen inputs from other sources, such as freshwater runoff and wasteloadings. Although this may be an extreme example, it is possible in many cases that marsh nitrogen export is "drowned" by the nitrogen exported from other sources. Phosphorus, according to Nixon, showed some export from marshes, but in very minor amounts, on the order of 0.4 to 1.8 $gP/m^2/yr$. Nixon concluded that the high primary and secondary productivity noted in nearshore waters of the Atlantic Coast was fueled primarily by nutrients derived from freshwater sources, not by "outwelling" from coastal marshes. Further, he indicated that each wetland system probably has its own unique nutrient flux involving both import and export of these materials, a conclusion seconded by Winfield (pers. comm.).

The primary productivity of wetlands, whether or not it is exported to nearshore waters, is still a major value because of the relationship of that productivity to wildlife activity within the wetland. Although complete data are limited, the work by the Los Angeles County Natural History Museum (Scribner 1979) in Ballona Lagoon and other research demonstrates the large numbers of species and individuals which actively feed in wetlands on wetland-produced vascular and non-vascular plants. However, primary productivity within coastal wetlands can vary considerably. Seasonally closed wetlands, for example, may have highly variable productivity. Both Zedler *et al.* (1980) and Eilers (1980) found that loss of tidal flushing could increase vascular plant production in southern California if freshwater input were relatively high. If loss of tidal flushing was followed by low freshwater inflow to the wetland, however, marsh vascular plant production could be lowered because of increased soil salinities. Smart and Barko (1978) found that salinity was a major limiting factor in marsh growth and Mall (1969) found that vegetative production of *Salicornia* was drastically limited when soil salinities were over 70 ppt. The variability of primary production from different habitat types and the relative lack of data on non-vascular production make specific restoration goals for this value still a matter for debate.

In the past, salt marsh restoration has received a large amount of attention because of its high primary productivity and the supposed link to secondary productivity outside the marsh. This has rsulted in a great deal of research on the technical aspects of salt marsh creation, especially on the East and Gulf coasts (Garbisch *et al.* 1977). It is possible that the availability of this technical research has also, in and of itself, provided a rationale for salt marsh creation. However, if the utilization of marsh detrital matter outside the wetland is as unclear as present data indicate, then restoration of salt marshes, as opposed to restoring low intertidal areas, may be a misplaced priority. The role of other producers, especially algae and submergent vegetation, must be more closely examined.

Shoreline Protection

Wetlands may protect shorelines from erosion by the ability of wetland plants to reduce wave energy. Wayne (1975) found that different wetland plant species can reduce wave heights and energy. Teal and Teal (1969) compared storm damage to areas with and without salt marshes in England and concluded that the areas with salt marshes received relatively less storm damage. Reppert *et al.* (1979) state that the amount of shoreline protection provided by a wetland depends upon the type of wetland vegetation and its density, the width of the marsh, and the fetch, or open water space adjacent to the marsh. Dense shrub or arboreal plants in the marsh and a wide marsh (greater than 200 yards) provide the greatest protection in regions of longest fetch (more than 5 miles). Considering the character of coastal wetlands in California, it seems reasonable to conclude that most coastal California wetlands do not presently provide even a moderate degree of open shoreline protection. They tend to have non-shrub vegetation of moderate density, narrow to moderate width, and are generally located in regions of sedimentation as opposed to erosion-prone coastlines.

Wildlife Habitat

A wide variety of wildlife species inhabit coastal wetlands at one time or another. For ease of discussion, this part of the paper is divided into separate sections on benthic invertebrates, fish, waterbirds, and endangered species. Groups which are not addressed include non-benthic invertebrates, mammals, and birds, such as the red-winged blackbird or marsh hawk, which are not generally classed as waterbirds (see Cogswell 1977). These organisms can, in some cases, be important components of wetland ecosystems, however, space and time limits their inclusion in this paper.

Benthic invertebrates play a major role in wetlands in a wide variety of niches. Ricketts and Calvin (1968) state that Pacific Coast wetlands are rather depauperate when compared to eastern and Gulf coast estuaries. They cite the near-absence or absence of estuarine fish, oysters, large crabs, or large prawns as evidence for this proposition. However, many invertebrate species are obviously well-adapted to the euryhaline environment of Pacific wetlands including recreationally important clams and crabs (Seapy 1981, Quammen 1980). Benthic invertebrates are an important consideration in restoration goals but the range of habitats which can be colonized by invertebrates makes the choice of a preferred habitat difficult. Low intertidal and shallow subtidal wetlands tend to have the greatest number of species and individuals (Bright 1974, Onuf pers. comm.). In contrast, small, seasonally closed or closed wetlands offer poor habitat for most invertebrates. A mix of fine and coarse sediments with some organic material included provides the most productive substrate (Nybakken *et al.* 1977).

Providing for mosquito control is also an important consideration for restoration projects. Of the eleven mosquito species known from southern California marshes, only two are found in marine systems. Of these two species, only the black salt marsh mosquito is a potential disease carrier (Cooper 1980). An estuarine system (mixed fresh and saltwater) on the south coast will support three disease carrying species while freshwater marshes may support six potential carrier species. Even in freshwater marshes, though, mosquito growth may be controlled by increasing the flushing in the system, deepening or eliminating shallow depressions, and controlling vegetative growth (Goleta Valley Mosquito Abatement District 1978).

The value of coastal wetlands as habitat for fish differs significantly among wetlands. This may be partially due to real differences among wetlands as well as differences in the methods used to conduct fish surveys (*c.f.* Horn and Allen 1981). California wetlands which are nontidal or which are closed to the ocean for long periods of time generally do not have a large role as fish habitat. Mudie *et al.* (1976) report 7 species of fish from two seasonally closed wetlands in northern San Diego County, San Dieguito and Batiquitos Lagoons, which is typical for these types of coastal wetlands.

Wetlands which have maintained constant tidal flushing over a long period of time have the greatest species abundance. Giguere *et al.* (1970) reported that Bolinas Bay contains 43 species of fish and Horn and Allen (1981) reported the same number of species from Upper Newport Bay. Not surprisingly, species abundance is likely to increase if seasonally closed wetlands are restored to full tidal contact. After 80 years of closure, the tidal gates at Bolsa Chica wetland in Orange Co. were opened and fish species abundance increased dramatically, from three species to 14 species (Knaggs and Mall 1981, Novick pers. comm.). A similar change occurred in Los Penasquitos Lagoon where, prior to 1966, there was little tidal contact and only five species of fish were known to inhabit the lagoon. After 1966, when tidal contact was restored, 20 species of fish were found (Bollman 1975).

The role of coastal wetlands in the life cycles of most of these fish is uncertain. Some species, such as the California killifish, topsmelt, gobies and the staghorn sculpin, appear to be year-round residents in wetlands and adapted to the euryhaline conditions (Jones and Stokes 1981, Winzler and Kelly 1977). Other species found in coastal wetlands as adults, such as the surfperch and rockfish, do not seem to be adapted to euryhaline waters and are more commonly found in nearshore waters and bays than in wetlands (Baxter 1980, Frey 1971). A third group of species, such as the Pacific sardine, sanddab, northern anchovy, California halibut, diamond turbot and croaker, are found in coastal wetlands in large numbers as juveniles, rather than as adults (Barry and Cailliet nd., Onuf *et al.* 1978). Zedler (1982) concluded that these species probably utilize coastal wetlands as spawning or nursery grounds. Most of these species are also found in large numbers as juveniles in nearshore waters (c.f. Horn and Allen 1976). The flatfish and anadromous fish are occasional as adults and juveniles in southern coastal wetlands but are more common in central and northern coastal wetlands (Miller and Lea 1972, Onuf *et al.* 1978). Some flatfish, such as the Dover and English soles, actively utilize coastal wetlands with significant freshwater inflow and may often spawn in river mouths and wetlands (Baxter 1980), but it is unclear to what extent the anadromous fish utilize coastal wetlands, separating wetlands for the moment from the associated stream or river channel. Adults rarely feed while in wetlands but outgoing juveniles may feed on species of invertebrates which inhabit salt marshes. Crow and Macdonald (1977) present data to suggest that anadromous fish in Alaska are dependent on certain wetland invertebrates for food.

The role that coastal wetlands play in the life cycles of the different waterbirds varies tremendously. For ease of discussion, the waterbirds are divided herein into four groups: waterfowl; shorebirds; wading and marsh birds; and diving birds (grebes, loons and cormorants).

Among the waterfowl, the dabbling ducks, such as the American wigeon or pintail, prefer freshwater ponds or lakes but are also seen on mudflats and pasture lands adjacent to wetlands (Smail 1972, Funderburk 1979). Although the total numbers of dabblers in coastal wetlands can be high, especially in north coast wetlands, the great percentage of dabblers flying through or over-wintering in California utilize the central valley or San Francisco Bay, not coastal wetlands (US FWS 1979). The loss of freshwater habitat on the coast may have led to the shift of migrating dabblers from the coast to the central valley or Mexico, but wetlands which still contain freshwater habitat, such as Upper Newport Bay, have relatively high bird counts.

Diving ducks, such as the lesser and greater scaup, generally prefer bays or lakes with water 3 to 20 feet deep for over-wintering or migrating habitat and usually eat aquatic vegetation or marine organisms (Standing *et al.* 1979). Large numbers of these birds are seen in coastal wetlands and, unlike the dabblers, a high percentage of their total California population utilizes coastal areas (US FWS 1979).

Sea ducks such as the scooters use a variety of habitats and feed on small fish or molluscs (Funderburk 1979). Habitat for these species is mostly offshore, not in coastal wetlands. Coastal wetlands with a large tidal prism and a supply of fish and molluscs may have high numbers of some species. In Anaheim Bay, Speth *et al.* (1976) found the surf scooter to be a relatively common species while only a few were censused at nearby San Dieguito Lagoon, a fairly shallow wetland, by Mudie *et al.* (1976).

Shorebirds, such as the sandpipers, plovers, or gulls tend to be opportunistic feeders and, within their migratory pathways, will generally move wherever an abundance of food is found. Jurek (1971) noted that in 1970, Batiquitos Lagoon had nearly six times as many shorebirds as in 1971, primarily because the greater runoff in 1971 flooded many of the mud flat and salt pan areas previously used for roosting and feeding. Numbers of American avocet, black-necked stilt, and the small sandpipers were greatly reduced. At Los Cerritos wetland in Long Beach, a shallow fresh water pond recently created to hold runoff from a new shopping center was found by CDFG (1981) to have extremely high seasonal use by shorebirds, primarily the American avocet, the black-necked stilt, the black-bellied plover, and the ring-billed gull.

Despite their opportunistic nature, certain shorebird species seem to prefer coastal wetlands as habitat over other areas, such as rocky shores or sand beaches. This group includes the semipalmated plover, black-bellied plover, greater yellowlegs, lesser yellowlegs, red knot, least sandpiper, dunlin, western sandpiper, short-billed dowitcher, long-billed dowitcher, black-necked stilt, American avocet, marbled godwit, and long-billed curlew. Other species, such as the snowy plover, black turnstone, common sniper, killdeer, willet, sanderling, northern phalarope, whimbrel, ruddy turnstone, solitary sandpiper, spotted sandpiper, and most gulls and terns may all be seen in coastal wetlands at some time but generally seem to prefer other habitat, like sandy beaches.

The wading and marsh birds found in California's coastal wetlands include the herons and egrets, such as the great blue heron and snowy egret, and the rails, such as the Virginia rail. These species are generally year-round residents in coastal wetlands. Herons and egrets are commonly seen in tidal creeks, mudflats, and other areas of shallow water where fish or amphibians are abundant (Udvardy 1977). The rails are more secretive, preferring densely vegetated tidal marshes and freshwater marshes.

The remaining waterbirds include the grebes, loons, and cormorants which are sometimes lumped together with the diving ducks and termed "diving birds." Loons and cormorants are generally found off-shore rather than in coastal wetlands although some species, such as the double-crested cormorant, are commonly seen in coastal wetlands (Funderburk 1979). All four grebe species, on the other hand, especially the pied-billed grebe, are almost common in coastal wetlands in deeper tidal channels and tidal flats (Udvardy 1977).

The different waterbirds seem to prefer different habitat, from freshwater ponds for dabbling ducks to dense marsh areas for rails, but the dependence of these species on any particular habitat is not always clear. Bird use of non-tidal areas in southern California has been described as very high relative to bird use of tidal areas (CDFG 1981). Yet the existence of extensive non-tidal marsh and flat areas is a relatively recent phenomena, possibly due to man's interference (Sorensen 1982). Bird counts at Bolsa Chica and Los Cerritos indicate the primary users of non-tidal areas are opportunistic shorebirds (CDFG 1981, Dellingham 1979). In other areas, such as Anaheim Bay, these birds seem to prefer other habitats such as freshwater ponds. Thus, it appears that while birds may utilize non-tidal areas extensively, particularly in southern California, this may be a result of loss of habitat rather than preference.

Endangered or Rare Species

One value absent from the lists contained in the literature on Atlantic or Gulf Coast wetlands is the importance of coastal wetlands to species considered rare or endangered. Of the twelve species of birds, reptiles, and mammals listed as endangered in California, nine species are either residents of or associated with coastal wetlands. Five species are almost entirely dependent on salt marshes:

- The salt marsh harvest mouse, *Reithrodontomys raviventris*, is restricted to scattered populations in salt and brackish water marshes around San Francisco Bay.
- The California clapper rail, *Rallus longirostris obsoletus*, breeds only in San Francisco Bay, San Pablo Bay, Napa Marsh, and, perhaps, Elkhorn Slough. It is a casual visitor in Bolinas and Tomales Bay, but does not appear to breed there. It requires densely vegetated salt or brackish water marshes (Gill 1977).
- The light-footed clapper rail, *Rallus longirostris levipes*, is found only in dense marsh vegetation from Goleta Slough to Baja California. Recent work by Zembal and

Massey (1981) indicates it may utilize freshwater marsh as well as cordgrass habitat.

- The California least tern, *Sterna albifrons browni*, is found along the coast of California from April to September, from San Francisco to Baja California. Breeding colonies are known only from San Luis Obispo County south on flat unvegetated areas of sandy soil near wetlands.
- The Belding's savannah sparrow, *Passerculus sandwichensis beldingi*, is found in pickleweed stands in salt marshes from Santa Barbara County to Baja California; it bred in about 29 areas in southern California in 1977.

Additionally, an endangered plant species, the salt marsh bird's beak inhabits upper marsh areas in southern California.

Water Purification

The activities of a marsh in sewage trestment are summarized by Reppert *et al.* (1979). These include: mechanical dispersion or removal of particulate matter; physical adsorption of pollutants, chemical precipitation; and biochemical uptake. Much of the emphasis on use of wetlands for tertiary treatment of waste effluent stems from reports by Gosselink *et al.* (1973) and others detailing the reduction in biological oxygen demand (BOD) from waters flowing through a marsh.

The results of sewage treatment by experimental wetlands in California have been limited and mixed, however (see Demgen 1981 for a review). Also, despite an emphasis in Section 201 of the Clean Water Act of 1972 (PL 92-500) on treatment of wastewater through innovative strategies, including cycling through natural systems such as wetlands, regulatory agencies have been reluctant to permit these types of projects, citing the evidence developed by EPA and others on the potential toxicity of sewage effluent to shellfish and other organisms (Allen and Gearheart 1978). Yet, some wetland organisms may benefit by the addition of wastewater flows even if they contain additional nutrients. Waterfowl numbers at San Dieguito Lagoon have been reduced sharply since the Del Mar sewage oxidation pond, located almost in the middle of the Lagoon, was shut down (Sea Science Services 1980).

Apparently, the use of wetlands as sewage treatment facilities cannot be termed a proven value. The low amount of freshwater inflow and low circulation rates common in most coastal wetlands during the summer make the introduction of high nutrient level effluent questionable for most wetlands. The introduction of toxic materials, such as heavy metals, pesticides, or herbicides, appears to be even more questionable. However, the introduction of freshwater flows into wetlands is often a highly desirable restoration strategy. Increasingly, the only freshwater available is effluent from sewage treatment plants. In cases where a specific restoration plan has indicated that a wetland would benefit from increased freshwater flows, it may prove advantageous to use treated effluent under appropriate discharge conditions. Major factors which must be analyzed in each case include: the amount and quality of natural freshwater inflow on a seasonal basis, present nutrient levels in the wetland, and circulation patterns.

Groundwater Recharge

Another value ascribed to wetlands is their beneficial role in recharging groundwater sources (Odum 1973). Theoretically, water flowing through a wetland is slowed down by marsh vegetation and the resulting containment facilitates percolation through marsh or riverine substrates to groundwater storage areas. Coastal wetlands in California play a very minor role in groundwater recharge, if any. Coastal wetland waters are usually saline and input of these waters to a freshwater aquifer is not considered beneficial. California coastal wetland soils also have a high clay content, limiting percolation. Not surprisingly, the wetlands noted for their recharge capabilities have been riverine wetlands associated with slow-moving, coastal rivers on the Atlantic Coast (Reppert *et al.*, 1979).

Flood Protection

Wetlands supposedly act to protect adjacent areas from flooding through the same mechanism noted for shoreline protection and groundwater storage; waters moving through the wetland are slowed down by marsh vegetation which also acts to reduce wave energies (Reppert *et al.* 1979). Like the values of shoreline protection and groundwater recharge, flood protection appears to be a value better associated with riverine wetlands along coastal rivers of the Atlantic Coast. Coastal wetlands in California tend to be flood hazard areas, rather than flood protection areas. Especially in southern California, the closure of wetland mouths usually acts to contain flood waters and flood adjacent lands. If these mouths were open, flood flows would tend to move through the wetland and on to the ocean. Wetlands also tend to trap sediments carried by flood flows unless these sediments are carried out to the ocean. Sediment loads raise the wetland bed, increasing the lateral movement of flood waters contributing to further flooding of adjacent lands. A major restoration concern in most coastal wetland restoration projects should be to reduce wetland-associated flood hazards as much as feasible. This can be accomplished by reducing sediment loads in wetlands, either through the use of sediment basins upstream from the wetland or by ensuring adequate flushing through the wetland by keeping the wetland mouth open as much as possible. Efforts to combine flood control and wildlife enhancement goals in a wetland restoration project are currently confined to two San Francisco Bay projects, at Palo Alto and Tiburon.

Commercially Important Fish and Shellfish

On the East and Gulf Coasts, scientists have claimed that a large percentage of the fish caught for commercial use are dependent on wetlands at some point in their life cycle (Gosselink *et al.* 1973). Bollman (1975) states that approximately 65 percent of all commercial fish species are dependent upon the estuarine zone for one or more phases of their life development. The National Estuary Study (US FWS 1970) concluded that two-thirds of the total landed value of commercial fish and shellfish is derived from estuarine dependent species.

The relationship between California fisheries and wetlands is not as clear. A recent paper by Barry and Cailliet (n.d.) identified several fish species inhabitating Elkhorn Slough as commercially-important. These were: staghorn sculpin, northern anchovy, Pacific herring, shiner surfperch, starry flounder, black surfperch, leopard shark, California halibut, bat ray, and English sole. Additionally, other coastal wetlands have been identified as important commercial fish habitat. MacDonald (1976) for example, found that topsmelt and surfperch, barred surfperch, and starry flounder bred in Mugu Lagoon, which also served as a "nursery" for halibut and turbot.

If the complete list of commercial fish landed in California (see Pinkas 1977) is examined, it seems that there are four different categories of fish. First are those which have no direct connection with wetlands, they do not use them as habitat or depend on them for food. Examples would be the Pacific bonito, mackerels and tuna. These comprise the majority of landed fish value. The second category is made up of those species which are only occasionally found in wetlands. Examples are the cabezon, rockfish and sculpin. These species, while not very important commercially, make up the majority of recreational fish caught from nearshore areas. The third category includes the anadromous fish. Although their dependence on coastal wetlands is unclear, their value is significant both commercially and recreationally. Lastly, there are the fish which have a significant portion of their population either spawning or breeding in coastal wetlands. Some of these, primarily the starry flounder, the Pacific herring, and the English sole, are commercially important. Others, such as the surfperches, topsmelt, leopard shark and the bat ray do not have much commercial importance.

It has also been theorized that coastal wetlands are important habitat for many of the commercially important shellfish (Gosselink *et al.* 1973). Data from the Atlantic and Gulf coasts seem to verify that theory but data from the California coast are not so clear. Some commercially important crab and clam species are found almost exclusively in coastal wetlands of California at one time or another (such as the juvenile market crab)but the total crab and clam catch in California is made up of other, non-wetland species also. Other commercially important shellfish—such as the abalone and most scallops—do not utilize wetlands. The clearest case for actual dependency of a commercially important shellfish is the oyster where mariculture is a major wetlands activity in Humboldt Bay, Tomales Bay, Elkhorn Slough and other areas. The oysters grown in these areas are non-native, however.

Most data indicates only a slight connection between coastal wetlands and the majority of landed value of fish or shellfish. However, it is uncertain how much lower trophic level fish or invertebrates which utilize wetlands serve as a food source for commercial fish or shellfish. No data reviewed by this author has provided convincing information either way.

Cultural Values

In the wetlands literature several values have been lumped together under the term "social" or "cultural" values, including wetlands' educational, recreational and aesthetic values. Apparently, these values have been joined together because they are difficult to evaluate and, hence, difficult to assign a political or economic value. Additionally, the boundaries between recreational, educational and aesthetic use of wetlands are often indiscernible. This ambiguity makes discussion of this category very difficult and precludes a specific examination of each value. However, certain observations need to be included in this paper to provide an idea of the scope of these values.

Coastal wetlands are definitely important for recreation. California Department of Fish and Game officials estimated that clammers spend up to 2,500 man-days per year searching for clams at Elkhorn Slough (Browning 1972). Recreational fishing in wetlands provides a large amount of enjoyment to many pier and skiff fishermen. Estimates from Morro Bay indicate that over 10,000 man-days are expended each year solely in bird watching (Gerdes *et al.* 1974).

The aesthetic and related values of wetlands are particularly difficult to evaluate. Wetlands might be considered to be natural parks which have large numbers of animals and scenic vistas. Like parks, they have values such as stress reduction, education, aesthetic pleasure, passive recreation and so on. Wetlands are also ecosystems, more or less natural. Ehrenfeld (1976) makes a strong case for the preservation, and therefore, restoration of natural systems because they are natural and evocative of an unknown, ineffable experience of social, educational and religious value.

Summary: Restoration Goals—Statewide and Regional

Statewide Goals

The major value of California's coastal wetlands is as a plant and wildlife habitat. Our present knowledge indicates coastal wetlands in California have relatively little value for most commercially important fish or as shoreline protectors, water purifiers, groundwater rechargers or flood controllers. Primary productivity of wetlands is high relative to other areas but wildlife utilization of that production takes place within the wetland. Cultural values including recreation are important but are dependent on the wetlands' value as plant and wildlife habitat.

Restoration goals for coastal wetlands should be based on the relative importance of different habitats for plants and wildlife. On a very general level, data presented here indicates that:

- Subtidal areas are utilized by marine plants, such as eelgrass, many invertebrates, some adult and juvenile fish, including recreationally important species, and diving birds. Utilization by these species apparently is greatest where tidal circulation is constant and effective in keeping dissolved oxygen levels high. Utilization may also vary with latitude as northern coastal subtidal areas have higher densities of, at least, flatfish, anadromous fish and diving birds than southern wetlands.
- Intertidal flats are utilized by macro and microalgae, many invertebrates, including recreationally important species, some adult and juvenile fish, shorebirds, some waterfowl, wading birds and some diving birds. Utilization of this habitat type does not seem to vary as much with latitude as the subtidal habitat as long as the tidal range is not overly constricted.
- Intertidal and high marsh areas are utilized by saltmarsh plants, many invertebrates, some juvenile fish, and relatively few birds. However, the birds which use these areas include three species listed as endangered—the clapper rails and the Belding's savannah sparrow. The range of these endangered species is restricted to central and southern California, the areas where loss of wetland has been greatest.
- Freshwater wetlands appear to be the most undersupplied habitat type in the coastal area, relative to past acreage. These areas presently are utilized by fresh and brackish water marsh plants, some invertebrates and fish, high numbers of waterfowl and also by certain shorebirds and wading birds.
- Nontidal salt marsh and salt flat areas appear to have relatively low utilization compared to other areas. They are utilized by some invertebrates and fish, and, in southern California especially, large numbers of certain species of shorebirds and some waterfowl. Perhaps these areas' major importance is that they exist as open space with shallow water ponds during winter migration periods. It is arguable that restoration of non-tidal salt flat areas is a mistaken use of funds, as other habitats may be preferable even for the species presently utilizing these areas. However, some species, such as the endangered least tern, require non-vegetated flats near wetlands for habitat. These areas can also provide buffers and are utilized by other shorebirds during high tide periods. Thus, non-tidal areas are not valueless.

The preceding discussion has examined the values of restoring different habitat types within wetlands on a state-wide basis. Wetland values and restoration goals should focus on the provision of plant and wildlife habitat for the use of wildlife and man not shoreline protection, groundwater recharge or any of the other values considered. The state-wide goals should become the basis for developing regional restoration plans and goals.

Regional Goals

Obviously, California's coastal wetlands change with latitude. Coastal wetland values and, therefore, restoration goals must also change. For this paper, the coast is divided into three regions. The North Region is comprised of Mendocino, Humboldt, and Del Norte Counties. The Central Region is made up of the counties from Sonoma south to San Luis Obispo. The South Region takes up the remaining coastal counties from Santa Barbara to San Diego.

North Region

Generally, wetlands in Humboldt, Del Norte, and Mendocino Counties are more estuarine in their makeup than other California wetlands. That is, they have an almost constant inflow of freshwater. This also means that they are usually less saline and have a more constant nutrient input from the watershed. Three general types of wetlands in the North are: relatively isolated freshwater lagoons or lakes, like Lakes Earl and Talawa or Big Lagoon; protected estuaries which are part of bays or coves, like the Humboldt Bay wetlands; and the river mouth areas, such as the Smith River Delta. The latter are characterized by estuarine habitat with little intertidal area.

All three types of wetlands have high values for different species. Restoration projects, though, should strive to create a predominance of open circulation, subtidal habitats connected to unobstructed coastal streams with good freshwater inflow. This type of habitat will enhance fish populations, especialy anadromous species, sea and diving duck populations, and the potential for oyster mariculture. A second goal would be open circulation, low intertidal habitat for shorebirds and invertebrates, such as recreationally important clams. Salt marsh habitat might be important if a link is established between anadromous fish and marsh prey species but otherwise its primary importance would be to marsh birds, which are not apparently endangered in this region. Wading birds, such as the egrets, also feed in marshes but the abundance of wet pasture lands near wetlands in this region indicates their feeding habitat is well-supplied. Finally, dabbling ducks would benefit from the provision of closed circulation, submerged freshwater habitat, but their populations in the north are not decreasing.

Central Region

This region comprises a large portion of the California coast, from Sonoma County to San Luis Obispo County. Many of the wetlands in this region are like Bolinas Lagoon or Bodega Harbor: they have limited freshwater inflow, they are intermediate in size, disturbance has been relatively slight (with some notable exceptions), and salinities are usually near marine levels. There are also many small coastal wetlands, usually at the terminus of coastal streams, and a complex of essentially freshwater lakes near the San Luis Obispo and Santa Barbara County borders.

Restoration goals for this region should emphasize a predominance of open circulation, shallow subtidal and low intertidal habitats and the creation of freshwater marshes/ponds. The tidal habitats should be utilized by shorebirds, diving ducks and recreationally important invertebrates, all of which are under pressure from past man-made habitat alterations and are important commercial (tourist) and recreational values in this region. The creation of freshwater wetlands is in recognition of the historic loss of these types of wetlands and the present need to provide habitat for waterfowl along the coast. Habitat for the California clapper rail, dense salt/brackish marsh, should also be created but as a less pressing goal. Habitat restoration within the San Francisco Bay wetlands appears to be of more concern for this species presently. Large sub-tidal areas with little adjacent development—Tomales Bay and Morrow Bay for example—are relatively common in this region and fish and diving duck habitat restoration may not be necessary. However, enhancement of anadromous fish habitat through riparian restoration is necessary.

South Region

At one time, Southern California had extensive wetlands with significant freshwater inflow. About 90 percent have been destroyed, leaving only a relatively few and isolated examples. Those that remain, such as Mugu Lagoon, were saved usually because they were part of a larger land reservation. Elsewhere along the south coast, if the wetlands were not filled in, they were often severely altered, as in San Diego County. Physically, this area is very different from the North Coast. Freshwater inflow is scarce and usually floodlike. These floods are accompanied by heavy sedimentation which can completely fill in the wetlands or, more often, decrease the tidal prisms to the point where the tidal access is reduced. Eventually, the wetlands become closed with widely fluctuating salinities and reduced habitat diversity. Their habitat value for fish and shellfish become relatively low. Wetlands which do have permanent ocean contact, like Tijuana Estuary or Upper Newport Bay, tend to have much higher habitat value, if species diversity and abundance are used as indicators.

The predominant restoration goal for this region should emphasize the creation of open circulation, low intertidal habitat interspersed with salt marsh patches to enhance shorebird, diving duck, and marsh and wading bird populations. The open circulation pattern will enhance local fish and invertebrate populations and keep mosquitos and flood control activities relatively easy. The salt marsh areas should be sufficient in size to maintain endangered species populations. These areas should be restored in conjunction with the creation of freshwater marshes and ponds. Data from the San Joaquin Marsh indicates the combination of freshwater wetlands with tidal wetlands results in the highest use by birds. Freshwater ponds should also enhance waterfowl populations. It is arguable that since the migration route of the majority of waterfowl is through the central valley, that the creation of waterfowl habitat in coastal southern California is unnecessary. However, as noted, freshwater wetlands benefit more than just waterfowl and, further, evidence from the 1976 drought period indicates that coastal areas are important back-up habitat for waterfowl normally flying through inland areas.

Conclusion

This paper focused on an analysis of values which have been ascribed to wetlands and their relevance as restoration goals. Of the values ascribed to coastal wetlands, not all are relevant to coastal California and, therefore, not relevant as restoration goals. The creation of habitat for wildlife and human use should be the major restoration goal on a state-wide basis. Regional restoration plans should be prepared utilizing this state-wide goal but within a more specific framework. One of the larger problems of developing restoration goals for projects—determining the areal extent of each habitat type—should be resolved within the framework of the regional restoration goals. The generalized regional goals presented should provide an outline of what should be accomplished; however, since man's utilization of wetlands is important, regional goals should be developed in conjunction with local support.

Development of Regional Wetland Restoration Goals: San Francisco Bay

Nancy Wakeman, *San Francisco Bay Conservation and Development Commission, San Francisco, CA*

Introduction

San Francisco Bay and its adjacent wetlands covered a 713 square mile area before 1850. By the mid 1950's, many of the tidal areas and wetlands were diked and filled so that today the Bay is about 423 square miles in area and its adjacent tidal marshes cover 125 miles. About 80 square miles of former Bay exist behind dikes and function as seasonal wetlands. These 80 square miles are candidates for all future mitigation and enhancement projects in San Francisco Bay.

This paper is based on two recent reports about diked baylands prepared for the Bay Conservation and Development Commission (BCDC). The first report is on regional habitat needs for San Francisco Bay (BCDC staff, 1982) and the second concerns specific criteria for restoration and enhancement (Harvey *et al.*, 1982).

Habitat Needs

BCDC staff (1982) concluded that the creation of four specific habitats would improve Bay wildlife resources. They are: (1) freshwater marsh, (2) brackish water marsh, (3) habitat for rare and endangered species, particularly high marsh, and (4) tidal marshes.

Freshwater Marsh

The reduction of freshwater inflow and destruction of freshwater wetlands through diking, draining, filling, and development has eliminated nearly all of the natural freshwater marshes once present around San Francisco Bay. Freshwater marshes are important because they support a great diversity of plants and animals. Creation of freshwater marshes can enhance the diversity of species at a specific location and also increase the diversity of the Bay system by interspersing tidal with freshwater marshes. This diversity, once quite common around the Bay, has all but disappeared today. The South Bay, at one time, supported several thousand acres of freshwater marsh. The only freshwater marsh in the South Bay is at Coyote Hills Regional Park, and it is only a few acres in size. The marsh is artifically maintained by urban runoff in winter and by well water in summer. Even with such management, the water in the marsh is somewhat saline.

Brackish Water Marsh

Many brackish water marshes that occurred at the mouths of the Napa River, Guadalupe Creek, Alameda Creek, and Corte Madera Creek have been physically altered or converted to salt marsh by changes to or diversion of freshwater. The North Bay marshes of the Petaluma River, Napa, and Suisun Bay are among the few remaining brackish marshes. There are 1,396 acres of diked brackish water marshes scattered around the Bay. In addition, there are a few scattered brackish marshes elsewhere, for example, at the upper ends of sloughs in the South Bay where salt water is sufficiently diluted by freshwater runoff.

Brackish water marshes are important because they support a variety of vegetation types. A great diversity of aquatic organisms and wildlife species and breeding populations of birds such as the salt marsh yellowthroat, a potentially threatened species, also use brackish water marshes. Creation of additional brackish habitats would increase the diversity of plants and wildlife around the Bay.

Rare and Endangered Species Habitat

As freshwater and brackish water marshes and their surrounding vegetation have become scarce, so too have many plant and animal species that were once common around the Bay. These include the endangered California clapper rail, salt marsh harvest mouse, San Francisco garter snake and the rare black rail. Plant species such as birds' beak, marsh gumweed, mudflat quill plant, Marin knotwood, and Suisun thistle are also threatened, rare, or endangered.

Special attention should be given to the creation of high marsh areas around and within tidal marshes to benefit clapper rail, harvest mouse, and black rail. Freshwater marsh and bordering transition zones could benefit the San Francisco garter snake. Brackish marshes and their edges are also required by several rare and endangered plant species.

Tidal Marsh Restoration

Diking and filling of historic tidal marshlands has decreased the productivity of the Bay ecosystem because dikes have cut off the source of nutrients and organic material from the Bay itself. The nutrients carried by freshwater runoff and the organic material resulting from decaying marsh vegetation are a food source for Bay dwelling organisms that is not available when tidal exchange and runoff is eliminated.

The productivity of the Bay should increase if diked areas are restored to tidal action because the inflow of organic material should enhance plant growth on newly created tidal mudflats. Plants growing on mudflats would also support small invertebrates and fish. Eventually the numbers of birds, mammals, and other animals that the Bay supports should increase because the food supply has increased.

But if the restoration of diked areas is not carefully planned and executed, none of these benefits will likely occur. Badly managed projects may result only in erosion, increased sedimentation, and turbidity with little increase in wildlife or fish.

Restoration of Diked Lands

In creating new habitat, three important factors must be considered. First, sites identified by fish and wildlife professionals as stable, productive habitats, should not be selected for restoration or enhancement. Secondly, wherever possible, a restoration or enhancement site should create more than one habitat zone e.g., a gradient from low wet areas to upland dry habitats. This is because such diversity is similar to the historic natural conditions. Thirdly, only native vegetation should be used in marsh restoration or enhancement projects. There are several reasons for this. One is a scientific and aesthetic interest in keeping the natural environment intact. Introduced species can sometimes become a nuisance if there are no checks and balances within the system to control them—the water hyacinth is a good example. In general, since introduced species are a less known entity, their use in marsh restoration or enhancement projects should be avoided.

In order to maximize regional habitat supply, marsh restoration and enhancement projects need to be carefully designed and constructed. The following checklist identifies much of the information necessary to design successful projects.

- Based on a survey, prepare a topographic map of the selected site in one foot contours. All elevations should be relative to National Geodetic Vertical Datum (NGVD). Include a vicinity map showing storm drains, the elevation of adjacent surrounding properties, and the limit of 100-year tide.
- Prepare a topographic map in one foot contours showing proposed modifications to the site. Include typical cross-sections showing proposed elevation of the marsh plain, any channels and any high areas. Include figures for the estimated tidal range related to Mean Higher High Water, Mean High Water, Mean Lower Low Water, Mean Sea Level, the maximum predicted tide, and the 100-year tide. Show figures for the ratios of typical horizontal to vertical slopes for existing and proposed levees and channels or sloughs. Show proposed plant species along the cross-sections of their expected zone of growth.
- Prepare calculations for determining the size of any levee breaches or pipe installations. Show the amount of cut and fill, the amount of material to be placed to strengthen the levee, and the expected tidal exchange. The expected tidal range should show expectations both inside and outside the levee breach. If plants will be used to moderate tidal forces at the breach, indicate the plant species that will be used. If plants will not serve that function, specify what rip-rap or other engineering solution will assure the integrity of the levee breach. Prepare a detailed drawing of any inlet-outlet structure to be placed, with a schedule of operation.
- Gather soil information identifying the type of soils found at the site and the type to be used if fill will be placed. Include quantitative measurements of salinity, pH, organic content, and bulk density. In addition to the soil analysis, the following water quality parameters should be analyzed: salinity, pH, biochemical oxygen demand (BOD), dissolved oxygen (DO), and, if appropriate, heavy metals.
- Prepare a schedule indicating when fill, dredging or grading will occur, the time to be allowed for settlement, the time when levee breaches or inlet structures will be operable and the time when planting will occur. Include an estimate of the extent of expected sedimentation over a ten-year period.
- Prepare a monitoring program to measure water quality, soil characteristics, plant survival and growth rates, and expected wildlife use. The program should last ten years. The monitoring program should describe how modifications will occur if adverse conditions are identified.

Panel Discussion

Robert Jones, *Jones and Stokes Associates, Inc., Sacramento, CA:*

I think John's paper in which he took the eight wetland values that had been identified as important throughout the country and considered their importance in California is a valuable contribution. John has concluded that for several of those values it's either unclear or unknown whether they are important in California. For others, it's pretty clear that they are not important. He then concludes that wildlife is probably the most important value for California's wetlands. So, my comments are going to be limited to wildlife.

The paper discusses and develops some wildlife goals, which I feel are too general. Based on my experience in resources planning, if you are going to prepare a regional plan or even a site-specific plan, you need to develop specific objectives and then outline programs to meet those objectives. A regional wildlife plan requires one to identify the various habitat types to be protected or developed. The plan also needs to identify those wildlife species and species groups that need to be encouraged. I recognize that many wildlife planners prefer to plan for habitats rather than for individual species, but even that approach forces one to establish species priorities. Let me give you a specific example.

Rolf Mall and I were involved in 1962 on Delta studies to figure out the impact of transfer of state project water. Rolf was responsible for dealing with the impacts of the state water project on the Suisun Marsh. In order to even cope with that question, somebody had to make some decisions as to how Suisun Marsh was to be managed. The Department of Fish and Game did make a decision that the priority for management was for pintail duck. Now, there are other values, but at that time this was an acceptable objective for most of the people interested in the marsh. With acceptance of a decision that you wanted to give priority to pintail ducks, you knew you were dealing with alkali bulrush—one of the important pintail foods. The decision to enhance alkali bulrush requires consideration of the salinity requirements for that plant. Each of these planning steps was absolutely necessary to intelligently identify the impacts of the state water project on the marsh and to develop needed mitigations.

The preparation of a regional wetlands plan requires the development of specific objectives and programs to meet them. The responsible governmental agency, with input from other interested citizens and academicians, needs to define these regional wildlife plans and regional goals. These plans should deal with habitat types, wildlife species, and species groups.

Regional wildlife planning also helps one cope with the needs of various wildlife species in both innovative and efficient ways. Let me use the clapper rail as an example. Clapper rails prefer low marsh and cord grass habitat. Upper Newport Bay and Anaheim Bay are important areas for clapper rail. We happen to be doing some work in the Los Cerritos wetland. One of the key questions which should be addressed in a regional wildlife plan for Los Angeles and Orange Counties, is whether you should try to provide for clapper rail habitat in Los Cerritos. There is little, if any, such habitat there now. If you look at the question regionally, you may find that the development of a cordgrass habitat can be done more economically and efficiently at some other location in the region. If you did not look at this question regionally, the general approach would probably be, "Well, we want diversification at Los Cerritos. We want all the different species we can get, so maybe we should build in something for clapper rail."

These are a few examples of how regional goals and wildlife planning help resource managers. John's recommendation for a regional approach is helpful. It needs to be developed further.

Emy Chan, *Association of Bay Area Governments, Berkeley, CA:*

The primary focus of ABAG is the San Francisco Bay Area, where we administer area-wide water quality management plans, also known as the 208 Water Quality Plan. The eight values that John mentioned are relevant to the San Francisco Bay Area.

One of the goals that John mentioned was wildlife habitat. Wetlands and their associated transition zones are important habitats to mammals, waterbirds and other wildlife. Shallow, generally inland areas, appeal to dabbling ducks, wading and marsh birds. The San Francisco Bay is an important part of the Pacific Flyway and restoration of any increment to this wetland habitat has significant value.

Another value that John mentioned was water purification. We feel this has merit and that, where possible, it should be incorporated into a wetland. Last year, ABAG published a literature survey on five wetland systems across the United States that received and treated, to some degree, urban runoff or storm water runoff. In such systems, there was good removal of nutrients, but this fluctuated by seasons and depended on the system. Suspended solids had very good removal, 85 to 99 percent. BOD was variable—sometimes 50 percent; sometimes as much as 97 percent. The amount of heavy metals were generally low and the removal varied within the system, so this needs further study.

We also looked at 14 wetland systems in the United States that treated municipal waste water, keeping in mind these are all freshwater systems. They had moderate to high nutrient levels and the removal was variable depending upon the season—generally good for nitrogen, poor for phosphorus. Suspended solids generally were low and the removal was good if you didn't count the algae. As for BOD, the removal was also good; 70 to 96 percent. We found that when storm water runoff levels were low, removal was variable, and more study is required.

Another value that John mentioned which we feel is important is flood protection. Flood protection has become very important in the San Francisco Bay Area. Whereas before, a flood district would try and channelize the stream to get the flood water out as soon as possible, we have a new problem: flood water coming down a channel meets the incoming tide, it backs up and floods. The solution to this problem has been to build detention basins and temporarily hold the flood water until it's convenient to release it to the Bay. This means that approximately all winter there is standing water in these basins, a seasonal wetland. We feel that with prudent planning and management we can make good use of this particular system and turn it into a wetland system.

Another value John mentioned was cultural values. The ones that obviously come to mind are recreational: clamming, fishing, birdwatching. We feel that open spaces are a very important part of this value. In San Francisco Bay, the wetland and the adjacent developed areas are very flat and this makes our angle of perception low. You can hardly see the Bay unless you are right next to it; thus, any object with a little bit of height such as trees, hills, whatever, become visually more important than the Bay itself. It's important, we feel, to keep this open space and continuity so we know where the Bay is.

The last part that Nancy Wakeman talked about were restoration goals for the Bay Area. We feel that most salt and freshwater marsh habitats have a high value. The ideal situation is an upstream freshwater marsh which drains into a brackish and salt marsh, dependent on the situation. As Nancy mentioned, of the tidal habitat that was lost throughout the Bay Area, it was the freshwater and brackish that went first because it was closest to where the people were. We feel that it's important to utilize freshwater sources rather than sending them directly to the Bay. This source generally doesn't require pumping or much pretreatment and little energy use. Because it goes through every jurisdiction in the Bay Area, this is a good way to encourage jurisdictions to look at wetland restoration.

ABAG is looking at areas where freshwater can be used to create or supplement marshes. Can we target specific types of marshes that we want to recreate and look for sites, hoping that the institutional and other requirements will fall into place? Or should we be more opportunistic, and look at ongoing projects—perhaps public works projects—and public lands, where it would be easier to put in a marsh and then create the type of wetland most suitable for that site?

Martin Cohen, *State Coastal Conservancy, Oakland, CA:*

John's paper raised some very interesting questions about the methodology for defining the goals for restoration enhancement projects. In discussing these goals, we are on the boundary between the descriptive and the normative—between analysis of what is and a vision of what could be—and a third dimension, the historical. If the goal for restoration were to recreate what's been lost, then we wouldn't have much trouble in deciding what we want to do, we would just make a historical inventory. But that's not entirely open to us, the land just isn't there.

I concur that John's paper is an excellent summary of the existing types and values of the coastal resources. It's myth-shattering. I think it's very important that if John's conclusions are verified, that a lot of the reasons that we have been given for wanting to protect coastal marshes don't hold water.

I would like to second Emy Chan's comments about waste water purification in wetlands. I think that many of the conventional water quality tests don't show the values that wetlands have in transforming potentially noxious and dangerous wastes into biomass which can be the basis for ecosystems. The mechanism by which the actual waste water treatment takes place needs to be looked at in that it's not the macrophytes which tend to do it, but the micro-organisms which make this transformation.

On the use of coastal wetlands by the Pacific Flyway population, it is important to remember that the southern California wetlands were prolific feeding and wintering grounds. To use the current small numbers as a reason for their not being valuable and therefore not having waterfowl as a restoration goal for southern California wetlands is, I think, a little premature. The Fish and Wildlife Service has studies that indicate that the limiting factors for the Pacific Flyway populations seem to be the wintering habitat, and if that is so, then increasing that wintering habitat could be an important goal even though the birds are not there right now.

The main point that I'd like to make is that we have a choice of methods. To restore what's there, to restore what was there, or to restore what will contribute to our normative vision of what kind of environment we want to live in. In particular cases, these methods may come to the same conclusion; they may come to different conclusions. I think that in a sense we're faced with different agency perspectives. If you are dealing from a regulatory perspective, your chief concern is to protect what you have. That's the Coastal Commission's necessary perspective. In the Coastal Conservancy projects, we have emphasized the historical perspective. We have used rationales in Humboldt Bay, the loss of the 90 percent of the freshwater lands as a reason for investing public funds to restore freshwater acreage. Similarly in south San Francisco Bay, the loss of fresh and brackish habitat has been a reason for investing public funds to restore that kind of habitat.

There is a good mix of people attending this workshop. There are more local government people than I would have expected. The emphasis that I want to make is that when we talk about a regional goal, and especially when we talk about the Conservancy or other public investment projects, it's the local people who must carry it out, monitor, maintain and be responsible for the long term management of that project, and it's the local constituency that ultimately must decide what kind of environment they want to live in and ultimately should have an important role in defining the normative goals we're seeking.

Audience Participation

JEANNIE CHRISTOPHER (University of San Diego): Because we're talking about goals and projects are often judged on the merits of their goals, we have to be very careful about the tack we take. While I agree with John that it's good to delineate which category contributes more to the value of a wetland, I feel very uncom-

fortable to designate a single goal on which to place our focus because in doing so we minimize the potential value of integrating several values. I will give three reasons.

First, if we focus on a single category, there will always be a person that will dismiss that category for some particular economic reason. Second, it's absurd to dismiss the function of wetlands as a valuable floodway protection. By focusing only on the wetland portion, you lost the ability to value the whole in its function as a floodway protection. In the case of wetlands at the terminal end of a floodway, they have a value as a floodway protection, as we found in Los Penasquitos Lagoon in southern California. Incorrect engineering based upon old data was used to conclude that the upstream and the downstream coastal riparian environments were merely occupying space that is necessary to convey water. Finally, I think we should add to our goals the physical and biological data that we will find in the future and those things which we do not fully understand today.

NONA DENNIS (Madrone Associates): Today's workshop has a glaring absence of the infidels, which is to say the landowners. And I think that as the experts, we can go on convincing ourselves and establishing regional goals which are ideal to us, to the agencies, to the public interest—but in fact, the capital is going to be coming from the landowners.

Are there any biologists who represent, for example, the enormous interests of offshore drilling, onshore drilling, onshore production of various sorts—and I don't mean just the developers in residential areas, but people who have interests in huge private components of the coast. We should prevent ourselves from lapsing into a kind of self-serving reinforcement of our goals in the absence of these other interests.

CAROL WILCOX (Department of Fish and Game): My concern is with regard to the use of treated water for wetlands. For example in Newport Bay the freshwater input to the Bay is continually increasing due to agricultural irrigation practices. The Bay is becoming more estuarine as the tidal prism decreases due to sediment loading, and we're being approached by sanitation districts that want to put more water in the Bay. We're losing species diversity because of the loss of tidal prism and increased freshwater input.

The problem we're faced with is that over the last 10 years continual low flow input to the upper Bay has increased, from a rate of 3 to 5 cfs to 20 and 30, and that's continuous flow. So we're considering increasing the tidal prism—to move the interface up farther into the Bay. But still, it's a problem of continually more freshwater coming into the Bay causing a management problem.

PAUL SPRINGER (Fish and Wildlife Service): I'd like to point out that while coastal wetlands are generally less important to waterfowl than inland, there are several species, notably canvasbacks and black brandt that use coastal wetlands heavily and I think we should recognize as was pointed out by Bob Jones that we have to consider the species we're talking about. Secondly, coastal wetlands are used by many of these species early in the fall when the Central Valley is well flooded and in times of drought. So there are times when they receive high use. The other thing is that I think there is more information available than generally recognized as to the values of wetlands to different species. I realize it's scattered. I think it's a challenge for us to bring this together so we better understand the preferences of the various species and how to manage them.

ROGER WOLCOTT (National Marine Fisheries Service): I think that John's thesis on the setting of regional goals in habitat maintenance and restoration is interesting and useful and it's unsettling and myth-shattering, in a lot of ways. I saw a lot of people besides myself wincing as you ticked through all the holies that a lot of us hold to.

I think that we must be very careful in setting these goals and in generalizing what goals we're going to optimize for in light of the quantity and quality of information used to derive those goals. A case in point is with salmon and the utility of estuaries, if I can use your sense of wetlands, and extend it to the estuary as a whole. I think it has been generally considered that the value of estuaries to salmonids for uses other than as a migratory corridor is very little. However, there has been very little work done to really look at this and in recent years there's been an increasing amount of information available on the value of estuaries in the rearing of salmon in Puget Sound, Canada, and estuaries along the coast of Oregon. There are several other biologists besides myself that are beginning to suspect that indeed the Bay here may be far more important in terms of rearing, growth, and survival of salmonids out of the Sacramento-San Joaquin system than previously thought. I just want to point out how careful one has to be in the kind of information used to draw these generalizations in establishing regional goals.

JIM McGRATH (California Coastal Commission): I agree with John's thesis that in their current state, estuaries don't play much of a role in cleaning waste water. The estuaries at the mouths of all the major streams in southern California are gone. The Los Angeles River is now a seaport. The other exit to the Los Angeles, the Biona Creek, is for the most part a marina. The mouth of the San Diego River is now a regional park. The mouth of the Santa Ana River is, for the most part, single-family homes. Thus, there is no appreciable cleansing action going on because the estuaries on the major rivers that could have performed that function are gone.

THOMAS HARVEY (San Jose State Universtiy): I want to join the growing list of those questioning dismissing certain values and specifically productivity, by citing Haines' work. Will you try to get a hold of Dr. Teal and see what his rebuttal is. You may find there are some

reasons to queston your statements.

MR. ZENTNER: I would cite Scott Nixon's work, which came out in a book edited by Hamilton and Mac Donald in which he reiterates Haines' theses.

PAUL KELLY (California Department of Fish and Game): I enjoyed the presentation, John, because it made me mad and got me thinking about some things. I hope at times you were playing the devil's advocate. But I guess in an effort to dispel some misconceptions about wetlands, you've created some other misconceptions. With respect to wildlife habitat requirements in wetlands, you emphasized the role of intertidal habitats as being a value to shorebirds and downplayed the role of higher marsh and vascular plants. You're 50 percent right, because shorebirds spend 50 percent of their time on the mudflats, but during high tides, when many of the smaller species must feed, they are feeding in the high marsh, pastureland, and salt marsh around San Francisco Bay and other habitat types you didn't even mention. So I think there is a real problem with simply identifying habitat requirements as you've done and making recommendations for wetland management.

MR. ZENTNER: I agree with you. Shorebirds definitely do spend, especially during high tide periods, a large amount of time in salt marsh habitats. They also spend a large amount of time in other areas. The question is how dependent are these species on the wetlands areas? That's what I was trying to answer. I think we will have salt marsh preserved, hopefully by the Coastal Commission, but we also need to look at intertidal habitats. My feeling is, and other people feel this way, that shorebird populations are probably being limited by the amount of intertidal habitat that's left, at least as far as feeding habitat goes. But I agree with your concern about the generalizations.

Legal and Institutional Constraints and Opportunities in Wetlands Enhancement

Scott McCreary, *State Coastal Conservancy, Oakland, CA*

Introduction

Like other pursuits that span the "wet side" and "dry side" of the coastal zone, the practice of wetlands restoration is guided by a complex, overlapping set of laws, agency policies, and attitudes. In his recent analysis of policies and institutions affecting coastal aquaculture, Bowden (1981) criticized what he called:

> *the tendency to impute reasoned and principled choice to a body of law that is really nothing more than a shoebox full of rag ends of recorded customs . . .*

The basic theme of Bowden's critique can be applied to wetlands enhancement: efforts to enhance wetlands must run the gamut of laws and policies not explicitly intended to promote marsh restoration. A majority of policies on the books are intended more to "hold the line" against further abuse.

Wetlands enhancement can benefit from a number of trends in the environmental planning field. These include many non-regulatory approaches: the Coastal Conservancy's resource enhancement program, the emerging trend to manage whole ecosystems, and the proliferation of land trusts and other locally based groups as stewards of sensitive resources.

This paper presents an overview of legal and institutional issues confronting wetland restoraton in California. The major issues I deal with include: 1) the evolution of state policy towards wetlands protection; 2) federal trends in wetlands management; 3) institutional issues related to land acquisition; 4) the relationship between wetlands protection and watershed management; 5) the role of scientists in enhancement activities; and 6) the perspectives of citizen activists in wetland enhancement. The paper concludes with a summary of recommendations drawn from each discussion. Source materials includes the planning and natural science literature, interviews, and personal experience in the practice of wetlands enhancement.

Evolution of State Policy Towards Wetlands

California's approach towards wetlands restoration has evolved from passive policy statements to acquisition of relatively pristine sites, stringent regulation, and active intervention in restoring habitat areas. Attitudes about how best to restore wetlands are as diverse as the agencies charged with special missions to save the resource. This portion of the paper traces the evolution of wetlands policy in the state.

Prior to the successful passage of Proposition 20 and subsequent legislation creating the Coastal Commission and Coastal Conservancy, the leading advocate of wetlands protection was the Department of Fish and Game (DFG). Through the early 1970's the DFG produced a series of background papers on 25 coastal wetlands, highlighting potential land use conflicts and management problems (DFG 1970-8). *Acquisition Priorities for the Coastal Wetlands of California* (DFG 1976) provided a significant policy statement and identified 19 coastal wetlands where key parcels of land should be brought into public ownership.

The 1976 *Coastal Plan* prepared by the California Coastal Zone Conservation Commission adopted many of the assumptions found in the DFG report and recommended that special protection be given to estuaries and wetlands (Policy 15). Three specific policies were stated to carry out the policy. First, a regulatory approach was expressed, prohibiting any development or filling of wetlands unless several conditions were met. Three preferable uses of wetlands were identified: restoration, aquaculture, and nature study. In addition to these uses, only military facilities, ports, energy facilities, port entrances, cables, and pipelines were allowed in wetlands. Second, degraded wetlands were to be restored, based on a priority list to be drawn up by appropriate resource management agencies. Finally, comprehensive plans for estuarine management were to be prepared and implemented. These plans, at minimum, were to emphasize resource protection and restoration, public health and public trust issues, as well as aquaculture and freshwater supplies. Plans were to specify management programs necessary to protect the wetland and identify the responsible agencies and funding sources.

Through the processes of negotiation and legislative compromise, the translation from *Coastal Plan* policies to Coastal Act mandate (Public Resources Code 30000, *et seq.*) gave only minor treatment to mechanisms to restore and manage wetlands. However, the Act did specify that biological productivity of wetlands be maintained, or where feasible, be restored (Section 30231). The Act also included a set of policies designed to clarify the circumstances under which development could occur in wetlands (Section 30411) and the potential uses which can be considered in wetlands (Section 30233):

1. ports and coastal dependent industrial facilities
2. maintenance of navigation channels and turning basins
3. entrance channels for new or expanded boating facilities
4. new or expanded boating facilities in open coastal waters
5. cables, pipes, and inspection of piers
6. mineral extraction, including sand for beach restoration
7. restoration
8. aquaculture

The Act makes a distinction between the 19 coastal wetlands identified by the DFG. In the sites listed as high priority for acquisition, only minor public facilities, restorative measures, and nature study are allowed, except in Bodega and San Diego Bays. If an area is identified as a degraded wetland by DFG, boating facilities may be developed, provided that a substantial portion of the degraded wetland is restored and maintained as a biologically productive wetland. In no case can the boating facilities exceed 25 percent of the total wetland area to be restored.

The restoration of wetlands found specific expression in the legislation that created the State Coastal Conservancy giving this agency the responsibility for implementing programs of resource enhancement and restoration within the coastal zone (Section 31054). Chapter 6 of the Conservancy Act spells out procedures for coastal restoration projects. Up to $50,000 may be allocated by the Conservancy for preparation of resource enhancement plans. All such plans must be reviewed by the Coastal Commission for consistency with the Coastal Act. The Conservancy Act strives for consistency with the LCP process by stipulating that areas proposed for restoration be identified in a certified LCP. The Conservancy also has the authority to pay up to the total cost of any coastal resource enhancement project, including the state share of federally funded projects. Since the Conservancy's enhancement program began in 1978, over 18 projects have been approved by the Board, and 4 have been completed.

A difficult decision remaining in restoration policy is the relative merits of off-site and on-site mitigation for permitted development in wetlands. In Los Angeles and Orange Counties where land prices are very high and most wetlands have in some way been impacted by surrounding development, there are few opportunities to enhance a wetland sufficiently to restore its natural functions without resorting to some drastic change in conditions on the site. In some cases projects have been proposed that involve filling of deteriorated areas in exchange for creation of new wetland areas. Unfortunately, the Coastal Act gives little positive guidance to projects that would allow filling on a given site in exchange for creating new and larger wetland habitat. The Commission and Conservancy staff have been involved in intense debates concerning off-site mitigation particularly as it relates to proposed Conservancy projects at Los Cerritos marsh and the Hellman properties in Orange County. Experience to date suggests that there are merits to testing and refining these techniques in the Los Angeles-Orange County area.

Federal Trends in Wetlands Management

Several federal agencies administer programs which impinge on wetlands restoration through policy guidance, regulation, special area management, and expenditure of capital improvement funds. These include the Office of Coastal Zone Management (policy guidance), the Council on Environmental Quality (policy guidance), the U.S. Army Corps of Engineers (regulation through permit authority), the Federal Emergency Management Agency (floodplain regulation and disaster relief in low-lying areas), and the Environmental Protection Agency (expenditure of capital improvement funds for sewage treatment plans; watershed management). This discussion will consider each of these in turn.

The 1980 reauthorization of the Coastal Zone Management Act (CZMA), first enacted in 1972, included specific language calling on states to manage resources of national significance, including wetlands and estuaries. However, the revised language fails to spell out any specific procedures or criteria for evaluating the effectiveness of state programs in meeting this goal.

During the first year of the Reagan administration, the federal policy on wetlands from the Department of Interior was cause for serious concern to wetland preservationists. Early policy statements and news coverage were slanted overwhelmingly towards a strategy of harvesting, mining, and logging. Another policy, intended mainly for Bureau of Land Management holdings in rural areas, called for returning jurisdiction over these areas to the local unit of government. This prompted at least one request by a local government, the City of Imperial Beach, to turn a 505-acre wildlife refuge purchased in 1980 back to the City for the construction of a marina.

In the present dynamic regulatory climate, two important forces are sections of federal laws administered by the Army Corps of Engineers. The first is Section 10 of the

Rivers and Harbors Act of 1899. Without a Corps permit under Section 10, it is unlawful to dump material in navigable waters or "to carry out any other action that would affect the course, condition, location or capacity of navigable waters." The second is Section 404 of the Clean Water Act which establishes a permit process to protect the quality of navigable waters and adjacent wetlands. Originally limited only to waters used to transport commerce and to areas subject to the rise and fall of the tide, the jurisdictional limits of Section 404 were expanded following two court decisions: *U.S. v. Holland*, [373 F. Supp. 665 (M.D. Fla., 1974)] and *Natural Resources Defense Council v. Callaway*, (392 F. Supp. 685 D.D.C., 1975). The revised guidelines for Section 404, issued in 1977, include the following areas:

> *coastal and inland waters and their tributaries; all waters of the U.S., such as isolated lakes and wetlands, intermittent streams, and other non-tributary waters.*

Taken together, enforcement of Section 10 and Section 404 presents an ideal opportunity to develop a coherent program of wetlands restoration projects as mitigation measures. In other words, the Corps would be in a position to develop a "mitigation bank" of prospective restoration sites in advance of permit processing.

To date, several forces have worked against greater Corps participation in a coherent program to restore wetlands. First, the Corps is fundamentally reactive. While the regulatory staff often tend to have an activist attitude, they must convince both legal staff and the district leadership before the Corps district has a different attitude toward wetlands protections. For example, the Charleston, South Carolina Corps was inclined not to require an Environmental Impact Statement for a major pipeline and refinery project adjacent to the Yawkey Wildlife Refuge, while San Francisco staff are supportive of an advocacy posture. This fragmentation works against any clear articulation of policy on the national level, and tends to perpetuate the negative elements of the Corps' public image among citizens who would otherwise be allies in wetland restoration.

A series of recommendations announced by the Army in mid-January 1982 would, if implemented, weaken wetland protection under Section 404. In developing its recommendations, the Army revised ten regulations recommended by the American Petroleum Institute. Major revisions proposed by the Army include:

- reduce the time to obtain a decision;
- delegate responsibility to states, except in cases where national economic development, energy and navigation are at stake;
- expand the categories or general permits, and projects which do not require permits;
- reduce the jurisdictional extent of Corps regulatory programs

The last goal would reverse the expansion of Corps jurisdiction determined by the two court cases cited above and would limit jurisdiction under Section 404 as areas that are either 1) used to transport interstate or foreign commerce; or 2) covered by floodwaters at least once each two years.

At the federal level, tax law can also have an effect on wetland preservation and restoration. Historically, many individuals and corporations who have decided to make sales or donations of their land have been motivated by tax benefits which accrue from these transactions. In fact, federal tax policy can be an important determinant of the feasibility of wetlands restoration, particularly where donations or sales of private land are required to complete a restoration project. Several new tax laws are, in effect, a disincentive to landowners considering donations or bargain sales. The reduction in maximum tax rates and the increase in exemption equivalents reduces the incentive to find ways to shelter income.

Effective in 1982, the maximum personal income tax dropped from 70 percent to 50 percent. Meanwhile the exclusion for capital gains remains at 60 percent, making 40 percent of the capital gain eligible for taxation. This means that the top tax rate on long term capital gains for individuals will be reduced from 28 percent (.70 x .40) to 20 percent (.50 x .40). In addition, the rules on estate taxes are changing. The maximum rates for gift and estate tax ("transfer tax") are 70 percent in 1982, but drop to 50 percent after 1982. The 50 percent maximum rate is reached in the case of all transfers over $2,500,000. After the transfer tax is computed, a Unified Credit is applied to reduce the tax payment. This Unified Credit increases from $47,000 for transfers in 1982 to $192,800 for transfers in 1987 and thereafter. For estate planning purposes, it is easier to think of the Unified Credit as the Exemption Equivalent— the portion of the landowner's estate that will be exempt from transfer tax. This figure will increase from $175,000 in 1981 to $600,000 in 1987 and thereafter (Brown 1981).

Another disincentive operating in federal tax policy is the absence of any special deferral or exemption for landowners who sell wetlands to land management agencies or private groups. Legislation has been introduced (H.R. 6465 Lagomarsino) to provide a full exemption on gross income to landowners who sell wetlands and other eligible habitat areas to the federal government, states, or qualified organizations. H.R. 6465, reintroduced as a revision of a bill first put forward in 1981, ties the definition of eligible land to those accepted by the Tax Treatment Act of 1980. The Conservancy has recommended offering a deferral instead of an exemption, and mandating IRS regulations to spell out review procedures (State Coastal Conservancy correspondence, December 23, 1981).

Institutional Issues Surrounding Land Acquisition

Often the completion of a wetlands enhancement project requires that the Coastal Conservancy negotiate the purchase of property and its transfer to public ownership. The process is far more complicated than a private land transaction, and also more complex than a transaction for conservation purposes undertaken by an organization such as The Nature Conservancy. In California wetland restoration projects, several agencies are typically involved: the Coastal Conservancy, the State Lands Commission, the Public Works Board, and the Real Estate Services Division of the Department of General Services.

The first steps at the Conservancy involve an assessment of project feasibility by a Conservancy analyst—especially examining land costs, contacting landowners, and ordering preliminary title reports. Once title reports are received, checked, and updated, the Conservancy staff convene a strategy session. These meetings cover tasks such as identifying acquisition priorities, identifying special negotiating requirements with landowners, deciding the manner of compliance with California Environmental Quality Act (CEQA), and identifying special requirements in the appraisal. In addition, a State Lands Commission determination of public ownership must be built into the process, and all permits and licenses needed to complete the project must be identified.

Before negotiations with a property owner can begin, the Conservancy must obtain an appraisal of fair market value using Real Estate Services (RES) analysts whenever possible. The choice of an appraiser is often a critical factor in land negotiation, and the merits of using RES staff appraisers are often outweighed by the desire of a landowner to use an independent appraiser. Other factors may include the need for quick evaluation services and the RES staff's lack of special expertise in appraising coastal real estate, especially wetlands. To alleviate some of these conflicts, the Conservancy and Department of General Services are developing a memorandum of understanding to govern future appraisal activity.

Following successful negotiations and signing of major documents for land acquisition, the next major step is securing the approval of the Public Works Board, as required under the Property Acquisition Law. Although the Public Works Board may use the power of eminent domain (Public Resources Code Section 31106), the Conservancy has chosen as a policy matter not to use this authority. By developing and publicizing a "willing seller" policy, the Conservancy has increased its effectiveness in dealing with private landowners. If the presentation of a proposed acquisition to the Public Works Board is successful, the remaining tasks involving title transfer are carried out by RES.

The complexity of the process hinders wetlands restoration in two ways. First, a large proportion of staff time must be devoted to administrative matters, rather than negotiating new purchases or developing stewardship plans for areas already acquired. Second, delays between the signing of the Property Acquisition Agreement and the close of escrow, and the negotiator's inability to predict these delays affect the Conservancy's ability to close a deal.

Watershed Management and Wetlands Protection

At its heart, wetlands restoration seeks to increase the size of the habitat area and increase the productivity and species diversity of wetland ecosystems. In doing so, wetlands restoration is intended to protect endangered species, provide a nursery for commercially and recreationally important fish; and create increased opportunities for education and scientific use of wetlands. Each of these goals can be thwarted if watershed management is not incorporated as an element of wetlands restoration. Prestagaard (1978) and Dickert and Tuttle (1980) have documented the linkages between watershed development and subsequent increases in erosion and sedimentation. Erosion and sedimentation lead to shifts in the extent of habitat areas and may influence community structure and wildlife diversity in wetlands.

In their study entitled *Collaborative Land Use Planning for the Coastal Zone*, Dickert and Sorensen (1978) proposed what they called an "alternative agenda" for the Coastal Commission. They argued that the Commission should prepare plans that crossed the boundaries of local jurisdictions. The "sub-regional plans" would then be broad enough in scope to deal with issues like watershed erosion, generation of traffic, and protection of visual corridors:

> *Without subregional planning, it is expected that most of the coastal systems problems ... will be largely unresolved, and California will be left with a mosaic of plans lacking inter-jurisdictional coordination for its coastal zone ... Each local program will seek to maximize benefits for its jurisdiction and pay relatively little attention to coastal resource systems which will lead to the degradation of resource systems, as well as providing a continuing source of conflict between adjoining jurisdictions.*

To a very large extent, the Commission has not used watersheds as a unit of analysis for coping with wetland and estuarine issues. This is partly a function of the degree of faith placed in the individual Local Coastal Plans to solve resource problems. The piecemeal approach is also a reflection of the original coastal zone. The coastal zone boundary, a narrow band which varies in width from 1,000 feet in many urban areas to as much as five miles in areas such as Big Sur, specifies the limits of Coastal Commission permit authority and planning areas for Local Coastal Programs. While this jurisdiction is large enough to capture most wetland basins, it normally excludes all but the smallest portion of that wetland's watershed or drainage basin.

The problem of controlling erosion and sedimentation generated in watersheds has been described as "an institutional bramble bush" by the John Muir Institute (1979) in a report for the State Water Resources Control Board. Fully 45 agencies and government entities at all levels share responsibility for portions of this resource management Armageddon. The study documents a leadership vacuum among the various state and federal agencies with responsibilities in watersheds, including the Soil Conservation Service, Resource Conservation Districts, Agricultural Stabilization and Conservation

Service, State and Regional Water Resources Control Boards, and the Coastal Commission.

At the time of the Muir report, the Coastal Conservancy was deemed unlikely to have a major impact, yet the agency has demonstrated a growing commitment to watershed problems and management. The Conservancy board has authorized two projects with entire watersheds used as the unit of analysis. Tomales Bay, a drowned rift valley in west Marin County, is the subject of a feasibility study to examine several strategies for resource management in the estuarine-watershed complex. The most promising approaches include the use of local land trusts in stewardship of riparian corridors and the creation of a watershed-wide management authority. A second project, approved in January 1982 by the Conservancy Board, is the Buena Vista Lagoon Watershed Enhancement Program (State Coastal Conservancy 1982). The project will address the problem of rapid deposit of sediments in Buena Vista Lagoon, San Diego County. This sediment deposition is the combined result of improper grading and construction activity and natural erosion in the 24 square-mile watershed. The first phase of the project involves technical assistance to strengthen grading ordinances and draw up an appropriate legal instrument to bind three local jurisdictions in a program of watershed management. Another part of the work is the preparation of a watershed enhancement plan including preliminary engineering specifications for silt basins and other structures.

In implementing the Lagoon Watershed enhancement plan, the Conservancy was initially constrained by its legislated jurisdiction. At the time the Conservancy Act was passed, the coastal zone was adopted as the agency's jurisdiction. However, fully 70 percent of the watershed lies in the jurisdiction of the inland City of Vista. The Conservancy could carry out studies outside the coastal zone, as it has already done for the Aliso Greenbelt and Irvine Ranch projects, but could not expend capital improvements funds outside the zone. This problem was resolved by the recent passage of AB 523 which provides that the Conservancy, at the request of a local agency, may undertake a project or award a grant to enhance a watershed resource outside the coastal zone. Under this language, the Buena Vista project would qualify for capital improvements grants, since Carlsbad, Oceanside, and Vista have all endorsed the Conservancy's involvement. This language will open the door to additional watershed management programs in sites such as Los Penasquitos Lagoon, Bataquitos Lagoon, Elkhorn Slough, and Tomales Bay.

The Role of Scientific Information in Wetlands Enhancement

Wetlands restoration requires the frequent and extensive use of scientific information. For example, scientific evidence is needed to make decisions on the appropriate configuration of a wetlands basin, the dimensions of buffers, and the mix of elevations and habitat types. The institutional mechanisms to facilitate this scientific involvement are only now evolving. The failure to see scientific advice as central to coastal decisionmaking stems in part from attitudes that prevailed early in California's coastal program. Scientific advice was lumped with scientific research, and both were thought to be subordinate to making the tough decisions. Joseph Bodovitz, the first Executive Director of the California Coastal Zone Conservation Commission, made this observation in 1973:

> *What is most needed now is a set of comprehensive policy decisions about the future of the coastal zone . . . Further research will help solve some problems, but I believe that we already know more about the coastal zone than we've thus far been willing to act upon.* (Bodovitz 1973)

Clark's (1979) analysis of the role of scientists during preparation of the Coastal Plan indicates that this bias persisted well into the mid-1970's. Three roles were identified for scientists: (1) research, (2) interpretive assistance, (3) advisory service. Clark found that participation of scientists as interpreters of information was not perceived as a role distinct from the research role. Administrative decisions made in the interests of expediting the planning process thus relegated scientists to passive review of staff materials, rather than engaging in research or interpretive assistance. Clark observed that:

> *The California Coastal Commission's planning program avoided coming to grips with underlying scientific issues. By postponing resolution of these issues, the Commission shifted them ahead to the implementation period and, in effect, transferred much of the burden of their resolution to local governments, which must formulate local coastal programs. This requires that there be extensive input by natural scientists into local planning, and that the Commissions find ways to facilitate this input.* (Clark 1979)

Onuf (1980) and Zedler (pers. comm.) have verified that Clark's prediction was correct: scientific involvement occurred late in the management process, and the Commission has not designed a mechanism to facilitate this involvement.

McCreary (1979) has identified a series of barriers that must be overcome to bring scientific information to the California coastal planning process. The first set of barriers are problems that must be confronted in all scientific research: establishing useful working definitions, establishing hypotheses, developing appropriate measurement techniques, and conducting rigorous tests. These factors are all significant for California wetlands science, because many of the findings reported in the literature are based on East Coast systems, where natural conditions are quite different.

The next set of barriers are those generic to any application of biological research: the fragmentation and abstraction of scientific inquiry, the difficulty of applying scientific expertise in the policy arena, and the limited ability of agencies to process and use information. The fact that scientists and planners operate under very different reward systems also complicates efforts to apply scientific findings. Bella and Williamson (1976) have observed that scientists are rewarded for rigorous scientific research, publishing in refereed journals, and, if possible, constructing new paradigms to advance the state of understanding in a particular field. Scientists may be subject to peer criticism if they spend too much time outside of these professional boundaries, or if they extrapolate research findings to policy statements. Planners, on the other hand, typically deal in short time frames and are very product oriented; they need concise data immediately.

Finally, there is a set of barriers peculiar to wetlands enhancement in California. These include the problems of interagency communication, lack of scientific expertise in many planning agencies and a corresponding lack of knowledge of planning processes by scientists, the problem of dispersed decisionmaking responsibility, and, of course, inadequate funding.

Substantial improvements have been made in involving of scientists in an interpretive and advising roles since Clark's study. Notable examples include the Coastal Commission's wetlands workshops, the development of the Estuarine Sanctuary proposal for Tijuana River, and a number of Conservancy wetlands enhancement plans. Beyond an invitation to participate, adequate funding must be available to ensure that scientific expertise is brought to bear on wetlands enhancement problems. With declining public dollars, this suggests the need to approach private foundations to underwrite rigorous wetland restoration planning. I would like to propose several other recommendations based on this discussion:

- planning and regulatory agencies should seek to hire staff with backgrounds in both science and planning;
- agencies with responsibilities in wetlands enhancement should contribute to the maintenance of an information clearinghouse for published reports and documents;
- the role of "broker" to communicate with both the scientific community and planners should be recognized and rewarded as a legitimate profession;
- scientists should be "invited in" early as team members in planning for wetlands restoration;
- scientists and planners should cooperate in developing an applied research agenda for wetlands restoration;
- a West Coast membership should be created with the National Wetlands Technical Council, a national organization designed to bring a unified scientific perspective to public policy questions involving wetlands.

The Citizen-Activist and the Role of Non-Profits

Since the voters ratified Proposition 20 in 1972, individuals and small local groups have maintained constant pressure on regulatory and planning agencies to keep the interests of wetlands in mind. The names of many of these groups reflect the commitment to preservation of local resources: Amigos de Bolsa Chica, Friends of Ballona, Friends of Upper Newport Bay. In 1982, many of these groups are beginning to make the transition from regulatory watchdogs to educators and land stewards. Often these groups have been responsible for keeping issues on the table, by appealing permits, or for triggering public land acquisition such as the nomination of Tijuana River Estuarine Sanctuary.

When a small sample of these activists were asked to describe institutional constraints, some interesting views emerged: agency staff are often ill-equipped to deal with the political tradeoffs inherent in wetlands protection; bureaucracy works too slow; enforcement is very weak; and a greater local role is needed for resource stewardship. These individuals have little patience for scientific or regulatory inactivity. Their frustrations need to be recognized and efforts made to utilize their enthusiasm towards constructive assistance in the restoration process. Increasing the role of non-profit organizations may be one mechanism to provide planning, management, and stewardship services at a time when government services are shrinking. The use of organizations such as The Nature Conservancy (TNC), the Trust for Public Land (TPL), and locally based land trusts must therefore become a part of an overall wetland restoration strategy.

Until recently, the action of nonprofits has not been consciously coordinated with regulatory or resource protection agencies. For example, TNC holds title to a parcel of land along the southern periphery of Elkhorn Slough, a National Estuarine Sanctuary. By virtue of its role as a major landowner, TNC became involved in the advisory committee for management of Elkhorn Slough. However, the agencies involved in protection of Elkhorn Slough (primarily the Department of Fish and Game and the Coastal Commission) didn't really use TNC as an ally until after the Sanctuary was established.

TNC's critical areas program for California has now raised over half of its $15 million goal, and hopes to buy the best examples of the state's most endangered ecosystems. In some cases these acquisitions may complement wetlands restoration projects, thus increasing the cost effectiveness of public expenditures and protecting a greater share of an ecosystem through a cooperative approach. Insofar as it is compatible with the goals of the private organizations, the resource protection agencies should make a more conscious effort to dovetail their own work with TNC and TPL through joint strategy meetings, more frequent phone calls, and a healthy flow of correspondence.

There is also a need for locally based organizations to act as land stewards and protect coastal wetland resources. Nationally, organizations as diverse as the Maine Coast Heritage Trust, the Jackson Hole Trust, and the Montana Land Reliance are developing a track record for resource stewardship. In California, the Humboldt North Coast Land Trust, Sonoma Land Trust, Marin Agricultural Land Trust, and Big Sur Trust are poised to move in this direction.

In recognition of the potential of these local nonprofit organizations, the Coastal Conservancy has initiated a new program to provide grants and technical assistance in several program areas, including wetlands enhancement (State Coastal Conservancy 1982). Under Sections 31400.3 and 31352 of the Public Resources Code, the Conservancy is expressly authorized to award grants from an allocation of $1,000,000 in Energy and Resources Funding (ERF). The first round of grants was approved by the Conservancy board and the first proposals were submitted in March, 1982. In order to qualify for awards up to $25,000, project sponsors were required to develop a clear enhancement or stewardship proposal, demonstrate the ability of the nonprofit organization to carry out the tasks, and attempt to identify a feasible method for repaying the loans. Three organizations were successful in applying for grants: the Buena Vista Lagoon Foundation, the Southwest Wetlands Interpretive Association (for Tijuana Estuary), and the Marin Agricultural Land Trust (for Tomales Bay/West Marin). The goals of these groups include land acquisition, acquisition of easements, and habitat restoration.

Ecosystem Management

A positive trend, evident in California and other states, is the development of programs to manage "unit resources"—mechanisms to couple the land side of the coastal zone together with the water side, thereby managing a unified zone of watershed, shoreline, and waterbody. A combination of techniques are used to create a unified management zone including land use regulation, land acquisition by public agencies, and on-site stewardship. In many ways, this trend towards management of whole ecosystems builds on earlier models of planning put forward in the 1970s. Bosselman and Callies (1971) predicted that substantial state intervention would be needed to manage resources of regional or state importance, such as wetlands. They predicted that:

> *The entire pattern of land development has been controlled by thousands of individual local governments, each seeking to maximize its own tax base and minimize its social problems, and caring less what happens to all others.*

They also predicted the emergence of a state-local collaborative process, in which states draft general policies and local governments implement them through land use planning and zoning.

> *As the states move towards more balanced systems of land use regulation that are not weighted exclusively toward the prevention of development, it will be increasingly necessary to merge both state and local regulations into a single system with specific roles for both state and local government in order to reduce the cost to the consumer and taxpayer of the duplicate regulatory mechanism.*

This mechanism is the basis for the LCP process administered by the California Coastal Commission.

In the 1980s, there is some rethinking of the merits of a strictly regulatory program to protect sensitive resources. There is growing recognition that tools such as limited acquisition or physical resource management are needed to supplement land use regulation. Clark and McCreary (1980) have documented the emergence of such programs at Apalachicola Bay, Florida; White Oak Estuary, California; and Elkhorn Slough, California. One of the most promising models appears to be the National Estuarine Sanctuary Program, especially the programs at Apalachicola Bay and Tijuana Estuary, California.

The National Estuarine Sanctuary program, enabled under the Coastal Zone Management Act (CZMA), was designed to protect the most outstanding estuarine areas in the nation for teaching and research. National guidelines require that states nominate candidates for sanctuary status which exhibit exceptional wildlife diversity and offer a representative ecosystem of a particular "biogeographical province." Guidelines also require that as much of the ecosystem be protected as possible, using state and federal matching funds for acquisition. However, only $3 million are allocated to the program nationally, forcing states to find creative techniques to implement each sanctuary.

Tijuana Estuary, California's second estuarine sanctuary, is an excellent example of the use of multiple techniques to manage an ecosystem. The estuary is southern California's largest tidally flushing system in near natural condition, supporting 1,100 acres of channels, sloughs, salt marsh, and mudflats. The proposal to create an Estuarine Sanctuary at the site was represented as an opportunity to manage the lower Tijuana Valley as an ecological unit, and to bring disparate public ownerships into a single coherent program for resource protection. Prior to the sanctuary nomination, several agencies had begun resource management programs, each with different purposes.

As shown in Figure 1, a 418 acre state park had been established on the old Navy Border Field site, complemented by a 263 acre area above the slough system leased to the Department of Parks and Recreation by the Navy. The U.S. Navy also manages 340 acres of the Imperial Beach Naval Air Station for clapper rail habitat. In late 1980, the U.S. Fish and Wildlife Service purchased 505 acres in the core of the wetland, once proposed as a marina site, and created a National Wildlife Refuge. Another public ownership includes 120 acres along the river corridor owned by the City of San Diego. The proposed Sanctuary boundary incorporates these public holdings, and proposed inclusion of 34 private parcels totalling about 775 acres.

In December 1981, the State Coastal Conservancy board approved a program to provide matching grants in the amount of $1.03 million to implement the Sanctuary and begin the purchase of private land (State Coastal Conservancy 1981). The project is designed as an agricultural preservation project in support of wetlands protection objectives. Conservancy planners and lawyers will develop specific agreements for acquisition and later

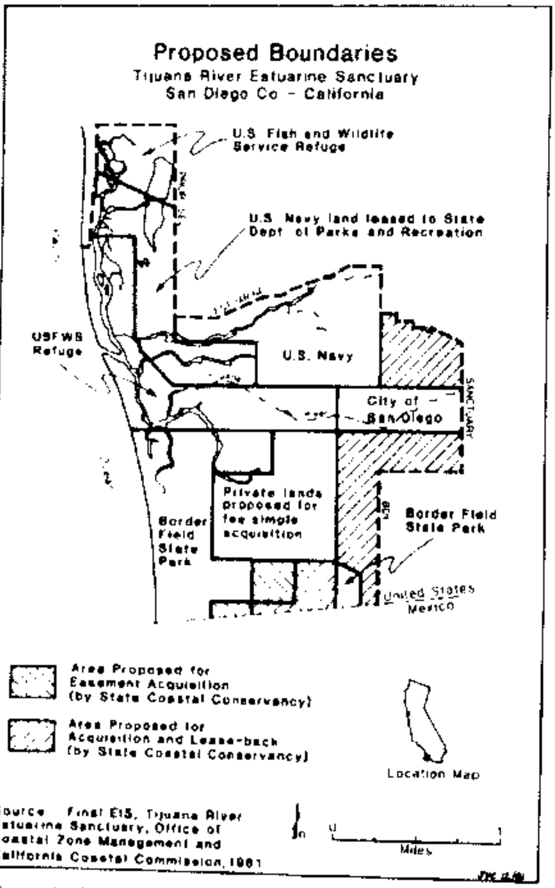


Figure 1: *Acquisition plan for the Tijuana River estuarine sanctuary*

lease. Legal instruments will be developed to direct revenues from the agricultural land back into management of the Sanctuary. In this way, the revenues can be used to develop erosion control measures for farmland, or test methods of integrated pest management, thereby reducing the stresses on the estuary.

A final feature of Sanctuary implementation is the stewardship role of the Southwest Wetlands Interpretive Association. The organization, founded as an educational group, has been an effective advocate for sanctuary designation, and has applied successfully to the new Conservancy program to provide seed money to local land trusts. Thus, local citizens will be directly responsible for some stewardship activities in the wetlands.

Several other Conservancy projects at Tomales Bay and Buena Vista Lagoon complement existing programs of public ownership and land use regulation with specific habitat improvements. Elkhorn Slough is also a strong candidate for this treatment. The Conservancy is evaluating some possible acquisition of land along the northern part of the Slough to complement the existing estuarine sanctuary along the southern part of the Slough. In addition, the Conservancy will investigate funding local land trusts to look after portions of the watershed outside the Sanctuary.

Conclusions and Recommendations

The foregoing discussion reveals a wide range of issues impinging on the practice of wetland restoration. At its root, wetlands restoration attempts to reverse the trend towards loss of valuable habitats through both catastrophic events (such as major dredging or filling projects) and more gradual degradation (through excessive siltation, loss of suitable buffers, or interruption of freshwater flows). A variety of legal and institutional tools are available to intervene against the loss of wetlands, and for the increase in the extent and productivity of wetland habitats. Together, they have been responsible for incremental progress in a number of geographic regions and problem areas, but we have yet to articulate a single coherent policy program on wetlands with the vision to move from general goals towards comprehensive implementation.

Ten recommendations are offered to move towards a more effective strategy:

1. ***Make wetlands restoration an explicit resource policy goal.***
   All resource management agencies in California should be put on notice that wetlands restoration is a major priority, and minor bureaucratic procedure should be amended to circumvent needless and costly delays and infighting. The state should mount a major campaign in Washington, D.C., to stem the loss of wetlands protection, much as it did for OCS development, drawing support from the growing wetlands restoration community.
2. ***Rationalize the permit process for wetlands restoration.***
   Develop and implement procedures that will reduce the cumulative time required to run the gamut of state and federal permits. This might include using a workshop setting for multiple agency review, or the use of hearings before multiple agencies.
3. ***Develop institutional mechanisms that enable negotiations for off-site mitigation.***
   Test and refine techniques as transfer of development rights, restoration off site in exchange for filling marginal wetlands, and development of a "bank" of suitable mitigation sites. The regulatory process must be used to intervene to reserve a sufficient inventory of low-lying sites suitable for restoration.
4. ***Refine and test methods for involving scientists and scientific information.***
   Encourage applied scientific research, but ensure that scientists are involved as technical advisors in plan development, and as critical reviewers during permitting. Planners and scientists must collaborate in developing an applied research agenda, securing adequate funding, and ensuring a rich flow of information on technical issues.

5. ***Develop strategies for managing whole ecosystems, using a combination of regulatory, acquisition, and stewardship techniques.***
Develop strategies to unify the shoreline, wetland basin, adjacent uplands, and watershed as a single management unit, borrowing from the growing body of experience at places like Tijuana Estuary (San Diego) and Apalachicola Bay (Florida).
6. ***Rationalize the land acquisition process for wetlands.***
This involves pressure for federal tax policy more conducive to private sales at favorable terms. Another element is elimination of unnecessary bureaucratic procedures in hiring appraisers and closing escrow.
7. ***Expand the role of nonprofits as agents for land acquisition and restore stewardship.***
Regulatory and acquisition agencies must work with national nonprofits where possible to stretch their limited fiscal resources for land acquisition. Locally-based nonprofits are ideal candidates for day-to-day enforcement, education, and maintenance, and must be given adequate seed money and technical assistance.
8. ***Recognize watershed as the logical unit for ecosystem management.***
Using the model of Buena Vista Lagoon, define and capitalize needed watershed improvements. Spell out maintenance and financing requirements as well as engineering solutions and biological improvements.
9. ***Call on the private sector for technical and financial support.***
Foundations, developers, and corporate interests should be engaged as partners in wetlands restoration.
10. ***Unify and develop the fragmentary wetlands restoration community.***
No single agency or private organization has ready access to the many interests pressing for wetlands restoration. Valuable opportunities exist for bringing this growing community under a single, or at least more coherent, umbrella.

Panel Discussion

Jonathan Smith, *Bay Conservation and Development Commission, San Francisco, CA:*

Scott didn't mention anything about the Bay Conservation and Development Commission. I guess he suspected I would be able to do that. BCDC is basically charged with the responsibility of attempting to protect and order the development of San Francisco Bay and the Suisun Marsh area, and it does so under several pieces of legislation and also on some plans that have been developed for the Bay and Suisun Marsh.

Probably the first and most important point to make is that BCDC has a limited geographic jurisdiction. It only includes the Bay and a very small slip of land around the Bay. It does include diked salt ponds, diked managed wetlands, but it still excludes a great many of what were historically baylands or marshlands, but were diked off and are not now considered to be either salt ponds or managed wetlands. It also excludes almost all of the watersheds for many of the streams which enter into San Francisco Bay. So to the extent that you would like to see a more geographically comprehensive jurisdiction and ability to regulate, BCDC is probably typical of such problems. Those decisions were political and I suspect in the present political climate they are unlikely to be changed in the near future. Unlike the Coastal Commission, BCDC is also more limited in terms of the areas it is interested in. In fact, its very title indicates that it has what at least may appear to be a somewhat schizophrenic attitude towards the Bay, trying to protect it and ordering development of it at the same time. An example might be the Hamilton Air Force Base where the Commission has felt so strongly as to become involved in litigation that Hamilton should be retained, at least for general aviation use, whereas certain other agencies would like to see it used for wetland enhancement and protection.

Moreover, BCDC is fairly typical in that its plans have very general policy statements regarding wetlands protection and enhancement and, in fact, are oriented more towards protection of existing wetlands rather than enhancement. Rather than being categorized in terms of wetland protection and enhancement, our policies come from various areas, such as wildlife protection, marshland and mudflat protection, and water quality and quantity statements.

Generally speaking, the Commission is somewhat of a reactive agency in that it becomes involved more often in terms of permit applications. After determining the minimum fill necessary for a specific project, the Commission may then determine that there still is some adverse environmental impact, or that the public benefit does not clearly exceed the public detriment and therefore, as mitigation for these unavoidable impacts of the fill, the Commission would like to see some enhancement or restoration of wetlands. To some people, the Commission is not nearly as active in seeking restoration as they would like to see. To that extent, I'd like to emphasize what Scott said concerning the role of organizations like the Trust for Public Lands and the Nature Conservancy. These organizations aid in the identification of sites that are available for mitigation and banking these sites so that they will be available at the time when a permit applicant needs a mitigation site.

Regarding the involvement of scientists, the Commission has generally used private consultants rather than having any ongoing advisory board dealing with specific problems of enhancement and improvement of wetlands. We do have two boards, an Engineering Criteria Review Board and a Design Review Board. In the case of the Design Review Board, public access problems come up in every permit application. The Engineering Criteria Review Board was spelled out specifically in our enabling legislation to deal with the problems of fill land and earthquakes. If there is sufficient pressure on the legislature or the Commission to identify marsh restoration and improvements as a specific policy goal, it would be advisable to have an advisory board that would include the people we're using at this point as private consultants.

The streamlining of the permit process was mentioned. I find that somewhat ironic since that's what the applicants have been telling us for years and now we're getting it from the other side. I'm not too sure to what extent it could be streamlined, so long as we have the conflicting goals with which BCDC is charged. The role of negotiation can never be overemphasized. It's much easier to try and deal with problems or work out solutions before the lawyers get involved. Probably the single strongest constraint on wetland enhancement is that the lawyers are going to get involved eventually, and when that happens, you've probably let it go too far.

Fred Roberts, *Alameda County Mosquito Abatement District, Oakland, CA:*

I think Scott's paper and presentation emphasizes the areas where enabling legislation to create marshes might be lacking. But there is, at least from my point of view, something left out and that has to do with regulatory agencies that are concerned with problems that may be created in the local area because of a wetlands restortaion project. These agencies include the State Health Department, the California Department of Fish and Game, local public works departments, local health departments, flood control agencies, and mosquito control agencies.

I'd like to give you some specifics from the point of view of mosquito control and the legal constraints on wetland restoration. Sections 2200 of the California Health and Safety Code provide the following authority to the Mosquito Abatement Districts: One, we have the right of entry upon lands that produce mosquitos; two, any lands that produce mosquitos, or where we find the larvae in the aquatic habitat, are defined as a public nuisance; and three, we have legal abatement procedures to correct the problem. Finally, the costs of correcting the mosquito problem can be transferred to the landowner or agencies involved.

We are dealing with a very stringent law that was created in 1915 because of malaria problems in the Central Valley of the State. The real push for the law however, came from people in residential areas affected by salt marsh mosquitos. In Alameda County, we're developing residential areas right out to the shorelines while also considering adjacent marsh restoration projects. So we've got a real problem.

Unfortunately, our legal authority applies only after the problem is created. All of the mosquito control agencies in the region do not want to wait until that happens. We have involved ourselves actively in planning processes to prevent mosquito problems. We have developed design recommendations that emphasize physical and biological methods of mosquito control that we hope are compatible with the objectives of wildlife biologists, water quality control specialists, and experts from other disciplines. The preventive recommendations are flexible. We would like to negotiate to avoid conflicts.

We support the spirit of the workshop, to bring together concerned agencies and individuals, to create the best possible ecosystem from everyone's point of view. There are some things that I'd like to recommend which emphasize what Scott said. One is that I think the planning of complex ecosystems, as we're attempting, is extremely difficult. Those of you who have been involved in wetland restorations know that the planning environment can be an absolute tarpit. I think we need to spend some time and research to develop planning mechanisms that will enable us to create complex systems in a way that avoids problems and benefits as many people as possible. I can't emphasize that enough. I also feel first we should deal in the planning process with specific goals and objectives. If environmentalists want to create a wetland habitat, and our agency has to see it to our constituency who may have to endure a higher level of mosquitos, we will need to know the benefits. If it means increased species diversity, fine, explain it fully and tell us how it's going to benefit us. If it means saving endangered species or certain desirable species, fine, define that so if we have a higher level of mosquitos we have some justification.

Finally, wetlands need long term management. We need a legal or administrative mechanism to insure that these systems are managed intensively over the long term.

David D. Smith, *David D. Smith Associates, La Jolla, CA:*

First of all, Scott's paper on constraints and opportunities regarding wetland enhancements is extremely well done. He's examined and probed a lot of different aspects. If I have one negative comment about his paper, it's that he didn't emphasize the constraints aspect, and I'll get a shot at it. Secondly, there is an opportunity for private sector involvement and the two tie together nicely.

The institutional constraints are very real. I've been through it on several projects. We have a very elaborate state, federal, and local regulatory process which tends, unfortunately, to frustrate the opportunities for wetlands restoration and enhancement. It isn't intended to do that, but that's the way it works out. I've published several papers about the institutional constraints, and what has happened in particular projects. Not infrequently the cost goes up to 50 and 80 percent and there is a two to three-year time delay. This is partly a question of attitude. Attitude on behalf of the regulatory agencies in a legal sense: they are straight interpretationists. Put a little bit more impolitely: everybody is very jealous of protecting their own turf and they want a piece of the action as the project goes by. For example, in San Diego, a dredging job worth ten million dollars eventually took $18 million to move half as much material. Not much wetlands restoration was keyed into that, but everybody argued for three years and they drove the cost up. They got some good things out of it. The project was better, but it did take longer and shouldn't have cost that much money, particularly with that little money redirected for wetlands implementation.

I sense a very high level of distrust on both sides. Sometimes on the applicant's; certainly on the agency's. You get in the situation where one agency, which shall be nameless, spent about a month arguing over a quarter of an acre of intertidal wetland which had been placed there by dredge fill two years before. That increases the frustration of the developer or the applicant and he becomes very belligerent, looking for his attorney. You are looking at a divorce situation with everybody hating each other and you are not going to get a reasonable settlement good for both parties. But there is a halfway street, and frankly I do see conflict resolution as being very critical, yet hard to achieve. The private sector views time as money because they are dealing with borrowed money and a very sizable debt service on that block of dollars. As a result, when something is dragged out for an extra year to hassle over something they view as minor and can be solved with just paying more dollars; if they can see a way to cut six months off a project, maybe that's your best selling point.

One of the things the private sector is looking at is whether there is a clearly defined set of regional goals and how might their projects fit into this? If we can arrive at clearly stated goals for a region and subregional units that make some sense, then I think you would get more private sector support. I would offer this: let's not reinvent the wheel. Basically, the concepts of resource management are quite well known and the National Resource Council and Brooking Institution are very sophisticated in dealing with how to manage a resource, to set objectives and goals, to implement policy, and to get it funded. Let's borrow from the procedural knowledge of other disciplines such as mineral resource management.

Steven Kaufmann, *Deputy Attorney General, Los Angeles, CA:*

This is very different than speaking to a court. I must begin by stating that the opinions and views which I may express do not necessarily represent those of the California Attorney General.

I would like to focus on an issue that was not covered by Scott's paper, because I think it is particularly important. Can a governmental body be forced to pay damages in the event its land use regulations go too far and result in an unconstitutional taking of a landowner's private property without compensation?

In a landmark California case, (1979) *Agins vs. City of Tiburon*, our state Supreme Court held that damages in inverse condemnation are not available to a landowner where a zoning ordinance or regulation deprives him of substantially all use of his land. The Court stated that the proper remedy instead is to simply invalidate the offending regulation. The Court in *Agins* was motivated by certain policy considerations. The Court was particularly concerned that the threat of unanticipated financial liability would intimidate governmental bodies and discourage them from implementing strict or innovative planning measures in favor of those which are less stringent, more traditional and fiscally safe.

Since *Agins*, there have been two interesting developments in this area that bear on the validity of the Court's decision in this case. The first suggests that the United States Supreme Court may not, in the future, be willing to go along with the decision of *Agins*. In March 1981, the United States Supreme Court decided the case of *San Diego Gas and Electric vs. The City of San Diego*. That case raised the question of the proper remedy in a taking case. The Court, however, in a five to four decision did not reach the issue, concluding instead that it really didn't have the jurisdiction. What is notable about that case is that the four dissenting justices indicated that they would reach the issue and that they would reject the *Agins* approach of invalidation where a taking has occurred. They would require a governmental body to pay just compensation in the form of what they called "interim damages" —that is damages which arise from the period commencing on the date the regulation first effects the taking, and ending on the date that the entity chooses to rescind or amend this regulation. In addition to these four dissenters, one justice joining with the majority indicated that if the case were properly before the Court, he too would have little difficulty with going along with what was stated in the dissent. Now, as a consequence of the positions expressed by these five justices, there are a number of commentators who believe that if the right case is presented to the High Court, as it is presently constituted, it will hold that interim damages are the appropriate remedy for an unconstitutional taking.

The second development arises from two recent California Appellate Court cases. In December 1981, one division of the California Court of Appeals in Los Angeles, decided the case of *Gilliland vs. County of Los Angeles*. One question raised in this case was whether one could avoid or sidestep *Agins* by simply seeking damages against local government under the Federal Civil Rights Act for violation of constitutional rights. The Court *in dicta*—that is, in language which was not necessarily essential to the ruling—stated that in view of the *Agins* decision, damages would not be available in the case of a claim brought under the Civil Rights Act.

Somewhat surprisingly, less than two weeks later, the very same Appellate Court decided a case brought by the same plaintiffs in the case of *Gilliland vs. The City of Palmdale*. We can call it Gilliland II. This time, the Court turned around and criticized the Supreme Court decision of *Agins*, and it held directly contrary to its decision of *Agins* of two weeks before, that one way of getting around *Agins* is to file a suit for damages under the Federal Civil Rights Act.

Well, this was somewhat of a perplexing problem. Hearings in both cases were sought in the Supreme Court and I am informed that the Supreme Court declined to review either case. To reconcile the conflicting language in those cases and, perhaps, more significantly than that, to protect the vitality of its decision of *Agins* the Court ordered Gilliland II depublished or removed from the official records.

In summary, unless the United States Supreme Court reaches a different conclusion, or the California Supreme Court for some reason changes its mind, *Agins* is still the law in California: namely, a governmental body will not be required to pay damages in the event its land use regulations result in what a Court determines is a taking of property without compensation. The proper solution would be simply to invalidate the regulation.

Audience Participation

WAYNE TYSON (Regrowth Associates): When a landowner is asking for just compensation, I wonder if the view of the Court is that the local agency zoning authority is required in some way, either directly or indirectly, to guarantee a different use of the land. In effect, is a speculator in—let's say, worthless tidal lands—guaranteed by government the right to use that for purposes which one would ordinarily not be able to use tide lands for?

MR. KAUFMANN: That's a complicated question when you deal with tide lands because of the public trust concept. It's very possible that because of the strength of the public trust in certain areas, that the government may have a stronger police power interest and may be able to regulate it differently than if it were just an ordinary piece of property. I attempted to focus here on the remedy because of the interest I feel that the landowner might have in finding out what lies at the end of the rainbow, if there is anything for him, and what the exposure of local government is. Usually these "taking cases" turn on a case by case approach and it's difficult under those circumstances to really give you an answer.

MR. TYSON: Let's say in a wetland situation that is not tide lands, where you have a private owner who has left it lie fallow for a number of years and then, all of a sudden, wants to put a shopping center on that land. The question that has occurred to me many times, as I have seen these cases go through the courts, is whether government does or does not have the responsibility to guarantee the speculator a profit on this investment?

MR. KAUFMANN: Well, I don't think that the law says that the government has to guarantee to a speculator a profit on his investment. You are not entitled, necessarily, to the highest and best use of your land and the government can, through its police power regulation, regulate it. I think these are questions, particularly because of the nature of the remedies involved, that if you are a landowner you should speak to your attorney and if you are an agency or government body, you should speak to your counsel.

WILLIAM DAVOREN (Bay Institute of San Francisco): I think Scott's paper was great, but I noted the slight treatment of San Francisco Bay. I was pleased that Jonathan Smith admitted that BCDC's jurisdiction in the Bay is really minimal. I have to disagree that the political climate isn't right to change. I have been hearing that since 1972, when the sponsors of BCDC stayed out of the Proposition 20 initiative; in 1976 when they stayed out of the Coastal Act. Fortunately, the duck shooters added the Suisun Marsh to BCDC jurisdiction. And in terms of the State Coastal Conservancy, it too was delayed in applying for the Bay for at least two years. This is not a good record. Whenever I hear someone saying this is not the political climate to change the BCDC jurisdiction, I always stand up and say something.

JIM STEWART (Department of Fish and Game): Scott, you brought up an interesting point about interagency conflicts and the Coastal Commission. Several times today, Los Cerritos has been brought up. I'm the biologist who started that whole mess. I got out and mapped the wetlands for the Coastal Commission. Paul Kelly, who you heard earlier, assisted me in doing some resource inventories. As time went on, the biologist who originally involved me in all of this was left standing on the wayside, while directors, deputy directors, former directors, lobbyists, lawyers, consultants, and everybody else grabbed all this information and started wheeling and dealing and coming up with restoration plans. I'd like to point out that many times the people who are originally involved in these identifications have a lot of information but are left out of the actual restoration planning. And I think it's really a shame that high level people within different departments wheel and deal at the top in closed door meetings and really don't reflect the biological needs of the wildlife species.

RICHARD MEWALDT (San Jose State University):

I have two questions for Mr. Roberts. One is somewhat tongue in cheek: is there such a thing as an endangered mosquito? The second is: in mosquito abatement, what is the state of the art? Are you breaking ground or losing ground when it comes to such things as the wetlands that we're talking about today?

MR. ROBERTS: Number one, believe it or not, we had a local species called the winter salt marsh mosquito, which was very nearly extinct at one time, due to the use of DDT. Now, it's back in great numbers—unfortunately or fortunately, depending upon how you look at it.

The state of the art in mosquito control is increasing by leaps and bounds. We are learning about planning; we are learning about ecosystem management. We are not just managing mosquitos any more and we have research going on by the University of California. We are seeing introduction of a pathogenic bacteria called BTI, *Bacillus thuringiensis israelensis* which looks promising. We should be able to provide control under emergency conditions in these wetlands without creating havoc. It will be costly and we'd like to avoid it through the planning stages, but I'd have to say we feel pretty good about the advance of technology in mosquito control.

JIM McGRATH (California Coastal Commission): I'd like to throw a general wet blanket on Scott's comments on offsite restoration and I'd like to give an example to do that.

Up in Eureka, there were a series of wetlands—5,000 to 8,000 square feet—and they really, perhaps, were viable, perhaps even could have been feasibly restored and redesigned, but they really were not a very valuable habitat. Everyone agrees on that. So we administratively ated a little loophole in the Coastal act to allow some offsite restoration. This was not without trepidation and concern by our lawyers. We did it very carefully. We then went out looking for an offsite restoration site and with some very able and very expert help in the local Department of Fish and Game, and the Coastal Conservancy, managed to find not one but actually three sites in Eureka. We found one willing seller, by hook or crook—it was almost a magic thing—to do a wetlands restoration project, which is now completed. It was keyed to one thing: a willing seller; and to another thing: the willingness of the Coastal Conservancy to operate at a loss in order to get a good wetlands restoration project off the ground.

Now, that's in Eureka, the most economically depressed real estate market in the state. If you go to Southern California, you look at a real estate market that is hyperinflated and the expectation of landowners affects the overall question of whether or not you are going to find a willing seller. Then you get into the very delicate legal balance between what is the proper role of the regulatory agency in dealing with property owner's expectations that may set a value on a piece of property. It's a limitation from our perspective to get too involved with negotiations on land. That is not a proper role for an administrative agency and we get into a legal quagmire when we do that.

So I have not seen it work offsite in Southern California. I don't believe, for instance, that anyone could put together the capital to go out and buy a piece of real estate and restore it. The economics just don't seem to make sense.

JENS SORENSEN (Jens Sorensen and Associates): The Public Trust Doctrine was quickly mentioned and I was hoping this panel would address the importance of the Public Trust Doctrine and the State Lands Commission and their red lines map. Can the panel elaborate on that?

MR. KAUFMANN: We have a bit of a void here. Greg Taylor who represents the State Lands Commission and who is absolutely familiar with that issue, asked me to come in his place and I'm not prepared to speak on that issue.

LINDA BREEDEN (California Coastal Commission): I'd just like to speak to the use of red line maps. They are purely for coastal permit jurisdiction. They don't have anything to do with the State Lands Commission jurisdiction, with regard to where the Public Trust land is or is not. There is a provision in the Coastal Act that allows the Coastal Commission to retain original permit jurisdiction over Public Trust lands. The Coastal Commission has never had the resources to map Public Trusts in great detail and it has to be done on a parcel by parcel basis. Red line maps are used to determine Coastal Commission jurisdiction.

STEVEN NELSON (EDAW, Inc.): I'd like to ask Dave Smith if he could provide us with some insight as to how to take some regional goals to a landowner and make him more appreciable of the value of wetlands and change his attitude, so to speak, and have him willing to come to the negotiating table.

MR. SMITH: I left my crystal ball at home, but I'll try. Two things are significant. One, is a regional plan. If he sees what the agencies and the public are trying to do and it's laid out and logical, I think that individual, as a business person, is more likely to look at where he might fit in as opposed to facing an almost unspeakable fear of what these agencies might try to do to him. And one reason the fear is there is another unseen and unspoken ghost: what is a wetland?

We've had a lot of argument about the Coastal Commission wetlands guidelines; there will probably be some litigation involved. My point is not to exacerbate the issues but to pose the question: what is a wetland and does a pond on Oakland Airport that's dry 11 and a half months a year—does that, in fact, meet the Coastal Commission guidelines of a wetland?

Eric Metz and I have had discussions about this. If you are arguing over what is the definition of a wetland and you are getting down to fractions of acres, as in some cases, you develop a climate of potential antagonism that's hard to surmount before you get around to the point of, "Hey, how do you restore this? How do you bring it to a landowner that has property and wants to do something about it?"

Let's be frank. Landowners see the agencies reaching out, trying to put a collar on them. In the case of vernal pools in San Diego, there are probably 10 acres of vernal pools out of thousands of acres of vernal pools. But the Coastal Commission did pick up on vernal pools, or at least they thought about them, though I think they eventually dropped them from the wetlands guidelines. There's mutual distrust; it's real and it's unfortunate and I don't know the answer.

Engineering Wetlands: Circulation, Sedimentation, and Water Quality

R.B. Krone, *Department of Civil Engineering, University of California, Davis*

Introduction

Restoration of diked lands to viable marshes includes the restoration of flooding and draining regimens and importation of fresh sediments that provide conditions for growth of desired plant species. Tidal flows in a marsh are complex, and the methods and information available for computing such flows are approximate. These methods, together with consideration of the properties of marsh soils, sediment transport at estuary margins, and data on the distribution of plant species with elevation are adequate, however, to design dike breaches and conveyances for tidal waters to achieve conditions for the restoration of desired plant species.

Every diked marshland has unique features, and its restoration poses challenges to an engineer. There are several common attributes to such lands, however, that are especially important. Soils of diked areas begin to dessicate as soon as flooding by tidal waters is precluded. These are clay soils, and drying causes them to shrink in volume, as shown by the development of large cracks. This shrinkage causes the land surface to gradually subside, and decreases in elevation by as much as four feet have been observed. Even so, such soils are often saturated and anaerobic a few decimeters below the surface. In the South Bay area of the San Francisco Bay system the lands have subsided further because of the long term effects of groundwater withdrawal. Poland (1972) has noted subsidence up to 8 feet in this area. Diked marshlands have been used for disposal of material dredged from harbors and channels to provide navigable water depths. Such fill elevates the land surface and poses difficulties for flooding by gravity flows. The elevation and contours of the surface of the lands to be reclaimed are primary factors in selecting a feasible reclamation plan.

Lands to be restored to marsh often have other uses. Flood control facilities of adjacent developed low lands often utilize the storage capacity of diked marshlands to provide a low elevation for discharge of storm waters during periods of high tides. The land surface subsidence described above, combined with high dikes, enlarges the volume of such flood basins. The basins drain during subsequent low tides through automatic tide gates. Making flood basins habitable for marsh plants without reducing the volume by sedimentation may require a fluctuating tide at a mean tide level below that of Bay waters outside of the dikes. Otherwise the flood basin can be opened to tidal waters during dry seasons.

Those interested in restoration of diked marshlands often envision use of restored lands for recreation and aesthetic enjoyment. The provision and control of access occasionally impacts on the design of hydraulic facilities. In addition, the many city, county, state, and federal agencies concerned with estuary margins have varying requirements for each site due to their individual perspectives. Two requirements that are relevant here are mosquito control and water quality management.

This paper describes methods that have been used in the San Francisco Bay system to design facilities for flooding and sedimentation on diked marshlands for the purposes of promoting growth of desirable plants and meeting the objectives of concerned agencies.

Natural Marsh Development

A brief description of the genesis of a natural marsh in the San Francisco Bay system is presented to elucidate the processes responsible for this unique land form. Restoration of marshlands to a continuing, viable marsh consists of reinstituting these processes and assuring their effectiveness.

Ocean tides along the Pacific coast are diurnal tides. The amplitudes of the semi-diurnal tides vary from neap to spring to neap during the 28 day lunar period. Sea level at the Golden Gate is rising at 0.6 ft. per century, and the mean tide range there is 4.0 ft. The mean tide range at Alviso in South Bay is 7.5 ft. It is larger than that at the Golden Gate because of resonance in the Bay system. The corresponding ranges between mean higher high and lower low water of this diurnal tide is 5.6 and 9.0 ft., respectively. The tide range is slightly greater in San Pablo Bay than at the Golden Gate, then diminishes with distance from the Carquinez Straits toward Sacramento. The mean tide range at Pittsburg, for example, is 3.4 ft. The local tide at each restoration side is used for design of hydraulic facilities.

About 80 percent of the sediment entering the San Francisco Bay system enters with high winter and spring fresh water flows from Central Valley drainage. These materials deposit initially in the upper Bays, with the largest portion depositing in San Pablo Bay. During late spring and summer months, when the Central Valley warms, daily onshore breezes blow across the shallow bays in the system and generate waves that suspend the new deposits. Tidal flows circulate water throughout the system, including South San Francisco Bay, and distribute the suspended material. Each night when the wind dies the material settles to the bed, and resuspension and circulation resumes the following day. This process continues throughout spring and summer. Sediment provided by local drainage participates in this circulation.

A portion of the circulating suspended material is carried to the ocean with each ebb flow through the Golden Gate. Suspended material also deposits in locations in the system where waves and tidal currents are not sufficient to resuspend it. About half of the annual supply reaches the ocean; the other half lodges on the bed of the system, in the marshes, or is disposed on land (Krone 1979). Bay waters gradually clear during summer and fall.

Marshes form as a result of the combined effects of the tides, rising sea level, sediment transport, and marsh plants. Mud flats develop along the edge of a bay where the limited fetch of the wind prevents growth of waves. Water tolerant plants, such as *Spartina*, establish themselves in a narrow band along the water's edge at about mean tide level and above. Such plants promote the deposition of sediment among themselves by facilitating aggregation of suspended particles and by protecting deposited material from wave action. Drainage of the narrow band of plants as the tide falls erodes proto-slough rivulets. The surface elevation of the marsh rises as suspended material accumulates. As the elevation of the marsh rises, however, the frequency and duration of its inundation by high tides diminish, diminishing the supply of suspended sediment, and the rate of accumulation of sediment slows markedly.

Rising sea level tends to increase the frequency and duration of inundation by tides. The marsh surface rises, therefore, in response to this sea level rise. Marsh plants are continually buried by this process, and the resulting marsh soils contain large amounts of plant residue. Marsh elevations in the Bay system are close to mean high water. The rising marsh surface causes the marsh to extend *landward* at rates that depend on the slope of the land. Evidence for the rising of the marsh includes the vertical walls of rivulets and the layering of marsh soils due to the seasonal supply of sediment.

Flooding and draining of the marsh occurs largely through the channels. During periods of wave action, water also enters along the bayward edge, and marshes are often slightly higher there due to the accumulation of debris and the very high concentration of suspended sediment that occurs under such conditions. As the marsh extends landward, the volume of water that floods the marsh increases. The increased volume of water conveyed by the sloughs erode them to enlarge the channel cross-sections until the currents are barely sufficient to keep them open. One can observe this relation between the amount of marshland flooded and the size of the sloughs in aerial photographs of any large marsh. Erosion even under the roots of plants occurs in sloughs near the bayward edge of a marsh.

Rising sea levels prevents the bayward propagation of marsh plants by increasing the duration of inundation. As both sea level and the marsh surface elevation rise, water depths increase along the bayward edge. Waves generated in the broad expanse of the bay impinge on this edge and continually erode it. A small cliff can be observed along the edges of marshes that are exposed to waves.

A natural marsh is the margin between a retreating shoreline and the landward intruding marsh edge. Its surface is nearly level and varies in elevation only a few tenths of a foot. The sloughs form dendritic patterns that flood the marsh uniformly. Plant species that are sensitive to the periods of inundation appear at different elevations: the relatively large area of flat marsh surface favors such species as *Salicornia*, with small amounts of *Spartina* where inundation or frequent exposure to overtopping waves inhibits other plants.

Marsh Soils

The seasonal supply of sediment, alternating with more rapid growth of plants in summer, causes a layered development of marsh soils. These soils typically contain large amounts of organic matter. Natural marsh soils are anaerobic almost to their surface. The combination of organic matter and anaerobic conditions facilitates reduction of iron and sulfur oxides to form iron sulfide. The soils are therefore black, and biological decomposition of roots and buried plant material is very slow.

The sediment transport processes described above sort the sediments so that the finest particles reach the marshes. The mineral particles in marsh soils are largely clay sized particles with some silt. This clay forms a thixotropic* gel that resists dewatering. Marsh soils and underlying mud around the San Francisco Bay system range in depth to 80 feet. This material provides precarious foundations for structures (Josselyn and Atwater 1982). It appears that marshes subside from their own weight about 0.2 ft. per century. Dikes must be very wide across their base and must be continually raised to compensate subsidence due to slow deformation or compression of the underlying soil caused by the added weight.

*Thixotropy is a property of saturated colloidal materials. When such materials are allowed to stand they become solid (gel.) Mechanical disturbance, however, make them fluid. It appears that the interstitial water becomes bound to clay mineral surfaces as marsh soils gel.

Hydraulic Design

Energy costs eliminate the use of pumps for restoration of tidal marshes. Flooding and drainage must flow by gravity. Land surface elevation relative to tidal datums are important and determine the need for interior channels to provide reasonably uniform flooding and adequate drainage. If plant species that flourish with frequent inundation are desired, ponds and channels must be at sufficiently low elevation to provide these conditions. Hydraulic design includes the selection of number and size of dike breaches, conduits, or tide gates and their location, and the layout and dimensions of interior channels and ponds. Successful restoration requires detailed computation of flows and water surface elevations.

One-dimensional hydraulic representations are suitable. Flows through dike breaches or imbedded conduits can be calculated as a succession of steady flows using conventional minor loss coefficients (Chow 1959). A link-node representation of channel flows (4) using the St. Venant equations (5) is appropriate. In many situations where flow through grasses lead to high friction coefficients the link-node model devolves to a succession of short period steady flows.

An example of a link-node model is shown in Figure 1. Flows are calculated from the differences in elevation between adjacent nodes and the channel dimensions and friction represented by the connecting link. Changes of water surface elevations are then computed from flows. The tide at the bayward end drives the computation.

There are two computational difficulties peculiar to marshlands. Marshes typically have flat or gradually sloping contours outside of the channels, so that as the water surface elevation rises the change in water volume with each increment of water surface elevations varies widely. If a two-dimensional model is used, the boundary of the area represented changes during a tidal cycle and new boundaries would be required after each few time steps of the computation. Such detail is not warranted for marshes. Instead, a power series representation of the change in wetted area with change of water surface elevation can be prepared by planimetering the marsh contours and fitting the area-elevation data to a power series by conventional least squares. A quadratic or cubic series is usually adequate. Similar functions can then be used to compute the change in volume at each node.

The second problem is the stability of the numerical computation that results from the short channels in typical reclamation projects. The usual criteria apply: typical systems require a 15-second time step.

A mean tide is usually a satisfactory input to the model. A spring or maximum tide should be used if dike elevations are important. The model should be exercized over two or more tidal cycles for each configuration to eliminate effects of estimated initial conditions.

Dimensions of conveyances are found by trial. The objective is to make the cross-sections large enough and at low enough elevations to provide flooding of the marsh

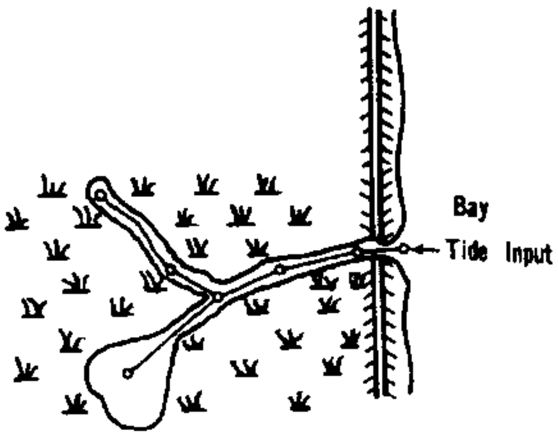


Figure 1: *Link node representation of a tidal slough.*

and to meet the requirements for plants along channel margins. More than adequate cross-sections can increase construction costs.

Sedimentation

The rates of deposition of suspended sediment in new channels and ponds is very sensitive to the suspended sediment concentration. Sediment is suspended by waves in shallow areas of the Bay system adjacent to marshlands, so that the concentration of suspended sediments in waters entering marshes is highly variable, depending on wave action. Concentrations range typically from 50 mg/l at night to more than a gram per liter during windy periods. Long term, reprsentative suspended solids concentration data from the site of entrances are rarely available for input to computations of sedimentation rates, so it is necessary to resort to experience with similar sites.

A useful guide is that for entrances off of mud flats exposed to wind and for quiet, protected interior water depths deeper than mean lower low water, such as the Palo Alto Yacht Harbor, for example, deposition rates are about two ft. per year. As water depths become shallower, deposition rates fall with the portion of time the area is covered until, at mean high water, the deposition rate is negligible.

Spartina flourishes on newly deposited sediment. If it is desired to have *Spartina* margins along channels and around ponds, their bottom depths should be at least 0.5 ft. below the lowest elevation that *Spartina* will grow to provide room for ample substrate. These elevations around the system of northern bays have been determined by Atwater and Hedel (1976). The channels should be wide enough to provide the conveyance calculated for hydraulic requirements. If margins of *Spartina* along the channels are desired, the widths should be increased to allow the extra space required. The channel edges will fill with sediment until the cross-section is reduced to the

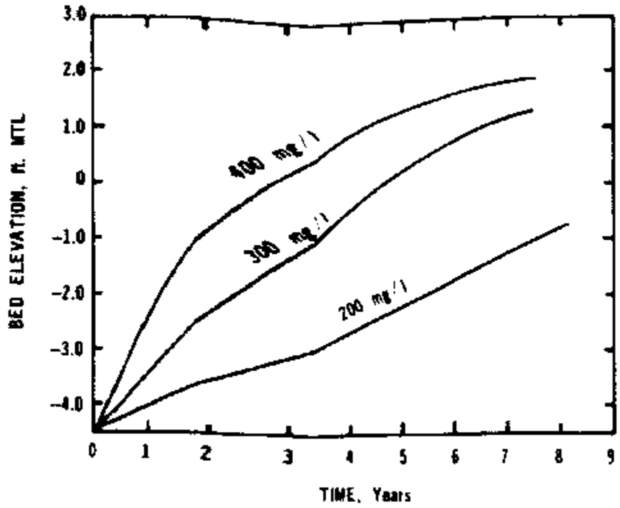


Figure 2: *Computed sedimentation rate for a shallow pond at Palo Alto, CA.*

point where bed shear stresses during ebb are sufficient to erode newly deposited material. This critical shear stress for freshly deposited Bay system sediment is about 4 dynes/sq. cm.

Rates of sedimentation in shallow ponds typically slow as the pond becomes shallower. An example of computed sedimentation rate for tide and sediment conditions at Palo Alto is shown in Figure 2. The plots show that the rate of deposition increases sharply as the suspended solids concentration rises, and the rate decreases as the pond becomes shallower. Two dimensional mathematical models of cohesive sediment transport are available for detailed computations, if such are warranted (Ariathuyai and Krone 1976).

Water Quality

Requirements for water quality in restored marshes include minimizing conditions favorable for mosquito larvae and preventing the development of algae scum. Waste and storm water discharges into reclaimed marshes can also lead to undesirable water quality. This is a separate problem, and is not discussed here.

Minimizing conditions suitable for mosquito larva consists of providing drainage for depressions in the marsh surface. Small shallow ponds with inadequate drainage also cause accumulation of salt to the detriment of plant growth. Ditches from such ponds to a channel also provide means for flooding ponds, which will increase sedimentation rates slightly and assist in their reclamation.

Accumulation of algae in the shallow waters of deeper ponds, that do not drain completely during a tidal cycle, and in dead end channels can be minimized by providing short retention time. The retention times can be calculated by use of a water quality model (Orlob 1972) based on the output of the link-node hydraulic model. The average retention time is calculated by assigning an initial concentration of a conservative solute within the pond or channel area of concern, exercizing the model through a number of tidal cycles, then computing the average retention time from the rate of decrease of concentration. This procedure includes effects of solute leaving the pond and returning on the following flood. Average retention times should be on the order of days for shallow ponds. For deeper ponds, maximum algae concentrations can be estimated for various water turbidities and retention times (Hydroqual 1981).

Excavation in diked marshlands exposes anaerobic soil. The large amount of iron sulfide in these soils is rapidly oxidized when exposed to dissolved oxygen. During the first few weeks of flooding of new channels, large amounts of "rust" may appear. This is harmless material that rapidly returns to the Bay and rejoins sediment transport. The exposed black soil will turn brown or gray, and new deposits will have the healthy appearance of new Bay mud.

Construction

Methods for constructing channels and dikes on marshlands are limited when soils are saturated a few feet below the surface because excavating equipment becomes mired in the soft soil. Under these conditions, options are limited to excavation from existing dikes by dragline or from a floating dredge. Design of the channel arrangement should include this consideration from the beginning. Figure 3 shows a channel excavated along a dike at Muzzi Marsh. The material was laid on the side of the dike and dressed after it had dried.

Drainage of interior depressions can be facilitated by small trenchers that are equipped for marsh operation. Figure 4 shows such a trench constructed by the Marin County Mosquito Abatement District equipment. The trench depth is limited to 1.5 ft. with this equipment. It is fast and relatively inexpensive, however, and is well suited to improvement of surface drainage.

Channel bottoms should be smooth enough to facilitate drainage. Sediment will fill in small depressions. Obstructing loose soil or obstructing ridges should be removed by hand.

Conclusions

A natural marsh is a continually evolving land form. Restoration of diked lands to evolving marshland inludes provision for flooding and draining by gravity flows and development of fresh sediment substrate for plants that require it. Consideration of the needs of other uses of the marsh including recreation, education, and flood water storage, may alter the design of the physical facilities significantly. Limitations of the bearing capacity of the soil for earthmoving equipment can also alter the design of facilities. Hydraulic design consists of application of unsteady flow computations to the peculiar conditions of

Figure 3: *Channel excavated by dragline from a dike at Muzzi marsh, Corte Madera, CA*

Figure 4: ***Drainage trench constructed by Marin-Sonoma Mosquito Abatement District at Muzzi marsh.***

marshlands, with tides, friction, and conveyance dimensions either specified or adjustable. Data on suspended sediment concentrations, needed to compute sedimentation rates, are seldom available, and it is necessary to estimate deposition rates from experiences with other sites. Water quality concerns in reclaimed marshes are drainage of shallow ponds and short retention times in ponds and channel ends that do not drain completely.

Suggestions for Future Research

The methods for providing water circulation and suitable habitat for plants described above are based on present knowledge of optimum hydrologic conditions for restoring marshlands. Improvement of this knowledge can be achieved by monitoring the few restored marshlands over a sufficient number of years and verifying the effectiveness of the restoration facilities.

Better knowledge of suspended sediment concentrations and wave conditions in near-shore waters are needed for prediction of sedimentation rates in the interior of the marsh and for design of protection of the marsh shore. Measurements of wave attenuation by mud flats is especially needed. These data can be obtained by suspended solids and wave height and period recorders located at two sites in a shallow region such as Corte Madera Bay.

Panel Discussion

Phil Williams, *Philip Williams and Associates, San Francisco, CA:*

Well, I'm left, within the context of this workshop format, to deal with the complex hydraulic and hydrologic processes involved in wetland restoration. Several times during this conference, biologists have come up to me and said, "Hey, you hydrologists have got it easy," implying that all we have to do is go out and measure the tidal prism and do our calculations and everything is deterministic. Whereas, in biology there are many variables and unknowns.

It's not exactly that simple. (Showing slide) What I'm showing here is an aerial photo, a U2 photo of Suisun Marsh and Suisun Bay, and there you have the hydrologic and hydraulic processes we have to deal with and they are very complex. Fresh water mixing with salt water, sedimentation, wave action, and tidal mixing. Maybe the difference between biologists and hydraulic engineers is that engineers, I suppose, have to end up making decisions. I think we're able to do this because possibly we're less aware of the consequences of our decisions than biologists are.

We have to start by understanding the natural hydrologic system. As Ray Krone has mentioned, the natural marsh is part of a natural evolving land form. So before starting you have to understand what the natural system is doing and in particular what changes have taken place in the natural system. A good starting point with marsh restoration design is to look at old hydrologic surveys and take note of the changes that have taken place. Also, aerial photographs are useful. Go out at low tide and take a look at what's happening at the adjacent mud flats and slough system.

As well as getting an understanding of the system and what changes have taken place, you ought to then think about what the natural processes are going to do in the future. For instance, levees subsiding, sea level rising and sediment accumulation are important factors. You do this before you actually get involved in looking at the hydraulic design, so you can see the thing in context.

The Bay Conservation and Development Commission will be coming out with a report on restoration techniques for diked wetlands in a few months. (Ed note: released in April, 1982). But I want to mention the six principles that you should consider in the hydrologic-hydraulic design of marsh restoration.

Number one is plan for the long term. When you do a design, think about what it's going to be looking like in 50 years. So you should actually not only have your design plan, but you should also have a drawing or plan of what you expect it to look like. The second thing is something that Felix Smith mentioned, and that is built-in environmental safety factors. And an example of this is taking advantage of sedimentation. If you dig a channel that's too small, it's a darn sight harder for these consolidated sediments to erode than if you dig it too big and allow sediments to accumulate to the equilibrium channel geometry. The third principle is attention to detail. Fourth is flexibility in the design. Fifth is making sure you consider the maintenance of any facility that you're putting in and this particularly applies to tide gates or anything that requires manipulation. And the sixth is that every single design element for a hydraulic design should have a specific rationale. You should understand why you are designing a channel in a particular location and why it's a certain dimension.

Tomas Firle, *San Diego Unified Port District, San Diego, CA:*

The San Diego Unified Port District is a trusteeship formed in 1962 to administer the overall natural resources of San Diego Bay for commerce, navigation, fisheries, and recreation. As a district of a multipurpose nature, we developed a master plan. For recreation, it required wet slips in a small boat basin in the Chula Vista area of South San Diego Bay. Some fill was placed in the '60's, but was only dredged to provide for an entrance channel to a launching ramp.

With the advent of the environmental consciousness in the '60's and subsequent environmental legislation, we found that the solution to dredging for adequate depth in the boat basin was to provide a coupled type of project—namely, to use the dredge spoils of the basin and deposit them nearby to create a salt marsh island instead of taking the spoils out to sea. The material incidentally, was clean Bay mud.

For those of you who are not familiar with San Diego Bay, it's a mini-San Francisco Bay but without major freshwater inflow. It's crescent-shaped, about 20 miles long, about a mile and a half across with a natural channel, but quite shallow in the southern third of it. The small boat basin is located on the east side in the City of Chula Vista. The dredge spoil disposal site is about a mile away from the end of the Bay. What we did was to remove by clam-shell the near-shore sediments and put the material adjacent to the boat basin to dry it out for subsequent use to construct dikes for containment basins. Before we could do any of that, of course, we had to establish the technical and economic feasibility of this approach which also involved the feasibility of obtaining permits for the creation of the marsh project. This was in the middle '70's, and that itself was quite some feat.

The next process was to do the engineering design and to get the money some place: we paid for it out of our own funds, two and a half million dollars. The next step was then to build containment dikes because the Water Quality Control Board would not let us deposit the material directly in the Bay without a containment. We put material on the shore, dried it, and then trucked it over via an existing dike which separated the cold water intake for a power plant from the hot water outlet.

Starting from the existing dike, we built a perimeter dike about a thousand feet across and about three thousand feet long on each side. A very important design criterion was to have species diversity for the marsh, hence elevation differences. So we tried to establish a slope from plus 1 foot on the low end to plus 10 on the other side, before breaching the dike. By slowly moving the discharge pipe along the existing dike, we did establish a slope to the hydraulic dredge spoil. There were problems, however, and for those of you who want to know what went wrong, call me at (714) 291-3900.

To gain local experience with marsh transplanting, we had a program where Dr. Joy Zedler of SDSU and her students removed some of the residual marsh from the boat basin. She concentrated on *Spartina* and indeed, six months later, some of the transplants did take well. However, the primary purpose was to get acquainted with particular techniques appropriate to our area. The basins have not yet been breached and we are going to monitor the salinity and the subsidence as a function of time before inundation.

Terry Bursztynsky, *Association of Bay Area Governments, Berkeley, CA:*

Although restoration of what few marshes are left is important, many saltwater marshes have been lost irrevocably to urbanization. There are also many marshes that are freshwater or estuarine marshes which develop to a large extent from the land. Associated with these marshes remain opportunities to create new freshwater marshes in many areas where these marshes had not existed previously.

Rivers, storm flow, even urban runoff serve essentially the same function as flooding bay water does in a saltwater marsh. That is principally to provide fresh sediment and nutrients to the ecosystem. A sediment mass balance indicates that annually the Bay Area watershed produces about nine million cubic yards of sediment per year. One-third of that washes to the Bay. One-third of it is deposited in streams and channels, much to the detriment of flood control districts; and one-third of it is deposited behind various water storage impoundments. The nutrient content and pollutants that may be present in surface runoff are significantly less than for waste water and can be considered as essential to a healthy ecosystem.

We have found the following in a survey of urban watersheds in the Bay Area: total nitrogen content of 2 to 5 mg/l; total phosporus level of 0.1 to 1 mg/l; suspended solids ranging from 100 to 400 mg/l; and BOD in the range of 20 to 25 mg/l. The heavy metals in the Bay Area watersheds that would be present in runoff to freshwater marshes range from 5 to 500 parts per billion; where generally lead has been measured at a high around 2 parts per million in the Bay Area to the low concentrations of mercury and silver in the range of 5 to 10 parts per billion.

One reason for creating freshwater wetlands in the Bay Area, other than the creation of habitat, or recreational opportunities, is the treatment of urban runoff. Our studies at ABAG have found that large expenditures on publicworks plans would effect maybe 10 to 15 percent of the pollutants from urban runoff. Whereas, in our studies of Palo Alto Marsh and in studies reported nationally, substantially higher pollutant removal can occur through wetlands without harming the wetland.

Specifically, total nitrogen removal has been reported in the range of 35 to 75 percent, principally through the nitrification-denitrification cycle. Total phosphorus has ranged from zero to 90 percent. However, in the long run, phosphorus is not successfully removed in a wetland, unless it's a seepage wetland, because phosphorus eventually reaches an equilibrium between the sediment and overlying water. Suspended solids removal is generally in the 90-plus percent range and toxic and heavy metals are removed 95-plus percent.

Essentially, wetlands, if you were going to construct them for pollution control, are of particular benefit for the removal of sediments, metals, hydrocarbons, and bacterial pollutants, and only to a much lesser extent for nutrient removals. Our studies have shown that, with the exception of extremely heavy pollutant loading from primary level sewage treatment plants, wetlands do not appear to exhibit significant damage from polluted waters. Yet we also recognize that this area has not been rigorously or exhaustively examined. For this reason we believe that polluted waters should be directed to constructed wetlands for treatment. In the unlikely event that there is long term cumulative damage to a wetland system we believe the environment will still have gained an 80 percent or so functioning wetland in comparison to the original condition of no wetland.

We strongly support the development of new wetlands in addition to the restoration of saltwater marshes. We are going to construct a new wetland adjacent to an existing wetland at Fremont in June, 1982. We invite you to review the results.

Thomas Inouye, *State Water Quality Control Board, Sacramento, CA:*

I must issue a disclaimer that I am speaking for myself and not the State Water Resources Control Board nor the Regional Water Quality Control Board.

I find it very heartening to see that engineering design of saltwater restoration has progressed to this point, especially when I compare it with the state of the art in about the mid-'70's when I heard a presentation describing restoration efforts on Pond 3 in San Francisco Bay.

Dr. Krone has mentioned three areas that are very important in marsh restoration. Circulation, sedimentation, and water quality. I'd like to make some comments related to these areas in my area of interest, which is waste water wetlands and in the use of waste water for wildlife habitat enhancement.

In the area of circulation, information we have is relatively scarce. We don't have really the information to the extent that Ray has for saltwater marshes. Often, you see reportings of circulation as inflow and outflow but little or no idea of what is really happening in that pond system or wetland rea. For example, we have seen in an oxidation pond that waters have come in and those same waters, as shown by dye studies, come out in as little as 10 percent of the theoretical detention time. The theoreticaly detention time does not describe what is happening within the pond system. It only describes a net flow velocity. The magnitude, velocity and direction of flow may vary greatly from the net velocity. Flow thus becomes critical for mosquito control and treatment. We need answers about flow, direction, and velocity to be able to model what is happening in these ponds and fine tune our design in the future.

In the area of sedimentation, a waste water pond is probably quite different from what one finds in a natural situation. Ray has mentioned that sediments are contributed by natural flows in San Francisco Bay. In a waste water plant, most of the inorganic sediments settle out in the primary treatment train. Therefore, you get a greater percentage of organic material in the marsh sediments. Consequently, nutrients are not isolated by an inorganic layer of material and can come out of the sediments. This is not a situation one might expect in a natural situation. We need some studies to look at the dynamics of what is happening with those materials.

In the area of water quality, Emy Chan yesterday mentioned that removals have been shown to vary anywhere from 50 to 95 percent. One thing that must be kept in mind when using removal figures is that you must also look at the initial concentration. A removal rate of 50 percent with an input BOD of 10 mg/l is not the same as a 50 percent removal of wastewater with an influent of 240 mg/l BOD. Consequently we must be very careful when examining this information, particularly since removal rates are not necessarily straight line relationships.

We are right now at a point where new, exciting information is being generated so that we can use wetlands in a controlled manner for waste water treatment. This information will be coming out within the next 2 or 3 years.

Audience Participation

GARY SHAWL: Mr. Burztynsky, in a typical Bay Area watershed which group of compounds do you see as the higher priority for removal by the wetlands?

MR. BURSZTYNSKY: In the Bay Area, I would give highest priority to hydrocarbons which are trapped in the wetland for a long period of time to be biologically degraded, and heavy metals which become entrapped in the sediments. There is a net accumulation of heavy metals in the wetland, but hopefully most of them do stay in an unavailable form in the sediments.

JAMES SWANSON (Department of Fish and Game): One of the criteria that we are missing in our haste to create wetlands is the existing values on some of the areas being used to create wetlands, particularly using urban runoff or treated effluent. In quite a few cases, we are destroying existing wetland habitats to create a different type and before we choose the sites, we should carefully examine the existing habitat values on these sites.

DON LOLLOCK (Department of Fish and Game): Ray Krone mentioned that farming is in conflict with some of our historical wetlands and that may be true in terms of what they once were. But we have found that the seasonal values of these farmlands near wetlands are tremendous, especially in terms of migratory waterfowl.

Also, we find that many of the cracked areas that you described are really not cracked during the winter. I was wondering if this four-foot shrinkage picks up seasonally?

DR. KRONE: The reason that the cracks close in winter is that the soils become wet on the surface, but they don't wet very far down, so that the expansion vertically is very small. Another point I'd like to make is that the subsidence, due to shrinkage, ranges up to four feet. If the soil hasn't been dried too long, it may not be as much as four feet. Most of them around South San Francisco Bay are about two feet.

PAGET LEH (National Marine Fisheries Service): I have a question for Dr. Krone. Should we be accounting for swelling of the soils when we are designing the elevations of marshes?

DR. KRONE: No, the shrinkage is due to the fact that the clay particles, which are largely little plates, smaller than a bacterium—desorb their water. They lose the water as they dry and they don't take up water and rearrange themselves back to their original condition. They swell some, as was just pointed out, but they don't swell back to their original elevation. It's an irreversible process and makes it difficult to establish plants that like to have soft, fresh sediments. You have to depend on new sedimentation for good substrate.

DR. STEVE BALLING (University of California, Berkeley): Dr. Krone, I'd like to inject a little biology into our discussion of engineering. And it regards ditching for mosquito control. It's not really necessary to completely drain a pond. Mosquitos lay their eggs on the dry mud bottoms of ponds and depressions in the marsh. If the pond has tidal circulation, if the entrance to the pond is low enough such that it receives tides often enough, mosquitos won't lay their eggs there and won't reproduce. Also, there will be fish coming in and feeding on the mosquitos.

PHYLLIS FABER (California Wetland Coalition): I wanted to comment about the shrinkage of the mud and make a comment that my observations on the Muzzi Property are that the cracks are not adverse to plant establishment and that often the young plants will become established in the cracks.

VIRGINIA RATH (Stanford University): Mr. Williams, I was wondering if you know how long it would take a certain amount of dredge spoil to consolidate and if you, in fact, could dispose of dredge spoil in such a way as to insure a certain final elevation.

DR. WILLIAMS: It depends on how the dredge spoil is being deposited. If a clam shell dredging is being dumped, you'll get a very uneven topography. If it's hydraulic dredging, it is possible to get even deposits, but it takes several years for the hydraulic dredging to really dry out.

MR. FIRLE: If I may add something to that. Obviously, we were very worried about that question and when our design was finished in 1977, we consulted with Mr. Paul Smith from the Corps precisely on that. At that time, he said if you come within two feet, you are doing very well.

Last night, it was interesting that he said they now have enough data that for hydraulic dredging you basically can start designing your elevations for different plants. So those of you starting projects of this nature, I think there is considerably more information now available which get you into a closer range.

DR. MICHAEL JOSSELYN (Tiburon Center for Environmental Studies): Yesterday we heard from some of the planners about erosion from the uplands watershed, causing rapid sedimentation in wetlands. Today, Dr. Krone stated that all marshes reach an equilibrium. Do we have to be concerned about the watershed and what steps ought to be taken in planning marshes with that concern in mind?

DR. WILLIAMS: Well, I think we ought to be clear, that we're dealing with different types of marshes. Around San Francisco Bay, the diked wetlands here have been isolated from a main drainage system, so usually the only watershed that drains into these diked wetlands is very small. Sedimentation from the adjacent watershed is not usually a major factor. The problem when you are opening an area like that to tidal action, is for sediment brought in by the tide.

However, on the coast, you have a different situation. The main sediments come from the uplands watershed. So there, erosion control, the amount of sediments coming down from the watershed, is a critical concern in marsh management.

DR. KRONE: I'd like to add to those comments. Marshes aren't really on equilibrium. They just follow the rising sea level. The supplies of sediments diminish as the marsh level elevates, so that there is not a problem with too much sediment.

On the other hand, in a watershed where there is sediment brought down by a stream, there is no limiting factor. That is, whenever there is a large storm, there is a large supply of sediment and that can be a serious problem. So they are distinctly different problems.

Restoration Techniques, Research, and Monitoring: Vegetation

Joy Zedler, *San Diego State University, San Diego, CA*
Michael Josselyn, *Tiburon Center for Environmental Studies, Tiburon, CA*
Christopher Onuf, *University of California, Santa Barbara, CA*

Introduction

Marsh vegetation provides a transition from aquatic to terrestrial habitats. To many people, wetlands symbolize a highly productive ecosystem which supports abundant wildlife; to others, they are wastelands suitable only for trash dumping or off-road vehicle use. Scientific study of California's marshes has provided further views of what these habitats are like, how they function in the total wetland ecosystem, and how some species might be established in attempts to restore or enhance disturbed habitats.

Our goals in this paper are to summarize the ecological features of wetland vegetation, review the data available on vegetation establishment in California wetlands, outline the ecological considerations which must be made in planning marsh establishment, and suggest research programs which are necessary to improve marsh restoration efforts. The paper discusses emergent and submerged vegetation, with emphasis on salt marshes, for which the most data exist. C. Onuf contributed information on eelgrass habitats; M. Josselyn summarized San Francisco Bay and northern California marshes; and J. Zedler summarized southern California marshes. We thank Fran Demgen, Tom Harvey, and John Oliver for their critical reviews of the manuscript.

Marsh Characteristics

Throughout California, wetland habitats are characterized by variable hydrologic regimes. Tidal marshes are regularly inundated and exposed. All marshes are subject to seasonal freshwater input, occasional heavy flooding, and long periods of exposure and evaporation. These extremes result in some conditions which are highly stressful and other conditions which are beneficial to and responsible for high plant productivity. For example, variable water levels may enhance or reduce plant growth, depending on the timing and duration of standing water/drought. Non-tidal marshes, which are subject to varying rainfall, river flow, and evaporation, may encounter the greatest extremes and the least predictable hydrologic regimes. Intertidal marshes experience regular cycles of inundation and exposure, which facilitate watering and drainage, but plants encounter the additional stresses of salinity. In coastal marshes of southern California, soil hypersalinity is a major stress for vascular plants. In addition, desiccation during periods of rain-free neap tides is stressful to soil algal mats. In central and northern California, hypersaline conditions can occur during summer months, but are restricted to the high marsh.

Soil salinity is a major controlling factor of both composition and productivity of marshes. Where soils are saline to hypersaline, a variety of halophytes, notably pickleweed and cordgrass, occur. Where soils are less saline to fresh, cattails, bulrushes, and sedges dominate and vascular plant productivity is higher. Throughout these marshes, soil algal mats develop when moisture and light permit. With a dense overstory, algal growth is light-limited; with a more open canopy, algal productivity can equal that of the vascular plants (Zedler 1980). Other factors which are known to influence marsh structure and function include microtopography, sediment type, and tidal regime (Table 1).

The basic function of marsh plants is primary productivity, however only a handful of productivity studies have been done in California (reviewed by Macdonald and Winfield unpubl.). Only one study examined algal productivity, and even the studies of vascular plant productivity are difficult to compare because of different measurement techniques. At present, it appears that California's coastal salt marshes are probably as productive as those on the East and Gulf of Mexico coasts, but that algal mats may play a more important role here, especially in hypersaline wetlands (Onuf *et al.* 1978, Winfield 1980, Zedler 1980). Export of organic matter from marshes to tidal creeks has been identified by Winfield (1980), but

Attribute	Southern California 32°-35°N Lat.	Central & Northern California 35°-43°N Lat.	San Francisco Bay 37°50′-38°20′N Lat.
Physiography	Narrow river valleys; small wetlands; tidal creeks & channels but few large embayments	Small wetlands on coast protected by sand dunes; gradual sloping marshes within embayments with variable occurrence of *Spartina foliosa*	Broad plains at MHHW traversed by deep sloughs; gradual slopes colonized by *Spartina foliosa* or precipitous margins undercutting high marsh
Precipitation and period of major surface runoff	10-30″ winter	30-100″ fall-winter-spring	20-40″ winter-spring
Sediment type	Sandy sediments on coast, clays within embayments	Sandy sediments on coast, clays within embayments	Primarily clays
Salinity	Soils generally hypersaline all year	Northern marshes are generally near or below seawater salinity	Seasonally hypersaline
Vegetation dominants			
lower elevations (below MHW)	*Spartina foliosa* (variable occurrence) *Salicornia virginica* *Batis maritima* *Salicornia bigelovii* *Jaumea carnosa* *Suaeda californica* *Frankenia grandifolia* *Triglochin concinnum*	*Spartina foliosa* (variable occurrence) *Salicornia virginica* *Jaumea carnosa* *Frankenia grandifolia*	*Spartina foliosa* *Salicornia europaea* *Scirpus robustus* *Frankenia grandifolia* *Cuscuta salina* *Salicornia virginica* *Cotula coronopifolia* *Cordylanthus mollis*
higher elevations (above MHW)	*Monanthochloe littoralis* *Salicornia subterminalis* *Distichlis spicata*	*Triglochin maritima* *Spergularia marina* *Distichlis spicata* *Limonium californicum* *Atriplex patula ssp. hastata*	*Distichlis spicata* *Atriplex patula ssp. hastata*
Vascular plant productivity and canopy structure	Generally under 1 kg/m²/yr due to hypersaline soils; relatively open canopy	Ranges between 0.5-1.5 kg/m²/yr relatively dense canopy; higher rates in areas of freshwater input.	
Soil algal mat development	Often lush algal mats with very high productivity (at times equalling vascular plant productivity)	Dense macroalgal mats (*Enteromorpha*) in pannes and on mudflats adjacent to marsh; productivity exceeds that of marsh plants	Algal growth restricted to open pannes in marsh; limited growth on mudflats due to high turbidity
Herbivores and detritivores			
molluscs	*Cerithidea californica* *Melampus olivaceus* *Assiminea californica*	*Assiminea californica* *Ovatella myosotis*	*Nassarius obsoleta* *Modiolus demissus* *Macoma balthica*
amphipods	*Orchestoidea spp.*	*Orchestia traskiana* *Corophium spinicorne*	*Ampelisca milleri*
isopods			*Sphaeroma pentadon*
crabs	*Uca crenulata* *Pachygrapsus crassipes* *Hemigrapsus oregonensis*	*Hemigrapsus oregonensis*	*Hemigrapsus oregonensis*
fish	various species of fish use algae and detritus during parts of their life cycles		
Carnivores			
fish in saltmarsh channels	arrow gobies, killifish	arrow gobies, killifish	arrow gobies, killifish
birds frequenting saltmarsh vegetation	Belding's Savannah sparrow; light-footed clapper rail; willet, long-billed curlew, long-billed marsh wren, pintail, marsh hawk, Say's phoebe	willet, long-billed curlew, marbled godwit, great blue heron, snowy egret, common egret, California clapper rail, merlin	Samuel's song sparrow, Alameda song sparrow, California black rail, California clapper rail, salt marsh yellowthroat, great blue heron, great egret, American bittern
Rare and endangered species			
animals	California least tern Light-footed clapper rail Belding's Savannah sparrow American peregrine falcon	American peregrine falcon California least tern California clapper rail	Salt marsh harvest mouse California least tern California clapper rail San Francisco garter snake
plants	*Cordylanthus maritimus ssp. maritimus*	*Cordylanthus maritimus ssp. palustris*	*Cordylanthus maritimus ssp. mollis*

measurements by Onuf *et al.* (1978) did not provide strong support for a net export. Both studies concerned southern California coastal wetlands. Only limited estimates for fresh or brackish marsh productivity are available for California (Atwater *et al.* 1979).

Restoration Objectives

The objectives of wetland enhancement and restoration projects capitalize on high biological productivity. The most commonly stated objective is the preservation and creation of wildlife habitat. Wetlands serve as the major feeding areas to migratory birds along the Pacific flyway (Gertenberg 1979; Recher 1966) and as a nursery to many larval and juvenile fish (California Sea Grant 1981). Shelter is provided by vegetation, both as a direct habitat and in reducing waves, currents, and wind. Several species of birds are directly dependent on marsh vegetation, and habitat destruction has endangered several species (Table 1). A guiding mandate has been to protect and expand wetlands wherever possible (California Resources Agency 1977).

Disturbances (dredging, filling, and altering hydrologic and sedimentation cycles) have substantially modified California's remaining marsh habitats (Table 2), and "restoration" implies the goal of returning these systems to their pre-disturbance condition. Just how these disturbances have changed marshes is almost impossible to assess. We have no pristine marshes left with which to compare more disturbed habitats. Even if we knew what historical marsh conditions were, too additional facts make it impossible to reproduce those conditions. First, since the character of marshes is linked to their respective watersheds, restoration of a marsh would require restoration of the watershed as well—clearly an impractical, if not impossible, requirement. Second, marshes are dynamic communities, constantly changing in response to sedimentation, flooding, rising sea level, and other coastal processes. On a geologic time scale, their existence is short (usually measured in thousands of years), and it would be difficult and arbitrary to recreate a single stage in their development.

For what, then, should a marsh restoration project strive? What should be the "model community?" Clearly a plan for saltmarsh establishment or restoration will have to be based on generalized ecological information on what natural marshes were probably like, developed in conjunction with the management goals of the locality and of the region. An overview of saltmarsh vegetation is given by Macdonald (1977a, b) and Zedler (1982), and several marshes have been described individually by authors cited in Table 5. These papers should provide the starting point for attempts to restore or enhance coastal wetland plant communities. Much less information is available for California's inland marshes.

At times, wetland creation has been promoted to perform tasks which might otherwise be too expensive or difficult to accomplish through other means. Dredge spoil disposal has become increasingly expensive due to reduced availability of disposal sites necessitating high transportation costs and the decontamination or control of polluted sediments. Wetland creation has provided the means to justify shallow aquatic and nearshore disposal and to stabilize the material. Microbiological processes in sediments colonized by marsh plants can lead to more permanent removal of heavy metals than otherwise economically possible (Windom 1977). The completion of the Dredged Material Research Program by the U.S. Army Corps of Engineers has led to several bookshelves of reports (Herner and Co. 1980) and a few dredgespoil wetlands have been created in California.

In addition, marshes have potential for tertiary treatment of sewage effluent. Wetlands are frequently labeled as nutrient traps, though their ability to remove nutrients varies considerably (Valiela *et al.* 1978; Winfield 1980). Most pilot investigations have focused on freshwater wetlands (Sloey *et al.* 1978) and several projects have been completed and are under investigation in California (Bastian and Reed 1979). A freshwater-brackish water marsh has recently been proposed for San Francisco Bay using treated effluent (State Coast. Conserv. 1981). Future large scale marsh creation for sewage treatment will depend heavily on the results of these pilot projects to prove their effectiveness (SFRWQCB 1977).

diking
filling
dredging
introduction of exotic species
reduced tidal flushing
  marsh becomes more saline than normal (in dry years)
  marsh becomes less saline than normal (in wet years)
toxins and fertilizers in runoff
  fertilizers may enhance vegetation
  toxins may stress vegetation
altered runoff patterns
  increasing flood flows
  decreasing flood flows
  constricting period of flooding
  prolonging period of flooding
altered sediment input
  increased sediment loads
  decreased sediment loads

Table 2: *Man-made disturbances to coastal marshes.*

Table 1: *Comparison of saltmarsh characteristics for California wetlands. Coastal wetlands delimited by phytogeographic provinces from MacDonald (1977 a,b). Authorities for scientific names: plants—Munz (1959,68); invertebrates—Smith and Carlton (1975); and common names: birds—Cogswell (1977).*

These three "restoration goals" (restoring what has been degraded, turning dredge spoil deposits into wildlife habitat, and treating sewage effluent) each require the creation of approriate marsh communities. Unfortunately we have insufficient background information on the past extent of specific marsh communities in California. We can provide only general guidance on what marsh types have been most altered and hence deserve greater consideration for restoration. Re-establishment of *Spartina foliosa* in southern California; removal of exotics such as *Avicennia* in Mission Bay marsh; and restoration of the transition zone habitat in San Francisco Bay deserve such attention. We have greater information on the habitat needs of certain wildlife species and such data should be included in restoration plans. The best data base concerns marsh plants which are utilized by water-related birds as food (e.g. widgeon grass, *Ruppia maritima;* alkali bulrush, *Scirpus robustus*) or cover (cordgrass, *Spartina foliosa*, for light-footed clapper rail nesting habitat; pickleweed, *Salicornia virginica*, nesting habitat for the Belding's Savannah sparrow, California clapper rail, and the black rail).

1. Maintain or expand the natural variety of habitats within the wetland. Design for heterogeneous topography and salinity regimes to create brackish and saltmarsh vegetation, pools, salt flats, and transitional areas.
2. Create habitats for endangered plants and animals. Usually involves establishing dominant plants such as cordgrass and pickleweed to support the endangered species within region. May also include creation of isolated upland and transitional plant communities.
3. Use of plant communities to improve water quality. Improve tidal flushing into restricted areas and/or use of treated effluent to increase water flow and effluent quality.
4. Creation of vegetated corridors to facilitate movement of animals between isolated wetlands.
5. Planting of vegetation to reduce shoreline erosion and stabilize dredge spoil.

Table 3: *General goals given for vegetation establishment when enhancing or restoring wetlands.*

Table 3 summarizes a number of general goals which have been given for previous marsh restoration projects. Basically, the overall plan has been to recreate tidally flushed wetlands with more species or a more diverse assemblage of species than currently exists. Since one site will probably not meet all of the restoration objectives for a region, (*i.e.* habitat for various endangered species such as least terns, light-footed and California clapper rails, various salt marsh sparrows, and harvest mice), and wildlife using coastal marshes migrate from one to another and utilize the collective assets of these wetlands, planning for marsh restoration projects should be coordinated within the region, if not within the state. Objectives which cannot be met within one site may be given higher priority for another.

- modification of hydrological regime
  - provide tidal flow
  - alter channels and creeks
  - control freshwater runoff (increase or decrease)
- provide suitable habitat for vegetation establishment
  - establish appropriate elevations with dredge spoils
  - contour topography to proper elevation & slope
  - cage out herbivores
  - stabilize soil
  - irrigate to reduce salinity
- augment natural vegetation establishment with plantings

Table 4: *Techniques used to enhance plant habitats in marshes.*

Marsh Restoration Techniques

The techniques used to meet the above objectives include modifying water circulation, establishing new substrate elevations, and planting (Table 4). Removal of man-made levees and dikes has been the most frequently used method to restore tidal flow; however, channel excavation may also be required to reduce mosquito problems. Discharge of treated sewage effluent to create a diversified wetland habitat is an important alternative to dike breaching, but is subject to water quality and public health constraints. Providing suitable elevations for the establishment of wetland vegetation in restorations has proven to be difficult from an engineering standpoint. Excess disposal of dredge spoils has resulted in numerous "marshes" with elevations above normal tidal influence (Josselyn and Atwater 1982). Excavation of channels and earthmoving within the restoration prior to dike breaching have been used to establish specific elevations and habitats, but can be quite costly compared to other restoration techniques. Planting of marsh vegetation, particularly *Spartina foliosa*, has been tested under a variety of conditions in California and is reviewed in Table 5. On the other hand, natural establishment of marsh vegetation following habitat creation has been followed in several marshes. At a restoration in northern San Francisco Bay, Faber (1980) reported that natural establishment of pickleweed and cordgrass was greatest between the third and fourth year of the restoration. Pickleweed, however, spread far more rapidly than cordgrass and comprised over 95 percent of the biomass by the fourth year. In

Topic	General	Southern Cal	Central and Northern Cal	San Francisco Bay
1. Plant community description for selection of appropriate species	Macdonald (1977a,b) Cal Fish and Game (1970-78) Harvey *et al.* (1976)	Zedler (1982) Vogl (1966) Macdonald (1967) Purer (1942) Zedler (1977) Massey & Zembal (1979) Warme (1969)	MacGinitie (1935) Proctor *et al.* (1980) Shapiro and Assoc. (1979)	Mahall and Park (1976) Atwater and Hedel (1976) Atwater *et al.* (1979) Hinde (1954) Mall (1969)
2. Conceptual planning and methods of site preparation	Garbisch (1977) Woodhouse (1979) Envir. Lab. (1978) Johnson and McGuinness (1975)	Smith *et al.* (1975) Firle and Smith (1977) Sorensen, unpubl.	Terrascan (1979) Camp, Dresser, and McKee, and Madrone Assoc. (1980)	Harvey *et al.* (1982)
3. Endangered species habitat needs	Cal Fish and Game (1974)	Massey (1979) Fox and Knudsen (1981) Dunn (1981) Massey and Zembal (1979) Zembal and Massey (1981)		Shellhammer and Harvey, unpubl. Jones and Stokes (1979)
4. Wastewater treatment projects	Tchobanoglous and Culp (1980) Demgen (1981)	Gearheart and Finney (1981)		Demgen (1979) Cederquist and Roche (1979)
5. Vegetation establishment including propagule selection, storage and handling, planting techniques, and natural recolonization	Envir. Lab. (1978) Maguire and Heuterman (1978) Kadlec and Wentz (1974)	Zedler (1980, 1981a, 1981b) Zedler *et al.* (1979) Nordby *et al.* (1980)	Oliver and Reilly (1981)	Newcombe and Pride (1976) Harvey *et al.* (1982) Niesen and Josselyn (1981) Mason (1980)
6. Substrate requirements of vegetation	Garbisch (1977) Envir. Lab. (1978)			Harvey *et al.* (1982)
7. Costs and maintenance requirements	Envir. Lab. (1978)		Terrascan (1979) Camp, Dresser, and McKee, and Madrone Assoc. (1980)	US Army Corps (1976) Josselyn and Atwater (1982)

Table 5: *Recent literature on vegetation establishment for California coastal and estuarine wetland restorations.*

southern San Francisco Bay sparse stands of pickleweed were observed in the Hayward restoration within the first year, but even after two years, no cordgrass had invaded despite extensive areas of suitable elevation (Josselyn and Perez 1981). Relatively high soil salinities may inhibit seed germination at this site which was formerly a salt evaporator. Soil salinity plays an important role in regulating rates of natural plant establishment and vegetative spread in southern California as well (Zedler 1981b). Regardless of the techniques used, the examples are too few, and their period of existence too short to provide an instructional guide for marsh restoration in California. At present, restoration must be viewed as experimental.

However, in the process of performing these studies, a number of limiting factors have been revealed (Table 6) and future projects should focus on overcoming these obstacles. The problems range from environmental stresses (wave force, subsidence, hypersalinity) to biological restraints (competition with other species, herbivory).

Submerged Seagrasses

Recent reviews of the vast literature of seagrass ecosystems (Phillips and McRoy 1980, McRoy and Helfferich 1977, Thayer *et al.* 1975) summarize the characteristics of eelgrass beds and list the values that argue for their incorporation in coastal wetland restoration projects. Some of them are as follows:

1. Primary production is very high. Based on the difference between maximum and minimum standing crops sampled during a year, eelgrass productivity in South and North Humboldt Bay was 590 and

Attribute	Southern California	Northern California Central California	San Francisco Bay
Source of vegetation propagules	limited area of marshes; most is protected as endangered species habitat	isolated wetlands; sources limited	sources usually readily available throughout Bay; seed sources limited for cordgrass
Seed production & seedling production	seeds are abundant for cordgrass & pickleweed, but germination rates are low; collection of seeds disturb marsh vegetation which is susceptible to trampling	cordgrass not found at all locations; pickleweed abundant	cordgrass seeds available in specific areas, collections should take place in Oct.; pickleweed seeds readily available
	natural reproduction predominantly vegetative		natural reproduction by seed in fresher portion of estuary; otherwise vegetative
Site characteristics	bare soils are often extremely hypersaline (over 100 ppt) due to evaporation	watershed disrupted by upstream activities causing increased sedimentation, pollution	tidal flow restricted by dikes; subsidence of land due to groundwater withdrawal and soil erosion requires fill or tidal gate control to support wetland vegetation
	tidal flushing is often reduced by sand bars	some areas restricted by dikes	
	wave force is problem on exposed shores		salt ponds create hypersaline soils which require leaching
Animal pests	pose a major problem, especially in areas near urban centers; ground squirrels and some birds seem to be the major problem		introduced invertebrate: *Sphaeroma* undercuts pickleweed marsh; need erosional control while cordgrass becoming established
Competition with more opportunistic species	pickleweed is the best natural invader, but cordgrass is often preferred for marsh enhancement because it supports light-footed clapper rails; pickleweed reduces survival, vegetative propagation of cordgrass	*Jaumea* invades rapidly, but is ultimately replaced by pickleweed	potential for escaped exotics to colonize upland areas and islands; potential for exotic species of cordgrass to invade native habitat
			cattails, tules, water hyacinth may take over freshwater marshes

Table 6: *Factors limiting the success of vegetation establishment in California wetland restorations.*

240 g dry wt/m²/yr respectively (Harding and Butler 1979).

2. Natural systems may filter sewage effluent. "In at least one recorded instance in Australia the efficacy of a *Zostera* meadow to filter raw sewage was established when the removal of the plants led to the poisoning of valuable benthos" (Phillips and McRoy 1980, p.300).

3. Coastal stabilization can be brought about by eelgrass. Drastic changes in coastal topography were observed in England and Denmark in the aftermath of the eelgrass "wasting disease" in the 1930's. Sandy beaches landward from eelgrass beds were replaced by cobble shores and bare muds (McRoy and Helfferich 1977, pp. 23-28).

4. The density and biomass of animals are much higher within and in the vicinity of eelgrass beds than away from the beds in the same general area and in the same depths (Orth 1977, Thayer *et al.* 1975). "We know that there are many reasons for the presence of animals in seagrass beds: the environment is more stable, since seagrasses hold sediments, baffle currents, provide shade and concomitant temperature modification. Also, there is as much as 20 times more surface area for small sessile flora and fauna as compared to unvegetated area. There are more hiding places for prey and thus more prey for predators to eat" (Phillips and McRoy 1980, p.322).

5. Ecological efficiency (ratio of the production of consumers to the amount that they consume) is high.

Habitat Factors	Vegetative Growth	Comments
Temperature		
Range	0-40°C	Probably not a constraint, since native populations exist along the whole coast of the state.
Optimum	10-20°	
Salinity		
Range	Freshwater—42 o/oo	
Optimum	10-30 o/oo	
Depth-Light		
Range	1.8 meters above MLLW to 30 meters deep	Light attenuation because of turbidity is likely to raise the lower limit considerably. Backman and Barilotti (1976) showed that light intensity determined the density and biomass of eelgrass at Agua Hedionda. Under ambient conditions, the lower limit was −2.5 to −3.0 (MLLW). In San Diego Bay a transplant at −1.5 to −1.8 m (MLLW) failed (Goforth and Peeling 1980).
Optimum	MLLW—6.6 m below MLLW (11 m at high tide)	
Substrate		
Range	Pure firm sand to pure soft mud	Apparently a reducing environment for the roots and an oxidizing environment for the leaves is necessary (Phillips 1974, pp. 255-258). Onuf's observations at Mugu Lagoon suggest that newly deposited unconsolidated muds are unsuitable. Transplants in coarser sediments performed better in San Diego Bay (Goforth and Peeling 1980).
pH	7.3-9.0	
Water Motion		
Range	Waves to stagnant water	May limit the development of eelgrass beds along the downwind side of shallow embayments with fine textured bottoms
Optimum	Little wave action. Gentle currents to 3.5 knots	

Table 7: *Environmental characteristics under which eelgrass grows (adapted from Phillips 1974, p. 260) with comments about application to coastal wetland restorations in California.*

"Our comparatively high efficiencies suggest that this eelgrass bed is an efficient system that provides resident fish with superior shelter, food, and protection . . . These fishes therefore would spend proportionately less of their assimilated energy coping with environmental extremes, searching for food, and escaping from predators, and hence may use a great proportion of consumed energy for growth and production" (Thayer *et al.* 1975).

6. At least for fishes, eelgrass is the most distinctive habitat of our coastal wetlands. The only clear habitat specialists encountered in five years of sampling at Mugu Lagoon are bay pipefish, *Syngnathus petorhynchus*, and shiner surfperch, *Cymatogaster aggregatus*, both only caught in eelgrass areas (Onuf and Quammen unpubl.). The eelgrass station yielded by far the biggest catches and largest number of species, until the eelgrass was destroyed by storm-caused sedimentation in 1978.

Where feasible, there are good reasons for incorporating eelgrass beds into future restoration projects. Unfortunately, information on how to accomplish this objective is inadequate. The published tolerance ranges of eelgrass for a variety of presumably important environmental factors provide a point of departure (Table 7); however, it is important to note that *Zostera marina* almost certainly is composed of different geographic stocks, with narrower ranges than indicated for the species (McRoy and Helfferich 1977, pp. 13-20, Phillips and McRoy 190, pp. 51-52).

Seagrass Restoration

Techniques for transplanting and culturing seagrasses are presented in Phillips and McRoy (1980) pp. 41-56 and 57-68, respectively. "Vegetative seagrass material gives an instant seagrass meadow when planted by sods, but sods are difficult to ship over large distances in the masses needed. Seeds are easy to transport in great masses, but the number of fruits and seeds produced per year is unpredictable and variable, seed germination rates can be low and unpredictable, many seeds appear to be lost in the field, and seedling survival appears to be low."

Planning the Nature of the Restoration

Map of existing site	topography
	vegetation mapped to indicate pockets of desirable species
	soil properties; e.g. salinities, pH, heavy metals, pollutants soil structure as required by site location
Conceptual plan	attempt to resolve the local and regional restoration goals in conjunction with restrictions of the site
	determination of desired vegetation habitat size, based on wildlife need and vector control considerations. (Lack of information on a number of important research questions limits the recommendations that can be made at this time, research needs are on Table 10)
	ecosystem level management is preferred over single species management
	plan should built on existing assets of the site
Development of site plan	engineering sketches for establishing appropriate elevations, slopes, channels, and dike breeches
	consideration of local sedimentation problems and provision for protection of newly establishing plants from strong wave action

Undertaking Plant Establishment Following Site Preparation

Map of Site	soil salinities, other soil properties appropriate to the site, i.e. pH; heavy metals, pollutants) hydrological features (e.g. wave force), and elevation 20 cm contours, if possible
Establishment test plantings	an intermediate area where on-site propagation of plants can occur. This is needed for large restoration sites or wherever propagules are limited in number. It should be located in the most favorable environment for rapid reproduction.
Detailed description of planting scheme	elevations determined for each species by reference to best information for the region
	timing specified: transplantation to occur during most favorable time of year (following rainfall but after flooding)
	protection devices provided against herbivores and wave force
	watering, if necessary
	type of materials to be planted (seed, sprig, core)
Monitoring program	details considered in Table 9
Plans for informaton dissemination	deposit findings in a central library

Table 8: *Recommended procedure for the establishment of vegetation in a wetland restoration plan.*

"Until methods are developed to initiate flowering in culture, with subsequent production of fruits and seeds, I recommend the plug" (plants with sediment intact placed in hole in substrate, 300 cm^2 x 15 cm deep) "as the single most important method of transplantation for mass-scale use... It would not be difficult to transport plugs in plastic sleeves or to hold them in such sleeves for later transplantation. It would not take as many plugs to 'patch' in a site as would sods." (Phillips and McRoy 1980, p.54).

Literature on the feasibility of eelgrass transplantation has been evaluated (Boone and Hoeppel 1976); field tests of techniques have been performed (Robilliard and Porter 1976); and two major transplants have been carried out and monitored in San Diego Bay (Goforth and Peeling 1980). Plugs of 410 cm^2 in fiber pots were set out at intervals of 0.6 m in rows that were 2 m apart. The intertidal transplant was successful; however, only the transplants on hummocks survived subtidally (-1.5 to -1.8 m MLLW) with the red alga *Gracilaria* dominating most of the site, presumably because of low light.

Restoration Plan and Project Monitoring

Once the goals of the restoration have been identified, the conditions of the site have been determined, and the constraints of materials and modifications are known, a specific implementation plan can be developed (Table 8). Because wetland restoration is still in its infancy, it is important that each project be recognized as an experiment and that the plan include monitoring of the site before and after implementation in order to assess the success of the effort. This type of interaction between planning and evaluation of results has been called "adaptive management" by Walters and Hilborn (1978) of the University of British Columbia, and interaction is essential to move marsh restoration from the experimental phase to the desired "state-of-the-art". Specifics for planting schedules and methods have been developed for many Atlantic and Gulf coast marsh plants (Environmental Laboratory 1978). Most of the information available for West Coast species has been taken from plantings on dredge spoils in San Francisco Bay (Newcombe and Pride 1976). Unfortunately, long term study of these plantings has not been conducted on a consistent basis (Hanley Smith pers. comm.). As a result, planting techniques for West Coast species are often based on unpublished observations of consultants or scientists. Zedler (in prep.) and Josselyn (in prep.) are developing guidebooks for vegetation establishment for Southern California and San Francisco Bay, respectively, based on relatively long-term research.

An important consideration in any marsh restoration plan is knowledge of both elevations and soil characteristics at the site. Although we often know the tolerances of the species desired, the diverse methods and terminologies used to measure these environmental parameters lead to confusion among planners and scientists. For example, the tidal datum used as a reference level differs among civil engineers, scientists, and geologists. The National Geodetic Vertical Datum of 1929 (NGVD) has been suggested as the common reference datum for wetland scientists (H.T. Harvey these proceedings). Likewise, similar agreement is needed on methodologies and units to describe wetland soil characteristics (K. Cunio these proceedings). Future workshops should consider and adopt a consistent set of measurements to describe West Coast wetland environments.

Monitoring efforts must be sufficient to determine what caused the successes or failures of project components. "Failures" to achieve project objectives may then be mitigated by improved knowledge of how to succeed in future attempts. Were problems caused by site characteristics or planting techniques? Which characteristics or techniques were to blame? Setting up the project in an experimental framework would help to assess these causes. Preliminary small scale experiments could reduce implementation costs. For example, if soil salinities are very high, the plantings could be watered in some locations and not in others. Improved establishment where watered would indicate that drier, saltier soils restricted plant growth and that irrigation is necessary on the site.

A minimal monitoring plan is proposed in Table 9. Aerial photos can be most useful in following the establishment of vegetation and the spread of plantings. Aerial photos can also be used to map developing channels and areas of sedimentation or erosion. Both black and white and infrared photos should be taken. In most cases, planting should be delayed from six to twelve months so that

1. aerial photos

   immediately following construction; yearly intervals afterwards done in spring.

2. establishment of permanent transects: sample at various elevations and flow regimes.

   a. soil survey at surface and 15 cm depth; salinity, pH, particle size, heavy metal/pollutants (as required by site)

   b. plant cover analyses and species composition; every six months (late summer; early spring) until marsh establishment is proceeding as expected

   c. sedimentation/erosion studies to assess long-term stability of site and possible corrective management practices

3. planting program; initiate six months to one year following construction activity.

   a. establish test plots at various elevations using natural plant volunteers as indication of planting sites

   b. evaluate growth of plants using expansion in diameter of clumps or number of stems

   c. develop complete planting program after initial results

   d. comparison with unplanted sites undergoing natural colonization

Table 9: *Recommendations for monitoring the establishment of vegetation in wetland restorations in California.*

sediments can reach equilibrium with the overlying water. This settling period can also be used to monitor naturally establishing plants and to assess their survival and growth. If planting is deemed necessary, several test plots should be established to develop recommendations for the complete planting program. Of course, the monitoring program should be expanded at restorations involving new site preparation techniques or in areas where no previous restorations have been completed or investigated.

Costs for monitoring should be included in the overall project and responsibility for evaluating the results of monitoring should be clearly identified. There is definitely a role for scientists in the process. Evaluation of management experiments could well be part of an ongoing scientific study of wetland functioning, although the monitoring alone would not likely be fundable by a research granting agency. Managers should seek the cooperation of researchers in all phases of the projects, from planning to final evaluation, to determine what aspects are compatible with existing research projects. Habitat enhancement needs of the U.S. Navy, U.S. Fish and Wildlife Service and the Unified Port of San Diego have been partially met through cooperation with researchers funded by the California Sea Grant Program (Zedler).

The results of the monitoring must be readily available to be useful to future restoration projects. A central depository with funds to keep and disseminate these reports is needed. We suggest that the two estuarine sanctuaries in California, Elkhorn Slough and Tijuana Estuary, be funded to establish this service.

Quoting from Walters and Hilborn (1978, p. 183):

When we can . . . learn to treat . . . the whole management process as fundamentally experimental activities requiring active planning and judgment, then we may begin to talk about a science of ecological management.

Suggestions for Future Research

Whenever possible, research should be undertaken to address questions beyond simple environmental monitoring (Table 10). Resolving some of these questions will improve the wildlife habitats created; answers to others are necessary to protect public health and meet state water quality standards. Of course, it will be difficult to set precise standards on the functioning of a wetland given its inherent variability and the degree of compromise needed to meet the demands of modern society. In addition, restoration and enhancement efforts should not take the single-species-management approach; instead we must manage for the entire ecosystem. Inter-relationships among wetland species are numerous, and altering one species will have impacts on many others. Research is our only tool to establish these relationships and to determine the optimal design and management procedures to protect wildlife and provide the public with the environmental quality they desire.

Table 10: *Research recommendations toward improving the design of wetland restorations in California*

Determination of optimal habitat size and configuration (e.g. pickleweed and cordgrass marsh) for wildlife utilization. Patch size necessary to attract and support native animal populations; necessary buffer zone width and type; sensitivity of various animal species to disturbance; desired location of developments adjacent to wetlands; and types of structures and activities tolerated by wetland animals.

Requirements of marsh vegetation for tidal flushing and preferred balance of fresh and salt water influence. For wetlands which must be closed to tidal influence during certain periods (e.g. flooding of neaby streams), how long can tidal circulation be absent and not jeopardize the marsh? For marshes where freshwater flooding can be regulated, or where wastewater input can be added, what is the maximum allowable freshwater input for maintenance of brackish or saline marshes?

Impacts of nutrients on marshes and the use of treated wastewater to create fresh/brackish marsh areas. What are the desirable levels of nutrients in coastal marshes? How effective are marshes in removing nutrients from sewage effluent?

Comparisons between natural rates of vegetation colonization with the establishment of vegetation following artificial transplantation. How much faster do marshes establish with planting? Which species are in greatest need of transplantation because of biological limitations?

Relationship between vegetation density and mosquito vector control. What is the optimal density of vegetation (usable by wildlife such as rails) that can still allow vector control, and how can it be maintained?

Panel Discussion

John Oliver, *Moss Landing, CA:*

My first comment is that the problems involving marsh restoration are primarily social and political and, therefore, economic. These issues were addressed in yesterday's sessions. The biological and physical problems are not difficult to overcome, but are intriguing.

I also want to emphasize the often neglected reality that nature is variable. We have management schemes and legal systems that are commonly invariant. Thus, while nature and our understanding of nature vary, our management and regulatory efforts are commonly inflexible and static. This is a tricky situation. I hope that realistic and useful management programs can be founded on these simple realities.

Another important point is that all marsh restoration or development projects are relatively large-scale experiments. Realizing the experimental nature of these activities will help in at least two ways. First, we can take advantage of the experimental setting to test relevant ideas and further our understanding of wetland communities, either for relatively applied or less applied goals. Second, a clear understanding of the experimental nature of these activities will help all parties to maintain an open mind about the entire process.

I want to make a few comments about monitoring. There is no distinct dichotomy between a monitoring activity and research, at least in most ecological monitoring efforts. Monitoring programs are generally used in a more applied research activity. Very little monitoring of biological phenomena is useful for short-term surveillance or "bell ringing". Bacteria counts around a waste outfall may be the only exception, for better or worse. We carry on remarkable monitoring programs that are advertised as regulatory efforts and not research. Commonly they are actually concerned with large-scale or long-term changes which are very relevant applied science problems. But just as commonly the relationship between the monitoring activities and the applied research problem has not been clearly formulated or even recognized. In fact, when one attempts to match relevant questions to the monitoring activities, we often find that the question already has a good answer, that the activity is inappropriate to the question of concern, or that the question cannot be answered. I am convinced that most of the surveillance monitoring of biological events is useless and that a clear focus on applied research questions is essential to any monitoring activity.

H. Thomas Harvey, *San Jose State University, San Jose, CA:*

I do feel that we need monitoring to find out what we'd hoped for has to some degree been successful. I think that's been a part that hasn't been either reported or encouraged to the degree that it should have been. But I would like to get to some nitty-gritties and inasmuch as there is a captive audience, I will get on my soap box that some of you have endured before

First, we should start using NGVD for the Land Elevation Datum—and how it relates properly to tidal elevations, which are entirely something else. The current useage of various tidal elevations as reference for marsh development has resulted in considerable confusion among engineers, scientists, and agency people. Second, I think I should mention that if there is anything that's lacking in the paper, it's some specifics. Admittedly, there is tremendous variety throughout California.

I tend to side with some of you who believe that if you set up the physical conditions you should step back and get out of the way. Nature in the long run is going to decide which vegetation will survive under the circumstances that are present. I realize we can manipulate, to a certain degree, and we probably should, if we want certain things. But I think one of the main ingredients in marsh restoration is patience. Those of us who have been around awhile have had to learn that you can't plan it all. We have to just take what comes sometimes.

I would close only by suggesting that we recognize that humankind is probably more of a rationalizing organism than a rational organism. We have our gut reactions, opinions, and desires. We, then, marshal all the facts and evidence that will support those points of view. We are very good at that. So take that to mind, as well as, perhaps, to heart.

Fran Demgen, *Demgen Aquatic Biology, Vallejo, CA:*

I want to make one minor correction. If you look at the data you might get the wrong impression that the Mt. View Sanitary District enhancement was created to treat waste water. It's purpose is wildlife habitat creation

The paper is very good in providing an overview. I think that what is missing are more specific facts, like the one given that one sprig in three years could develop an eight meter wide patch of grass. I think that even the range between complete failure and an eight-meter patch in three years is valuable to the people trying to do things. And I think that this paper would be a very valuable place to have specific data so that the people designing and doing projects have something to use as guidelines. Even if it's bad news, it's better than no news at all. There is a need to provide site-specific information, so that planners can interpolate and use the data in making their own conclusions. Many people are afraid of trying to tell other people what they've done, or applying their conclusions to other things, but I think this would be an important addition.

It seems like—and I didn't realize it originally—the major thrust here has been salt marshes and hopefully there will be more people that will also allude to freshwater systems, particularly those using waste water. It's very encouraging and heartening for me that so many other people have mentioned waste water wetlands. As few as about six years ago, you'd bring up waste water wetlands and people would look at you askance and wonder what on earth you were talking about. The two things are not incompatible and there are quite a few projects in existence now and others are planned.

One will be the big East Bay Regional Park-East Bay Dischargers Project that will be adjacent to our field trip site tomorrow. It's approximately 162 acres and will be a good opportunity to gain new information, processes that happen in these waste water marshes. Another project that should be happening this year is in Eureka, a 60-acre site. The City of Eureka will be restoring wetlands to the Elk River, including a certain amount of marsh using waste water. It will also include some that's returned to tidal action and some freshwater areas. There are, in addition, some seasonal ponds on that site making it a multi-habitat site. If everybody crosses their fingers in unison in this room, we may be able to get some water for the New Chicago Marsh down in the South Bay. We are working on possibilities of getting close to ten million gallons a day of treated effluent from San Jose, which is adjacent to the San Francisco Bay Wildlife Refuge and the water needy New Chicago Marsh.

Audience Participation

KATHERINE CUNEO (Madrone Associates): I would like to make a suggestion. At the same time we form the depository of information, we should have a committee to work on the standardization of measurements used in published papers. Considering salinity, we find it is reported as molarity, as milliosmoles, as osmolarity in terms of pressure bars, and atmospheric pressure. We should have a method of transposing these to one standardized measure that planners could use. I suggest that on this committee we have a soils scientist, a plant physiologist, a wildlife biologist, a hydrologist, and a planner.

DR. ZEDLER: Good suggestion.

WAYNE TYSON (Regrowth Associates): What research is available on the reproductive biology of marshland plant species?

DR. HARVEY: It's controversial and scattered. Some information is available from the Army Corps of Engineers.

RICHARD WARNER (Field Study Center in Davis): Just a general comment to the panel at large and I mean this in a kindly, if critical way. I would suggest that we have failed rather thoroughly in the second half of our charge for this panel and that is to address the needs and opportunities for monitoring. The use of monitoring as separate and dichotomous from research in our American frame of reference is looked on with some humor by European scientists. They look at us in this context as a bunch of dilettantes jumping in and doing brilliant research for a couple of years and then rushing off to do equally brilliant research elsewhere with very little follow-through and exploitation of the cumulative empirical data base from our studies. And rarely, if ever, are we using the continued frame of reference of a growing data base to modify and even learn from our research efforts. Maybe the panel may have some comments about something that is germinating at the present time, but I presently see no plan for the required institutionalization of this data base.

DR. ZEDLER: The National Science Foundation has just begun a long-term ecological research program. We've been nagging at Sea Grant to do something similar for a number of years. But I can't say that anything is germinating yet. A lot of seeds have been sewn.

DR. ONUF: I wrote a proposal to Sea Grant that was essentially aimed at this area you have pointed out. Maybe the institutions aren't ready for it yet, or the way I wrote it didn't get it across properly, but I met with a resounding lack of interest.

I think restoration is often regarded as a sell out to development. There are examples of failed restoration projects, where the trade-offs that were made can be shown, after the fact to have not been in the best interest of the natural systems concerned. There is, I think, a legitimate concern that restoration, as a mitigation, can be abused in the management system. And so there is this legitimate resistance to really making it a much more viable activity, until it can be shown to do the job.

The problem is we don't have the luxury in California of just leaving things alone and preserving what we have got. Because of what goes on in watersheds, wetlands will disappear if they are left alone. We have to get in and be heavy-handed. I'm trying, and obviously others of us are, too, but I think there is enough sales resistance that it's going to be a little while longer before we are going to get some systematic system of evaluation.

VIRGINIA RATH (Stanford University): We have seen yesterday that there is often an absence of clear goals in what we are trying to accomplish by these restorations. And it seems that often we move towards assuming that the maximum species diversity is what should be sought for in these restorations.

Dr. Zedler mentioned that pickleweed is often a superior competitor, even to the detriment of other species such as *Spartina* or other succulents. Often times, we have *Salcornia* marshes coming in even though we have planted *Spartina* as in the Faber Tract in San Francisco Bay.

Why all the push to plant *Spartina* here on the west coast when *Spartina* is often just fringing vegetation and the bulk of the marshes contain *Salcornia*. Is this another example of trying to get East Coast technology and East Coast dogma and plant it on the West Coast?

DR. HARVEY: The reason I was planting cordgrass at Faber Tract was to find out what the tidal elevation was. I wasn't trying to emulate East Coast marshes. I didn't know about them in '69 and '70. Anza Pacific is planted at about two feet above mean low or low water in an attempt to see what transplant procedures, seeds, seedlings, dwarf versus robust would survive under that end of the range.

MS. RATH: It's obvious many experimental pieces of information could come from these plantings. However, it seems that we persist in trying to plant *Spartina* marshes.

DR. HARVEY: That's why I made the comment about patience sometimes as your best approach. But cordgrass can and probably should be planted in certain places where you want to establish vegetation at the lower elevational range rapidly. Faber Tract is one of the longest duration. Cordgrass has spread throughout that 95 acres, although it's predominantly pickleweed, I agree.

DR. JOSSELYN: In Southern California, the reason there's been emphasis on cordgrass is that it is the habitat for the light-footed clapper rail and also the habitat that has been destroyed most frequently through development activity.

In San Francisco Bay, I agree that the pickleweed marshes do represent the pristine condition. Pickleweed is a great volunteer, it comes in very rapidly. Cordgrass, however, is very slow to colonize and some activity often is required in order to establish it.

Salt Marsh Faunas: Colonization and Monitoring

Milton J. Boyd, *Humboldt State University, Arcata, CA*

Introduction

Any consideration of salt marsh restoration and recolonization techniques must begin with a statement of the dominant animals found in little disturbed California salt marshes. Unfortunately, most investigators of salt marshes have focused their attention on plant species (Chapman 1977), with only secondary attention paid to the animals. Some notable exceptions to this pattern have been MacDonald's work (1967, 1969a, 1969b) on salt marsh molluscs, Cameron's (1972) study of insects, Zedler's (1982) review of southern California salt marshes, and MacDonald's (1977a) review of animal communities found in Pacific North American salt marshes.

In this review I will present some preliminary findings on patterns of colonization and establishment of animal populations at a marsh restoration site on Humboldt Bay and compare these findings to others for a marsh on San Francisco Bay. Investigations of the animal communities of Pacific coast salt marshes are still at an early stage of development and will be fruitful areas for further work. The relatively low diversity of animal populations of salt marshes (MacDonald 1977a) offer interesting opportunities to work within communities which may be readily manipulated by experimental approaches.

The Pacific Coast Salt Marsh Fauna

Meiofaunal Organisms

The meiofaunal components of Pacific coast salt marshes have not been extensively studied, although these animals undoubtedly play a significant role in the detrital microbial pathways of marshes in general (Fenchel 1978). Phleger (1967) studied the Foraminiferan (grouped here with meiofauna for convenience) of three Pacific coast salt marshes, one north of Vancouver, B.C., and two south of Pt. Conception. He reported distinctive faunas in low and high marsh environments, with the highest populations of foraminiferans found at higher marsh elevations. He also recognized distinctive geographical assemblages.

Warme (1971) reported only one species of ostracod from the marshes at Mugu Lagoon, California, although several other ostracod species occurred on adjacent mudflats and at subtidal depths. MacDonald (1977a) reported nematodes as quite abundant in cores taken in a marsh of Goleta Slough, California, a finding which seems to confirm the dominance of this group in salt marshes as well as in other meiofaunal assemblages (Fenchel 1978).

The study of meiofaunal assemblages of the Pacific coast in general, and of salt marshes in particular, is at a very young stage. I know of no investigations of salt marsh restoration in California which has used meiofaunal groups to monitor the progress of colonization and marsh development.

Molluscs

The most common components of mollusc assemblages in California salt marshes are small gastropods which feed on algae or detritus on the surface of marshes. In northern California, the two most common species are *Assiminea californica* and *Ovatella myosotis*. Much less common, and restricted to only a few marsh sites at Humboldt Bay, is *Littorina newcombiana*, reportedly somewhat more abundant in Oregon salt marshes (MacDonald 1977a). A larger gastropod, *Cerithidea californica*, occurs with *A. californica* and *Ovatella myosotis* in central California salt marshes and ranges into Baja California (MacDonald 1969a, Morris *et al.* 1980, Zedler 1982). In central and southern California, the pulmonate *Melampus olivaceus* replaces *O. Myosotis* as the most common high salt marsh gastropod (MacDonald 1969a, 1977a).

An introduced gastropod (*Batillaria attrementaria*) was brought in on oyster spat from Japan and has become well established at marshes in central California (Tomales Bay and Elkhorn Slough). It is not found at Humboldt Bay, although a population has become established in British Columbia (Morris *et al.* 1980). *B. attrementaria* is abundant in salt marsh tidal channels and at lower elevations on the edge of marshes. An introduced bivalve, the horse mussel, *Ischadium demissum*, was brought in with oyster spat from the Atlantic coast of North America, and is common at lower elevations of salt marshes in San Francisco Bay and somewhat less common in southern California bays (Morris *et al.* 1980, Zedler 1982).

Two species of opisthobranch gastropods are occasionally encountered at lower marsh elevations, *Acteocina culcitella* in southern California (MacDonald 1969a) and *Alderia modesta* in central and northern California (Barbour *et al.* 1973). These animals probably feed on algae (*Ulva, Enteromorpha, Vaucheria*) growing on the surface of the low marsh and adjacent mud flats.

MacDonald (1977a) suggested that a relationship exists between standing crop of gastropods and latitude. He cites figures of less than 1 to more than 10 gm of gastropod dry wt m^{-2} from north to south, and suggests this indicates more abundant trophic resources in southern marshes. Present data does not support the notion of increased species diversity at southern latitudes, thus, the niche structure of marsh gastropods must remain approximately similar at temperate and sub-tropical latitudes in California.

Polychaetes

We have collected polychaetes from lower marsh elevations at a restoration site bordering Humboldt Bay, and others have also noted the occurrence of polychaetes in lower elevation marsh sediments (MacDonald 1977a; Reisch and Barnard 1967; Niesen and Lyke 1981). The phyllodocid *Etone californica* was the first polychaete to arrive at our restoration site and is practically cosmopolitan in mud-sand sediments of California (Hartman 1968). Eight to nine months after the site was restored to tidal inundation, we also noted *Capitella capitata*, and the spionids *Polydora ligni* and *Streblospio benedicti*. These species are widely distributed in estuarine mudflats and bays of California (Blake 1975) and have been noted previously in salt marshes of California (MacDonald 1977a). We have also collected numerous oligochaetes at low marsh elevations, but these are quite difficult to identify and practically nothing is known of their comparative abundance in other estuarine habitats.

Crustaceans

Most of the crustaceans found in salt marshes are small and inconspicuous. Particularly if sampled at low tide, many species aggregate in plant debris or under driftwood. Quantitative sampling of these animals is thus difficult. The most common crustacean at lower elevations of salt marshes around Humboldt Bay is the amphipod *Orchestia traskiana*. This species is particularly abundant at low tide under boards and driftwood, and around the base of *Spartina foliosa*. The estuarine amphipod *Anisogammarus confervicolus* appeared abundantly in samples from our restoration site from late February to August 1981. We have taken this species in plankton nets and benthic grabs from the adjacent slough, and suspect that animals were swept into the restoration marsh and stranded on decaying vegetation. The species is rarely taken in established marshes around Humboldt Bay. In tidal creeks that dissect the lower elevations of salt marshes, the crab *Hemigrapsus oregonensis* frequently burrows into the banks, although this species is not as common in salt marshes at Humboldt Bay as at locations in central and southern California (MacDonald 1977a). Two crabs usually found on the outer coast, *Pachygrapsus crassipes* and *Hemigrapsus nudus*, are sometimes abundant in salt marshes (Barbour *et al.* 1973; Zedler 1982).

At higher marsh elevations (typically dominated by *Distichlis spicata* at Humboldt Bay), several oniscoidean isopods are common. We have taken *Armadilloniscus coronocapitalis*, *Littorophiloscia richardsonae*, and *Porcellio* spp. at both our restoration site and in established marshes. MacDonald (1977a) noted the occurrence of *Callianassa californiensis* in California salt marshes, but at Humboldt Bay this animal is found only on adjacent mudflats.

Insects and Arachnids

Despite their abundance and importance as consumers in salt marshes (Teal 1962), insects have not been well studied as components of the Pacific coast salt marsh fauna. MacDonald (1977a) presented a summary of the findings of Lane (1969) and Cameron (1972) in central California salt marshes, and Foster and Treherne (1976) have discussed the physiological problems encountered by insects under marine conditions. The methods used in sampling insects have a considerable influence on the species collected. Lane (1969) used several sweep net techniques during summer and fall months and collected 134 species. Cameron (1972) used a clip-quadrat technique and extracted insects using Berlese-Tullgren funnels. He collected 103 species of adult insects. Only about 10 percent of the insects collected in these two studies co-occurred in Cameron's and Lane's samples. If the species collected by Lane and Cameron are totaled, over 200 species were collected in two San Francisco Bay salt marshes. Zedler (1982) reported the possibility of as many as 1,200 species in one southern California salt marsh. Clearly, insects far exceed in both abundance and diversity all other macroinvertebrates of salt marshes.

Cameron (1972) concluded that spiders are the most important predators of small insects in salt marshes. He showed a close relationship between spider abundance and insect herbivore abundance during spring months and a relationship to the numbers of insect saprovores available as prey in winter. Teal (1962) also identified spiders as important predators of salt marsh insects in Georgia. Despite their recognized importance in energy flow, and as predators of insects, virtually nothing is known of the taxonomy and ecology of salt marsh spiders.

Fish

Few fish species are restricted to salt marshes along the coast of California, in contrast to the large number of species dependent on salt marshes along the Gulf and Atlantic coasts of the U.S. (McHugh 1967). Collections in and adjacent to Pacific coast salt marshes contain large numbers of larval fish (Eldridge 1977; Pearcy and Myers

1974), but the dependence of these larvae on salt marshes is unknown. The most abundant larval fish taken are Pacific herring (*Clopea harengus pallasi*), northern anchovy (*Engraulis mordax*), and various goby larvae. These typically account for 90-98 percent of the larval fish caught (Eldridge 1977; Pearcy and Myers 1974). MacDonald (1977) lists several euryhaline species as characteristic of salt marsh habitats, but none of the species listed are restricted to salt marshes and are found in a vairety of estuarine and marine habitats (Miller and Lea 1972; Hart 1973). Use of salt marshes by larval fish for feeding is largely unknown, although an obviously important aspect of the significance of marshes in sustaining coastal marine fish populations. The importance of salt marshes as refuges from predation by larger fish is clearly important (Zedler 1982).

Birds

The number of bird species which are endemic to Pacific coast salt marshes is low (MacDonald 1977a). Only two species, both now quite rare (the clapper rail and black rail), are obligately associated with salt marshes. Neither species is found at Humboldt Bay, although the clapper rail did apparently occur there before eradication by man (Yocum and Harris 1975). Despite the lack of endemic bird species, use of salt marshes by birds, especially shorebirds and migratory waterfowl, can be high. More than 100 bird species use the Pacific flyway (Peterson 1961), many of which can be found loafing, resting, or feeding in and near coastal salt marshes (MacDonald 1977a). These activities may involve many thousands of birds during some parts of the year (Zedler 1982). Shorebird use of a marsh restoration site and adjacent mudflats at San Francisco Bay was greatest during winter and spring months (Cogswell 1981), in agreement with observations at Humboldt Bay. Stage of the tide has a marked influence on bird use of marshes, with the greatest number of birds noted in marshes during periods when adjacent mudflats are covered by water.

Several species, mainly herons and egrets, take fish and larger invertebrates from the tidal creeks in salt marshes. Unfortunately, there is little information available on the direct importance of salt marshes to the feeding activities of the many bird species which have been recorded in Pacific coast salt marshes.

Other Vertebrates

Other vertebrates, usually encountered more frequently above the highest high water mark, may occasionally be found in the marsh. The Pacific treefrog (*Hyla regilla*), the southern alligator lizard (*Gerrhonotus multicarinatus*), western fence lizard (*Sceloporus occidentalis*), and gopher snake (*Pituophis melanoleucus*) move into and prey on the insects or small mammals of salt marshes in southern California (Zedler 1982). Around San Francisco Bay, the endemic salt marsh harvest mouse (*Reithrodontomys raviventris*) is critically dependent on vegetation growing at the edge of salt marshes, particularly *Salicornia* spp. (Shellhammer 1982).

Monitoring the Establishment of the Salt Marsh Fauna

The critical variables to be monitored in establishment of the salt marsh fauna are the species composition and population density of key species. Since a relatively well known complex of species is characteristic of California coastal marshes, restoration sites can be surveyed periodically and the presence of these species catalogued. Species with different capacities for dispersal will obviously arrive at different times in restoration sites, and the early history of species occurrences may be quite different from the pattern of species composition in established marshes. The species occurring at a restoration site adjacent to Humboldt Bay were somewhat different from those seen in a nearby established marsh (Table 1). Jaccard's Coefficient of Similarity,

$$J = \frac{C}{A + B + C}$$

was applied to these species presence-absence data and yielded a value of 35.7 percent, indicating a modest degree of similarity after 9 months of tidal inundation at the restoration site.

The differences between the two sites can be accounted for by the presence at the restoration site of highly motile species which are widely distributed throughout estuarine habitats of the bay. The amphipod *Anisogammarus confervicolus* and the spionid polychaetes were taken in benthic samples from the adjacent slough and both adults and larvae were probably brought into the marsh by tidal activity. These species were not collected in the established marsh nearby, and probably reflect a transitional stage in the establishment of characteristic marsh species.

The comparative measurement of population density is a challenging and difficult task. Presence-absence data (Table 1) are often a vast over-simplification in assessing the establishment of marsh populations. At our restoration site, the (usually) common marsh gastropods *Assiminea californica* and *Ovatella myosotis* occurred in single samples collected over the 9-month sampling period (total of 75 samples taken). In 90 samples collected simultaneously at the established marsh, these species occurred in 80 percent of the samples taken. It appears that the single animals recorded arrived in the restoration site by clinging to floating vegetation, and that establishment of population densities comparable to those of established marshes will require years, rather than months.

Standardized sampling techniques for salt marsh animals are not available. Development of such standardized methods should receive high priority in developing restoration monitoring techniques, although several problems are associated with attempting to adequately sample the diverse kinds of populations found in salt marshes. MacDonald (1969a) noted vegetation cover in a 0.19 m^2 area and then sampled the molluscan fauna from a 200 cm^2 area. In tidal creeks, he sampled an area of 25 cm^2. In

Restoration Site	Established Marsh
Gastropods	Gastropods
Assiminea californica	*Assiminea californica*
Ovatella myosotis	*Ovatella myosotis*
Alderia modesta	
Crustaceans	Crustaceans
Anisogammarus confervicolus (A)	*Orchestia traskiana* (A)
Corophium spinicorne (A)	*Armadilloniscus coronocapitalis* (I)
Orchestia traskiana (A)	*Gnorimosphaeroma oregonense* (I)
Gnorimosphaeroma oregonense (I)	*Littorophiloscia richardsonae* (I)
Porcellio sp. (I)	
I = Isopod	A = Amphipod
Polychaetes	Polychaetes
Eteone californica	*Eteone californica*
Streblospio benedicti	
Polydora ligni	
Pseudopolydora kempi	
Insects, arachnids, and oligochaetes were collected at both sites, but were not identified.	

Table 1: *Invertebrate species collected from an established marsh (Bay Street site) and restoration site (Park Street site) from February 1981 — August 1981. Tidal inundation of the restoration site occurred in November 1980.*

established and restoration marsh sites at Humboldt Bay, I used a coring device 163 cm² in area to remove the top 2-3 cm of surface sediment and vegetation. These samples were placed in plastic bags, returned to the lab, and all organisms retained on a 0.50 mm sieve were preserved for later identification. Sample sites were established following a stratified-random sampling technique. The number of samples required to compare the densities of common animals in the established marsh and restoration site was estimated using the method of Sokal and Rohlf (1969):

$$n \geq 2\,(\sigma/\delta)^2\,[t_{\alpha(\nu z)} + t_{2(1-p)(\nu)}]^2$$

Where:

n = number of replicates

σ = true standard deviation

δ = the smallest true difference it is desired to detect

ν = degrees of freedom of the sample standard deviation

α = desired significance level

p = desired probability that a difference will be detected

Using data from the samples collected in the established marsh, it was found that to compare the densities in the two marshes at a 10 percent confidence level with 50 percent chance of detecting a significant difference, it would be necessary to collect over 900 samples per sampling interval at both sites. The reason for this large number of samples is, of course, the high standard deviation seen in samples from populations which are aggregated. Thus, it seems unlikely that sufficient resources will be available to make statistical comparisons of population densities at marsh restoration sites. Rather, more imprecise methods of comparison may be required to monitor the establishment of marsh faunas, especially considering that a limited number of species are usually involved, with the notable exception of insects. Presence-absence information, combined with data on population density (gastropods) and biomass (polychaetes) may be quite sufficient to monitor establishment of salt marsh faunas. The advantages of sampling these invertebrates to monitor establishment of the salt marsh fauna are 1) their relatively early appearance at a restoration site and 2) their perennial occurrence in the marsh. Bird and fish populations of salt marshes vary greatly on a seasonal basis and from year to year (Zedler 1982).

Samples can probably be taken at quarterly intervals, and it may even be possible to monitor salt marshes only during summer months, when population densities of invertebrates (except saprovorous insects) are typically at their peak. Standardized techniques would be desirable in monitoring establishment of faunas, but have not been developed.

Recommendation

The significant species have been identified at marshes in California and form a fairly homogeneous fauna. What is now required is a standardized method for sampling patterns of recruitment and establishment of the salt marsh fauna. Ideally, this task should be accomplished at once, preferably by a thorough investigation of the sampling techniques needed to accurately estimate densities of dominant species in established marshes.

Many of the smaller polychaete species are difficult to identify without the help of highly trained individuals. It may be necessary to group these animals together and measure their abundance by some fairly gross method, such as standing crop biomass through time. Traditional methods of collecting, sorting, and identification to species level may be simply too expensive to contemplate in monitoring establishment of faunas at salt marsh restoration sites. Similar difficulties are likely to arise in monitoring the establishment and abundance of insect populations. Although semi-quantitative methods for estimating insect abundance were used by Cameron (1972), it seems unlikely that his methods will have wide applicability in monitoring salt marsh restoration sites, again because of the extensive sampling effort required and time needed for identification by qualified entomologists.

Some groups traditionally sampled (birds, fish larvae), although they may be found at marsh sites in impressive numbers, may not utilize directly the trophic resources of the marsh. Such animals are more dependent on the marsh as a refuge from predators found in deeper water (fish), or as loafing and resting grounds during periods of high water on adjacent mudflats (birds). The relationships of these animals to the trophic resouces of salt marshes is little known at present, and is another significant area for further study.

The frequency of sampling necessary to determine patterns of establishment by salt marsh animals is critically important. My own studies of a restoration site at Humboldt Bay suggest that sampling could have been conducted at quarterly or even semiannual intervals during the first year of tidal inundation without a significant loss of resolution. Niesen and Lyke (1981) reported low densities of macroinvertebrates retained on a 2 mm sieve during the first year of quarterly sampling at the Hayward marsh restoration site and high variability in numbers of invertebrates retained on a 0.50 mm sieve.

Agencies responsible for assessing the effectiveness of salt marsh restoration should consider monitoring the establishment of salt marsh faunas at intervals which are appropriate to detect major changes in faunal composition. Since it appears that such changes may occur over periods of years, rather than months, significant changes in traditional funding patterns may be required. Modest amounts of yearly funding, spread over several years, may be the most effective way to ultimately judge the success of restoration efforts.

Panel Discussion

Paul Springer, *Wildlife Research Field Station, Eureka, CA:*

The focus of this panel is on various techniques that may be used in achieving the restoration of different species or groups of species of animals and the steps required to measure their success. To achieve this goal, I would like to discuss, first, what research design and methodology is needed and, second, what techniques are available. At the outset, one needs to develop a study design. Ideally this would involve: (1) conduct of a study before and after restoration in order to measure what changes occur, (2) provision for a treated area (the tract on which restoration is undertaken) and an untreated, or control, area (a reasonably close, relatively undisturbed marsh that typifies the original condition that is being strived for) so that one can appraise the success of the restoration effort, (3) arrangement for replicate treated and untreated areas, if possible, to improve the chances of avoiding an individual area that is atypical and to allow some degree of statistical analysis. Also, unless one can conduct a complete census, one needs to take randomly selected samples, repeated in both space and time, and (4) provision for a study (if the restoration project involves mitigation for a development project that will damage or destroy an existing wetland) to determine the magnitude of that loss and how successful the restoration project is in compensating for it.

This is a large order that usually cannot be achieved, not only because of budgetary and time constraints but, perhaps even more importantly, because of the lack of comparable control areas. To the extent possible, however, I think one needs to consider the conditions that should be strived for in designing and conducting the "ideal" study. At the same time, though, one needs to be realistic enough be able to fall back to a lesser level of sophistication when he ideal design cannot be achieved.

It cannot be stressed too strongly that the design is very important if a study is to produce findings that will be accepted. Too many times, and I am as guilty as anyone, not enough planning goes into this phase, and one ends up with results that are not as strong or revealing as they could have been.

In regard to study methodology, I agree heartily with Milt on the need to standardize research techniques insofar as it is feasible, so results are comparable from one study to another. It is important to recognize, however, that one should not be a slave to a particular methodology that may be inappropriate for a given situation. At times it may be necessary to use other techniques or develop new and better ones.

Milt makes a significant point that monitoring may be conducted at quarterly or even semiannual intervals during the first year of restoration without a significant loss of resolution. Until we gain greater knowledge on this matter, however, I see no alternative but to acquire the baseline data and then continue the study to determine what important changes take place and why. Sometimes a critical or unusual event may occur, such as a storm, drought, or disease outbreak. If one does not monitor closely enough to witness these events, it may not be possible to interpret correctly why something has happened that is of significance to the restoration progam.

Milt, as an invertebrate ecologist and particularly a benthic specialist, concentrated on defining some of the study techniques that are available in that discipline, and the findings that he and his colleagues have obtained. To be fair and equitable, I believe the paper should give adequate attention to all forms of animal life that occur in wetlands, including mammals which are not now mentioned. In this regard, it may be possible to focus attention on key species or groups of species rather than attempt to monitor all animal species.

As an ornithologist I noted some statements that need to be corrected. For example, there are considerably more than 100 species of birds in the Pacific Flyway. Also, although certain ones such as the clapper rail and black rail occur in salt marshes in California, these species as a whole are not obligately associated with only this habitat;

certain subspecies in other parts of the country frequent fresh or non-salt marshes. These statements should be modified accordingly.

As far as use of coastal marsh is concerned, it is true, as has been stated, that some species of birds, such as short-legged waders, use them only for resting and loafing at high tides when the mud flats and lower parts of the marsh are inundated. Contrary to the implication left, however, it is also true that some species are resident in marshes and make their livelihoods there, and depend on such habitat to feed on a number of the invertebrates mentioned.

In regard to the use of marshes for feeding, documentation of the kind and number of birds engaged in such activity is fundamental. Other aspects, however, such as feeding ecology and partitioning of food resources are also important. Investigation of these subjects will eventually be needed if one is to better understand how a marsh serves the needs of particular species, and, thus, what the management strategies for them should be.

Finally, one gets back to the question of the various techniques available for achieving restoration of different species or groups of species of animals. Some restoration projects have incorporated construction and management features based on knowledge already available. They have involved construction of dikes, channels, and islands; installation of tide gates or other water control structures; regulation of water levels; introduction of plants by various techniques; and even manipulation of animals, such as providing resting or nesting structures for birds or controlling pests. Depending on what is done, these can be very expensive but may be essential and can be justified costwise, particularly for endangered species or in areas such as southern California where real estate costs and human populations are high but wetlands are limited and thus more valuable to the people there. These projects, in particular, need to be evaluated adequately to determine if they are effective in terms of the results achieved for the costs involved.

Thomas Niesen, *San Francisco State University, San Francisco, CA:*

As Ray Krone pointed out this morning, development of marsh restoration is a gradual progression of sedimentation, plant estblishment, and marsh level build up. At the Hayward Shoreline Project, we started from former diked land and the initial substratum was barren. When the dikes were breached, we were not immediately establishing a salt marsh but a mudflat. It's the mudflat organisms that we must address our initial monitoring observations, at least in these situations.

I would like to note several parallels seen in our studies at Hayward with those mentioned by Milt Boyd at Humboldt, and then, because our restoration site was a former salt evaporator in the San Francisco Bay, I would like to mention a few unique things that we saw.

First of all, a substantial and complex meiofaunal assemblage was observed at both locations. The meiofauna, the organisms that fall through a 0.5 mm mesh, are probably very important in what is established in terms of the macroinvertebrate populations. However, monitoring that group is almost impossible on a cost-effective basis.

Another similarity between Hayward and Humboldt was the composition of the dominant polychaetes. This isn't surprising because the species observed are adapted to handle disturbed estuarine conditions. Another parallel is the sporadic or patchy pattern we saw in polychaete settlement. As Milt mentioned 900 samples would be the necessary number to get a valid sample for a comparison. Nine hundred benthic samples would take a team of 20 graduate students five years to process. So this poses a problem of sampling replication and the question of whether it's cost effective.

As an alternative to standard benthic monitoring methods that Milt and I employed, one of the techniques employed by Dr. Nybakkan at Moss Landing might be applicable. They focus on organisms that are known dominants of a particular habitat and follow them, particularly if they have tractable life histories to get an idea of what their reproduction is, what their growth is, and how successful they are. This information can be used as an indication of how successful the restored habitat is in terms of progressing to the end point that you wish. In the case of a salt marsh, you can investigate the invertebrate fauna of a nearby, established salt marsh, and determine which species are dominants. These species then can be monitored as they come into your restoration and their progress noted as an indication of the health and the success of the restoration.

A few comments about monitoring in San Francisco Bay, and particularly on a former salt evaporator. In my study of the Hayward Marsh, I was greatly aided by the fact that students at Hayward had done much work on the mudflats adjacent to the restoration. Also, Dr. Fred Nichols, from the U.S. Geological Survey, had done extensive work on the mudflats in the South San Francisco Bay. Dr. Nichols has found that the mudflats in the South San Francisco Bay are constantly in a perturbed state. Therefore, the organisms that are found as dominants on these perturbed mudflats, are organisms adept at colonizing disturbed habitats. It's not surprising that the same organisms that we found coming into our restoration site were these same basic colonizing organisms.

Another interesting sidelight is that the majority of these organisms were introduced. They were animals from other estuarine habitats—mostly from our East Coast and from Europe and the Orient. San Francisco Bay poses a unique problem in that we are a major port; we have had waves of introductions of organisms and the reasons they are successful in San Francisco Bay also make them successful at being colonizers in our restoration sites. Now, the question is, in tracking these highly adaptable estuarine animals are we getting information that is going to be valuable or necessary in terms of judging how our restoration sites are coming along?

Perhaps another method to look at invertebrate populations was alluded to by Dr. Howard Cogswell, who watched the bird usage at our restoration site. Dr. Cogswell found that birds did use the marsh mudflats, but not to the same level that they used adjacent mudflats. Perhaps there is a correlation between the amount of bird usage on a mudflat and the relative abundance of organisms that are building up, without going through the standard process of going out, coring, sampling, and sorting.

Steve Balling, *University of California Berkeley, CA:*

Before I assume my role as an entomologist, I'd first like to play the devil's advocate. I'm concerned with our use of the term "monitoring." I agree that experimental designs need to be developed to establish marsh design and maintenance criteria. I agree that post-development documentation of these systems is a very valuable point and something to be considered. And in mitigation situations, I think monitoring it is also a vital component. But often, the concept of monitoring is that it is the search for something going wrong. For example, pest managers in agricultural sitautions monitor insect populations to determine when they are reaching an outbreak level. Industries monitor their outfall to find out when contaminants reach too high a concentration. Vector biologists try to monitor mosquito populations to make sure that they don't reach too high a level. In restored marshes, I don't believe that we really need to monitor animal populations to see if the new marsh is exactly like the old marsh. I think it's important to document successional changes. However, the process of a marsh reaching equilibrium or apparent equilibrium—since it's a naturally dynamic habitat—is a slow process; one that will not be complete in the first nine months of study.

My second point is that marshes exist along a broad tidal continuum. Marshes begin about mean tide level and extend to extreme high water. Along that continuum are the obvious vegetational gradients. In addition there are also salt marsh faunal gradients. Sampling such systems will of course lead to high vriability.

I think Milton was probably discussing the characterization of several strata when he suggested 900 samples were necessary, but we can decrease sampling variability drastically by stratifying very carefully over the elevational gradients within a marsh. This presents a major difficulty when comparing two different marshes. When you are comparing an established marsh with a newly-restored marsh, they should be the same height or you are going to find a very different faunal component. The tidal frequency, *i.e.* the inundation frequencies, are very important in establishing faunal and floral composition.

Finally, as the panel's entomologist, I'd like to say that insects really aren't that difficult to study. There are admittedly over 200 species in San Francisco Bay marshes. The two studies that Milton referred to were done in two pickleweed marshes in the San Francisco Bay area. Cameron used a clip quadrat method, where he randomly dropped the quadrat, took out the vegetation within and then extracted the insects via Berlese funnels. Lane used aerial methods. It's no wonder they got different results. They were sampling completely different faunal components. It is necessary to stratify in those instances too.

Insects can be used to establish the effects of perturbation. There are ways of doing diversity analysis where we don't really need a constant counting and identification of insects. For example, the Sequential Comparison Index is an empirical method of establishing Simpson's index, and is normally distributed so that it can be easily analyzed statistically. Also, there are dominants within the insect community that can be easily sampled for perturbation analysis.

Howard Shellhammer, *San Jose State University, San Jose, CA:*

I will talk about a slightly different subject—the design of marshes so they will support certain species of small mammals and birds. My remarks are restricted to the San Francisco Bay Region. I have four points to make.

The first is that the upper zone of marshes is very valuable to small mammals and birds. The zone of peripheral, seldom-submerged halophytes acts as a refugium during the highest tides and a buffer between the marsh and upland vegetation or development. It has received little attention during this meeting. Two endangered species, the salt marsh harvest mouse and the California clapper rail, retreat to the zone of the peripheral halophytes during the highest tides. In those marshes that lack an upper zone, salt marsh harvest mice are seldom present. The ruderal edge that constitutes the transition into upland vegetation is also an important refugium for salt marsh harvest mice. Today there is less than three miles around the entire margin of the San Francisco Bay in which there is a natural transition zone present. Throughout most of the Bay, a dike replaces the upper zone of the marsh, and there is no band of ruderal vegetation.

The restoration or recreation of the upper edge of a marsh is very difficult; it is very expensive. As Felix Smith suggested yesterday, one of the ways that might be accomplished is by the use of spoils to change the grade of the marsh so the halophyte zone might re-establish itself. In some areas the dikes may have to be moved back, and that is even a more expensive technique.

My second point concerns dike maintenance. It again has to do with the upper zones of the marshes. In many areas of the Bay, there is a broad band of pickleweed, or in some cases alkali bulrush or cord grass, crowding against the peripheral halophyte zone at the base of the dike at the rear of the marsh. As the average tide level and hence marshes move upward, as Ray Krone has suggested, the band of the peripheral halophytes will become even smaller. If we maintain our dikes poorly, we will impact that latter zone from above as changes in sea level effect it from below. In the case of two endangered species, the impact will be extremely serious.

A third point concerns the size and shape of marshes. We need to design marshes so that most of them will contain the channels that are very important in the life of California clapper rails and similar marsh-dwelling birds.

My last point is that marshes should have a continuity of cover as most of the species restricted to salt marshes are cover-dependent. The salt marsh harvest mouse, for example, is so cover-dependent that a small break in cover, be it a road or bare spot of ten feet or less, acts as a functional barrier and cuts down the marsh into much smaller units.

Robert Holmes, *University of California, Santa Barbara, CA:*

I have a disclaimer to make. That is, I am a botanist and I don't know what I am doing on this panel! So you'll have to bear with me because much of the information and comments I will make actually have evolved through time in my very close association with Drs. Chris Onuf and Millicent Quammen and graduate students in our research work at Mugu Lagoon.

Prior to commenting specifically on certain items, I would like to express my strong feeling that I think the limitation of a discussion of wetlands that we've seen in the last two sessions to the salt marsh is an injustice to the subtidal zone. In terms of primary productivity, if we wish to use this as a judgment for the value of the subtidal and intertidal, we find that in terms of production of carbon on an annual basis, the intertidal and subtidal are about as productive as the marsh. So I feel a little unhappy that the remarks have been restricted to the higher part of the marsh, namely that in which the aquatic higher plants exist.

Now, I think that Milton clearly recognizes the problem that we have in adequately assessing the population density and the identification of the organisms that we find in salt marshes. Certainly the perception of the public probably doesn't coincide with that of the invertebrate biologist at this time. The public perceives the salt marsh habitat as one in which birds and fish occur and in some cases in which edible mollusks occur. And I wonder in our consideration of making evaluations of restorations, whether we shouldn't consider these very obvious components of salt marsh habitat, as well as or perhaps in place of such things as gastropods and polychaetes. That touches me because I work with algae, and the public doesn't give one hoot about algae, except they do complain that it forms messy, slimy things and that hurts my feelings. But I certainly wouldn't try to justify or evaluate the success of a restoration as a common citizen based on the algae that I work with.

I was impressed, too, with the comments that were made yesterday by a number of people concerning the establishment of regional and/or local goals for restoration projects. What we want in Mugu Lagoon or some place in San Diego may be very different from what is perceived to be desired in other areas in the State of California, and certainly the participation and active involvement of the public and the private sector should be sought in all of these projects.

Audience Participation

JIM McGRATH (California Coastal Commission): Questions have been raised both about the utility of changing one type of habitat into another, say, a freshwater to a saltwater marsh, and whether or not you can ever effectively mitigate the loss of a healthy marsh. Dr. Boyd's infrared photographs show a dramatic lack of activity in the restoration project. It was rather shocking to see. The Woodley Island Marina Project, a controversial project, commenced in 1977. The restoration didn't start until 1980. Can you give us some comments on the two issues I mentioned in relation to this project?

DR. BOYD: You hit a critical issue here whenever you consider mitigation. I don't think that the evidence is in to deal with that question. We're coming down to a question of can we trade off one type of habitat (*i.e.* mudflats, subtidal areas, marshes) for the other? I don't think you can. I think that they are fundamentally different in faunal composition, in patterns of productivity, in dependent species. As a practical matter, I suppose, at times, it's what you have to accept.

Paul, did you want to respond further?

DR. SPRINGER: In the Woodley Marina mitigation, we thought we would end up with fewer birds and maybe a better habitat for fish, which we couldn't get into the marsh originally because it was blocked off from tidal activity. We're still in an evolutionary stage. I'm not sure what is going to happen, but we could have a poorer habitat for birds than originally existed in the restoration area. However, it's an open marsh now with fish entering and leaving and a number of invertebrates. There is a trade off and much depends on your sense of values. We could try to get a consensus among the scientific community—is it a net gain or a net loss?

JOHN ZENTNER (California Coastal Commission): Based on the data we have from the East Coast, grazing is a very minor use of salt marsh productivity. Have you seen any large amounts of grazing taking place on newly-restored marshes and if not, what are the critters eating?

DR. BALLING: I have been working with the insects in natural tidal marshes. There is very little grazing effect. Most of the insects are quite small and are not an important energy component. However, Chris Onuf made an important point in a paper a couple of years ago that Pacific Coast marshes do not provide a large amount of detritus to the estuarine system as they do on the East Coast. This concept has been used to support marshlands for years. Marshes are important in their own right, but on the West Coast many of the marsh areas reside at mean high water, are not innundated very often, and don't supply a large amount of detritus to the estuary.

DR. BOYD: As far as I am aware, the invertebrate species in the sediments are primarily detritus feeders. They are not feeding directly on the plant production as would be the case for insects.

DR. SPRINGER: Birds do not appear to graze in marshes to any significant extent.

MARTIN COHEN (State Coastal Conservancy): The restoration and enhancement projects with which I am familiar range from maybe six acres up to 160 acres, a cost of $25,000 to $550,000. How can we make a coherent monitoring program that will be proportional to the public investment that's involved in the actual restoration? Should a monitoring program cost a fixed amount or a fixed amount per acre regardless of the extent of change that is actually taking place? It seems to me that if you are just increasing the tidal circulation, that's different than re-establishing tidal circulation, bringing on an entirely new water source, revegetating, or changing the land contours. Is there a way that we can balance the monitoring study we do with the kind of work that we have undertaken on the marsh?

DR. BOYD: I think it depends on the goal for the restoration. If that's clearly defined, then I think you are going to be at least halfway towards knowing what you should monitor. In our particular case in Humboldt Bay, I don't think there was ever any existing set of goals laid out for the restoration project. And I think that's a serious weakness. Whether that's the case elsewhere, I don't know. I'd invite others to comment.

DR. NIESEN: John Oliver hit a nerve in the earlier panel when he said just that. There has to be an objective. He went on to say that you have to view these monitoring projects as experiments. What we need is an array of experimental data to say this is what happens in such and such a situation. Monitoring should provide a framework for the progression of successional stages that marshes go through. Then we can say this marsh or this mitigation project had this in place so this is what we can expect. But we don't have that information. We are just in the process of experimenting every day.

DR. SHELLHAMMER: It's a good question but I think of the wrong panel. Ultimately, I think that information comes from the vegetation studies and not the animal ones and probably will be much more efficient and quite a bit less costly.

JIM SWANSON (California Fish and Game): Most restoration projects, particularly around San Francisco Bay, are a result of mitigation or development. We feel lucky just to get the projects. We very seldom get funds even to design; consequently, we can't ever ask for funds for monitoring. I ask the panel or anybody here how would you propose to get funds to do these desperately needed monitoring programs?

DR. BALLING: Well, we were going to apply to Fish and Game for it. I gather that was a rhetorical question.

DR. JAMES SCHOOLEY (California State University, Hayward): I have one distinction I'd like to make concerning monitoring which attempts to determine cause and effect relationships during marsh evolution or simply asks the question: "Have we been successful in restoration?" Does the panel have any recommendations as to whether you can state a yes or no question, was this a successful restoration project?

DR. SHELLHAMMER: I will repeat my response, monitor the plants. Honestly, I think that's where, in a general way, we're going to have the best index. That's, in effect, what we set up normally. We want to restore a certain marsh; we don't say we want to set up certain isopods.

ROBERT RADOVICH (California Department of Fish and Game): It seems that the importance of coastal wetlands and fisheries resources, especially in Southern California, is being underemphasized. It seems that several fish species are very intimately involved in wetlands, like the California yellowfish, and need wetlands basically for survival, and other fish are benefited by wetlands, though not necessarily obligatorily towards wetlands, like white sea bass and California halibut. If you look at comparative densities of these species, in Southern California's wetlands and adjacent estuarine waters, you'll find that the densities are astronomically high in those areas as compared to open coastal waters. Therefore, it is logical to assume that those areas are very important to the life histories of these fish species. I think that it's misleading to state that fisheries resources are not clearly supported by wetlands or there is no clear evidence that they are supported. I just wanted to make a point.

Towards an Overall Strategy in Designing Wetland Restorations

Jens Sorensen, *Jens Sorensen and Associates, San Diego, California*

Introduction

The process for designing a wetland restoration strategy derives primarily from my consulting work over the last year for the California State Coastal Conservancy. The focus of the work was a program for restoring and enhancing wetlands in Los Angeles and Orange Counties. The project for the Coastal Conservancy builds upon my prior 13 years of research in coastal zone management—which was largely supported by the California Sea Grant College Program. The idea of placing the process in a flow diagram emerged from an invitation to give a seminar last September on "Southern California Wetlands Restoration" at Woods Hole Oceanographic Institute.

As a long-time observer of the politics and environmental policy making, I realize that information collection and analyses on complex policy areas—such as wetland management—do not usually follow a process that can be clearly illustrated by a flow diagram. There are usually cross-overs, short-circuits, parallelisms, and feedbacks that fuzz up a clear step-by-step process. A flow diagram, however, does serve as a means to systematically assess and discuss a dynamic and complex process such as wetland restoration.

The process diagrammed by Figure 1 is designed to develop a wetlands restoration plan for systems that possess the three following conditions:

- environmentally degraded in respect to its former "pristine" condition or in respect to other well-functioning wetlands,
- partly or entirely in private ownership
- not likely to be restored without the infusion of private sector funds in a quid-pro-quo arrangement between public agencies and property owners (or developers).

There are approximately 110 discrete coastal wetland systems in California. It appears that at least a majority of the total number of wetlands possess these three conditions. Wetlands in central and southern California particularly fit this situation. A state-wide inventory of coastal wetlands should provide a good basis for assessing the generalizability of the process outlined by this paper.

In a quid-pro-quo arrangement, property owners or developers are allowed sufficient development potential by government to provide *both* a reasonable return on their investment *and* sufficient funds to underwrite the costs of restoring and maintaining the wetlands at desired levels of environmental quality. Even if a degraded wetland system is entirely in public ownership, given the lack of government funds for environmental enhancement projects, a public and private sector quid-pro-quo arrangement will become increasingly appropriate in the years ahead.

It is clear that for any plan for wetlands management or restoration which generates significant controversy, the following groups are likely to be involved:

- property owners, developers, and their respective consultants
- federal, state, and local government agencies
- conservation organizations (it appears that every major wetland system has a "Friends of ______" organization)
- educators and researchers (it appears that every major wetland has at least one educational or research institution regularly assessing one or more aspects of the system)
- state legislators (side-line actors who usually stay out of the game until the stakes become large or are drawn into the game by a court decision)
- courts (usually come into play during the later stages to resolve the taking issue or the public trust issue)
- God (unanticipated acts of nature such as: massive flooding and sedimentation, earthquakes, and tsunamis)

Numerous gaming simulations have been devised by academicians or consultants as one means of educating students and policy makers on the difficulties of resolving common types of controversial issues. Wetland planning and restoration appears to have all the characteristics for constructing a useful gaming simulation.

As a final introductory point, I should note that the conclusions and recommendations in this paper are my own and do not necessarily reflect the position of the California State Coastal Conservancy or any other institution.

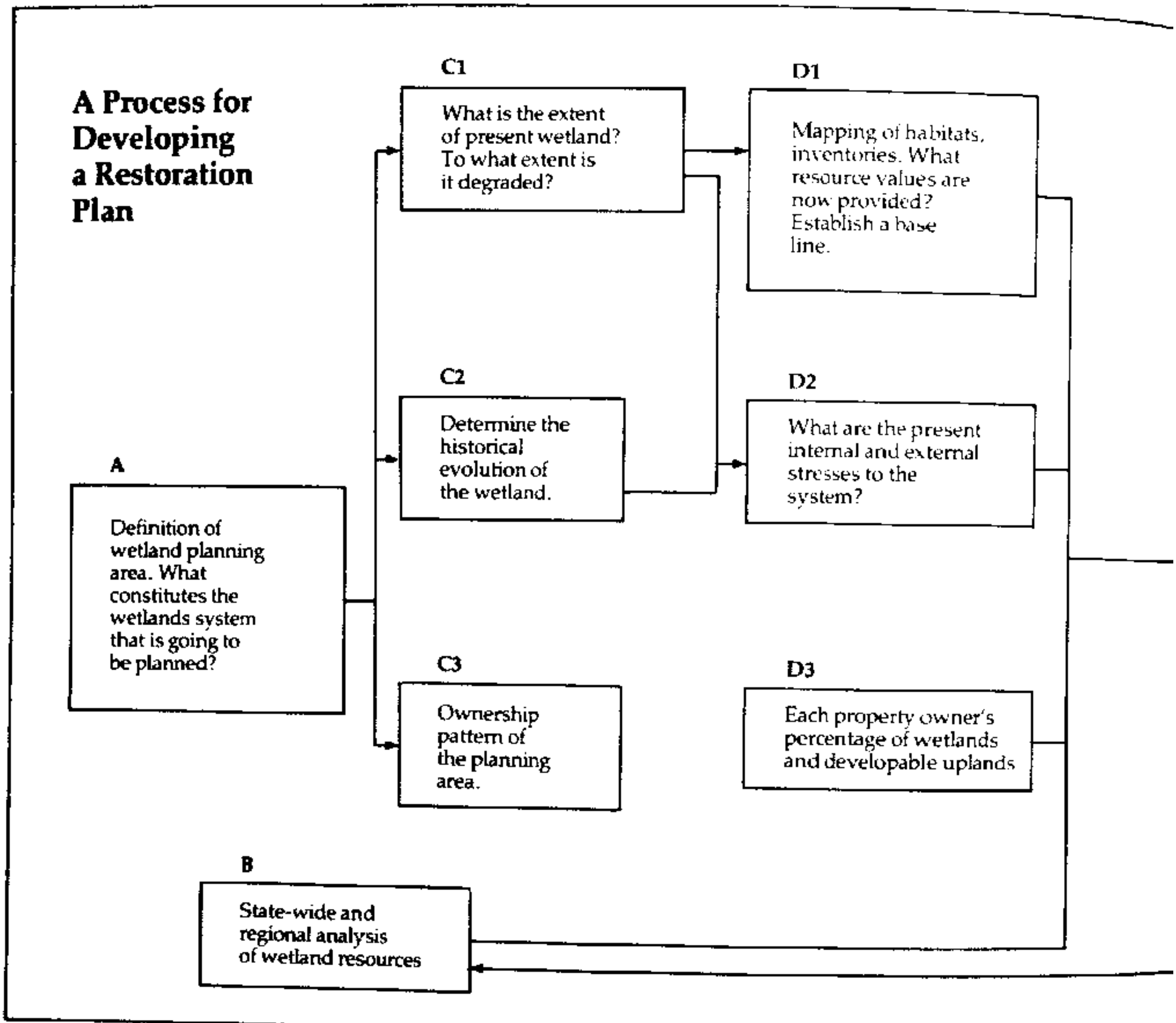


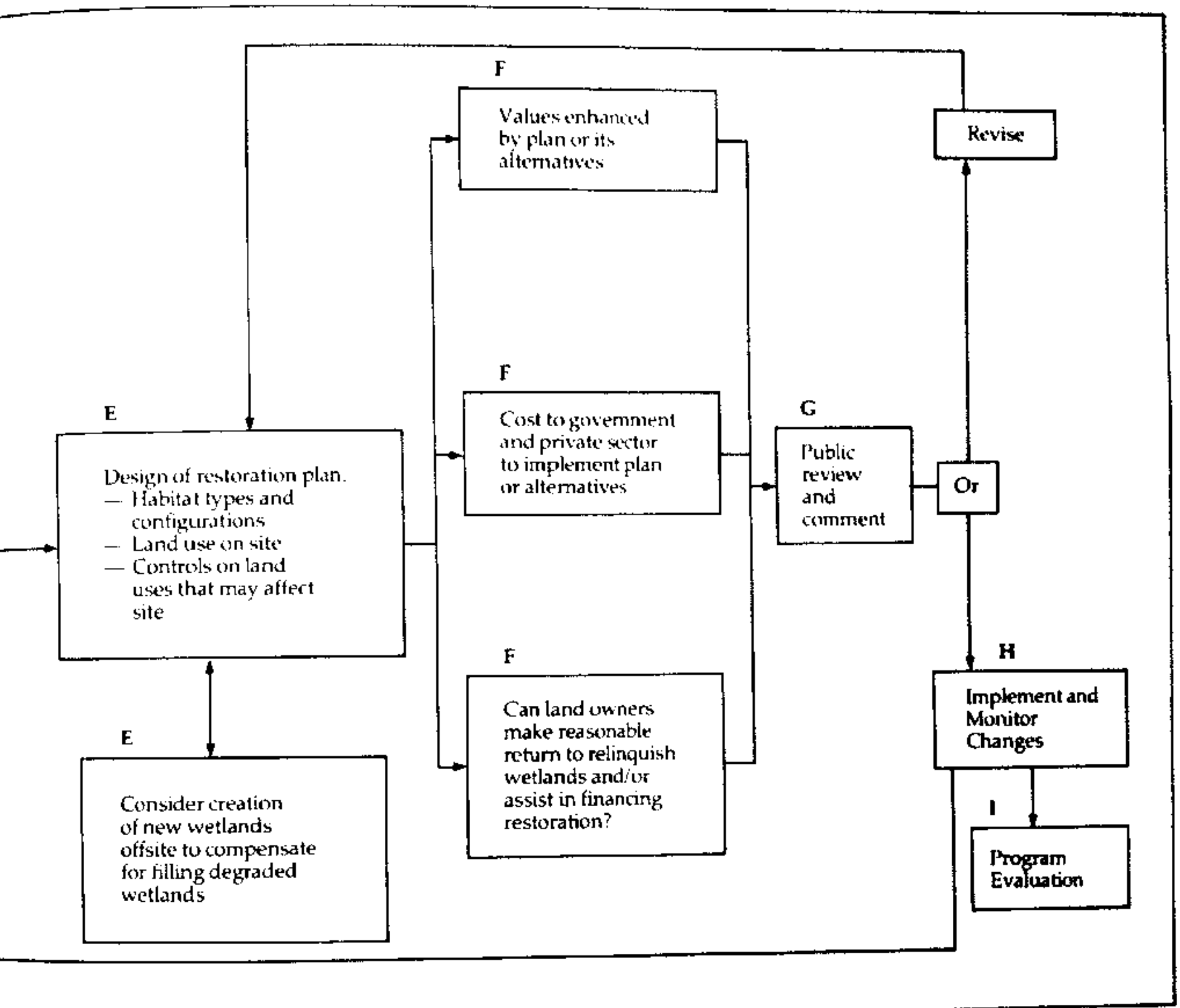
Figure 1: *A conceptual process for developing a wetlands restoration plan.*

A. Definition of Wetland Planning Area

It is now widely recognized that the geographic extent of a wetland plan should be the area in which land use activities may significantly effect the present and future environmental qualities of the wetland system. Obviously, the first problem is defining this area. Assuming this area can be defined, such as Dickert's work in the watersheds of Elkhorn Slough and Jacoby Creek (Humboldt Bay), the follow-on problem usually is the extent to which this planning area is within the jurisdiction of the agencies that will develop and implement the plan (Dickert, 1981). In most cases the Coastal Commission and the State Coastal Conservancy will have the central roles in developing and implementing a wetlands plan. However, it appears that in most cases the limits of the Coastal Commission's jurisdiction do not extend inland far enough to include most if not all of the area in which land uses could significantly affect coastal wetlands. The problem of the inadequate extent of the Coastal Commission's inland jurisdiction is most evident in central and northern California because of both the large size of the watersheds and the large scale of potential impacts of the land use—particularly logging, agriculture, and second home development.

B. State-wide and Regional Analyses

Ideally this step should occur prior to the definition of



the wetland planning area. Since there are no completed state-wide or regional wetlands analyses this is a moot point. There are at least four reasons why wetlands restoration plans should be viewed from both a regional and state-wide perspective.

Most wetland associated birds (and perhaps some fish) move among a number of coastal wetlands—this is true of both migrant and resident species. Optimal protection and enhancement of these mobile populations requires a regional distribution of habitats among a number of wetland systems. In the case of migratory species this means a linear series of wetland systems—such as the Pacific Flyway. For resident species, a cluster of wetlands within a region is necessary to provide alternative habitats in order to accommodate daily and monthly fluctuations in local environments—such as tidal inundation, the evaporation of winter ponds, or the seasonal change of vegetation.

Secondly, the relative scarcity and abundance of the resource needs to be determined on a region-wide basis in order to set priorities on the types and location of habitats that should be provided in a restoration site plan. In setting priorities on habitats, consideration should not only be given to the present scarcity of a species or environment but also to scarcity in terms of the previous relative abundance in the region.

Thirdly, comparative analysis among wetlands in a region is necessary to determine the types and mix of environmental factors that create optimal habitats for the fish and wildlife populations. The regional analysis consists of comparing quantitative indicators of wetland resource values—such as diversity of species, population counts, and intensity of use—with environmental measurements of the related habitats.

Regional analysis of species populations and habitats will also establish a baseline from which to measure changes in resource values. A baseline is needed for two purposes: (1) to determine natural fluctuation in environments and resources that occur in seasonal, annual, and multiple year cycles: (2) to monitor the extent to which restoration and enhancement plans are collectively increasing wetland resource values.

Defining the boundaries of a region is the first and most basic problem to resolve, whether it be wetlands or any other geographic phenomena. In the case of wetlands there are three apparent criteria for setting regional boundaries.

- The geographical limits of movement by migrant fish and wildlife populations deemed to be a resource value. Depending on the species, the regional boundary for migratory waterfowl or shore birds can be set from Alaska to South America.
- The geographic range in which a species is known to inhabit. This criterion is most applicable to rare and endangered species. For example, the Belding Savannah sparrow's range is from San Quintin, Baja California to Santa Barbara County. Even if the species are residents, the endangered status requires knowledge of habitat availability within the entire range in order to maintain or enhance the population.
- The biogeographical extent of a wetland type as distinguished by its flora and fauna. The southern California hypersaline marsh can be distinguished as the characteristic wetland type from Pt. Conception to San Quintin in Baja (Zedler, 1981). This type is characterized by hypersaline soils and plants and animals associated with cordgrass and pickleweed dominance.

A study may also be termed regional if the geographic extent of analysis includes the jurisdictional area of two or more governmental units. This is the case in the regional analysis just completed for the coastal wetlands within Los Angeles and Orange counties (Sorensen, 1982). Although the geographical scope of this two-county study is defined by jurisdictional boundaries and not biogeographic or species boundaries, the analyses will assist, to an extent, in achieving the four objectives of regional assessment just outlined.

There has been only one effort to map and measure in a consistent fashion all the coastal wetlands in California. This is the U.S. Fish and Wildlife Service's National Wetland Inventory ("NWI"). The scale of the maps (1:24,000), the ground truth, and the classification of environmental types limits its applicability to a regional assessment of southern California. These limitations are understandable since this is a nation-wide inventory. Unfortunately measurement of the various wetland classifications recorded on the NWI maps will not be completed and released until sometime later this year, if then.

No studies have been done in a consistent fashion for California coastal biogeographic regions. Based on flora and fauna criteria there should be at least three biographical regional studies done to cover coastal California:

- San Quintin, Baja California, to Pt. Conception
- Pt. Conception to Cape Mendocino
- Cape Mendocino to Cape Blanco, Oregon

C1. Determine the present coverage of wetlands and the extent of degradation.

The preparation of the Coastal Conservancy's first major wetlands restoration project in the "quid pro quo" context, the "Los Cerritos Enhancement Plan," indicates to me that the greatest impediment at this moment in the restoration planning process is the definition of wetlands, degraded wetlands, and uplands. It is understandable that making these determinations will always be something of a sticking point in the process. This is where the stakes are the highest in the wetlands game. The development potential and associated property values at risk (measured in the hundreds of thousands of dollars per acre in southern California) hinge upon reching consensus among the state agencies, federal agencies and the property owners (or developers) on the map that delineates the acreage of wetlands, degraded wetlands, and uplands. To fully describe the convoluted processes the Department of Fish and Game, the Coastal Conservancy, the Coastal Commission, the City of Long Beach, and the property owners went through to hammer out an agreement on the total amount of wetland and upland areas on the 244-acre Los Cerritos site would probably require a paper longer than this one.

The Coastal Act's provisions on wetlands and the CCC's guidelines on wetlands allow the Department of Fish and Game and the Coastal Commission some degree of flexibility and creativity in defining wetlands, degraded wetlands, and uplands. Landowners and developers with wetlands on their property as well as their consultants have expressed concern that these two agencies have tended to be too creative in their wetland definitions and determinations. Wetlands and degraded wetlands appear to be popping up all over the place. In the wetlands restoration process landowners and developers have both political and judicial means to limit the creative ability of the state or federal agencies to find more and more acreage of wetlands or degraded wetlands. If the private sector perceives that agencies are not making wetland definitions and determinations in a reasonable and consistent manner, one or more of the following actions can be expected:

- strongly worded, widely circulated letters questioning the reasonableness, inconsistency and legality of DFG's wetland definition
- direct pressure on state agencies to get their act together
- litigation of a DFG wetland definition and determination

- direct lobbying of state legislators to amend the Coastal Act to: (1) more precisely define wetlands, degraded wetlands and uplands, and, (2) make explicit the roles and responsibilities of the various state agencies in regulating and restoring wetlands.

It is understandable that state and federal agencies mandated to protect and enhance wetlands will tend to define the resource and determine its geographic extent in a manner that will achieve the most acres of wetlands possible. However, these agencies must recognize that too zealous a pursuit of increasing and enhancing wetland acreage may provide the private sector with sufficient ammunition to mount a successful frontal assault and change the rules of the wetlands game in favor of the property owners and developers.

The Los Cerritos experience and review of California wetlands literature also indicates we know very little about the past condition of wetlands and how their functioning has degraded over time. Determination of a degraded condition—as required by the Coastal Act and Coastal Commision's guidelines—assumes some knowledge of how the system has changed over time. One important dimension of this determination is assessing the extent that fill or sediments contain wastes and debris which may complicate or modify a restoration plan.

The determination of wetlands exercise usually elicits the quantity versus quality debate. State and federal agencies backed by respective legislation, policies, and guidelines tend to blur the distinction between quantity and quality. For example, the California Senate's Concurrent Resolution 29 in 1979 calls for a 50 percent increase in the total acreage of coastal wetlands state-wide by the year 2000.

Increasing the total quantity will not necessarily produce a corresponding increase in the total quality of the resource. With few exceptions, a thousand acres of intertidal cordgrass has much greater aggregate resource value than a thousand acres of non-tidal saltpans which are periodically flooded every winter or so. The exception would be rare and endangered species habitat, such as the least tern or Belding Savannah sparrow. It is understandable that agencies tend to rely on acreages in plan making and permit letting. Acreage is easy to visualize and measure. It is also understandable that property owners, developers, and their environmental consultants argue that restoration should be measured more by the quality increases in the wetland resources than acreages. Their argument is that a presently degraded wetland area can be restored into a well functioning wetland system of a *smaller* size which will produce far more resource values (such as ducks, shorebirds, fish) than the larger degraded wetland was capable of producing. For example, 100 acres of degraded wetland may support half the duck and shorebird population compared to restoring 75 acres into a well-functioning wetland and filling 25 acres for intensive development.

Given the astronomic development values of coastal property in southern California, I expect that government agencies will barely be able to keep the total existing acreage of wetlands in that portion of the state. *Substantially* increasing the total acreage of coastal wetlands in southern California appears to be both politically and economically unrealistic.

C2. Determine the historical evolution of the wetland.

The major focus of this step is determining to what extent the public trust doctrine regarding submerged lands is applicable to the wetlands restoration plan. The history of litigation on Bolsa Chica provides a textbook example on the complexity and implications of public trust determination in coastal wetlands.

C3. Analyze ownership of the restoration plan area

Determining who owns the land within the restoration planning area is usually a straightforward exercise. The importance of this lies both in the pattern of ownership and in the ownership conditions. Generally, the restoration planning processes will become more difficult as the following factors increase:

- the proportion of the restoration planning area in private ownership
- the number of individual private ownerships
- the net cost to the property owner or developer of holding the land in its present condition
- the impact of the net cost of holding the land in its present condition in respect to the property owner or developer's financial stability
- the proportion of each property owner's or developer's land that has been determined to be wetlands

D1. Determine existing resource values

As the diagram indicates, this step is a follow-on to determining wetlands, degraded wetlands, and uplands. The step consists of analyzing the site to determine the existing resource values and establish the environmental base line needed for the monitoring and evaluation aspects of the restoration planning process. There are at least two major problems associated with this step. There has not been a consensus either among the government community or the academic community on: (1) uniform system for classifying wetland environments and habitats and (2) indicators to measure resource value.

One of my tasks for the Coastal Conservancy was to review existing wetland classification systems. The U.S. Fish and Wildlife Service's "Classification of Wetlands and Deepwater Habitats of the United States" is the best-known system (Cowardin *et al.* 1977). The USFWS system was found to be too broad in its classifications for direct application to California's restoration planning. Although it provides a good overall framework, the generality of the classifications cannot adequately describe the important environmental variations among California's estuary and wetland systems. For example, distinction is not made between regular tidal systems and systems which are only periodically open to tidal exchange when barrier beaches are broken open. The review for the Coastal Conservancy also included reports that mapped and analyzed specific wetland systems in California. These included the Department of Fish and Game wetland report series, reports by USFWS, and studies done by consultants for wetland property owners. As was to be expected, there was considerable variation in clssification systems used.

It was concluded that a new system is needed for California in order to both provide more specificity than USFWS national survey and to guide the future inventories that will be done of individual wetlands.

A new habitat and fauna classification system should be designed with two primary objectives in mind:

- to indicate how types of fauna will be influenced by the restoration site plan (or alternative plans).
- to provide a set of measures on the extent to which restoration site plans have changed the aggregate amount of habitat types and associated fauna resources within a region.

The first objective is based on the presumption that public support for wetlands restoration and enhancement will largely depend on how the site plans will benefit fauna of recreational and aesthetic significance—such as sport fish, ducks, and shorebirds.

The second objective can best be met if all wetlands in the region are mapped using the habitat classification system. A regional inventory using the system proposed would indicate the distribution and relative abundance and scarcity of habitats. This information would be the basis for setting regional goals for wetlands restoration and enhancement. For example knowledge of the amount of habitat suitable for migratory waterfowl would indicate where and to what extent waterfowl habitat types should be expanded. Another regional goal might be the expansion of habitats that are relatively scarce, particularly in comparison to their historical abundance.

The regional inventory would also facilitate the recording of a continual count of how restoration plans are changing the aggregate amount as well as the distribution of habitat types. For example, such a system could show that over a five-year period there has been a threefold increase in intertidal habitats and a small decrease in both non-tidal, intermittently flooded salt flats and non-tidal intermittently flooded *Salicornia* and succulent habitats.

The proposed classification system was tested in Mugu Lagoon, Los Cerritos Wetlands, and Tijuana Estuary. These areas were chosen because of the quality of existing information. The classification system is described in the project report to the Coastal Conservancy (Sorensen 1982).

The absence of time series data on the functioning of a wetland system is the second major problem in determining existing resource values. The wetlands for which we have good time series data—such as Tijuana Lagoon, Mugu Lagoon, Elkhorn Slough, Tomales Bay, and parts of the San Francisco Bay system—are, unfortunately, the exception rather than the rule.

D2. Assessment of present internal and external stresses to the system

In concept this is a fairly straightforward step of impact assessment. However, as anyone familiar with the business of impact assessment knows, there are numerous impediments such as inadequate base-line data and inadequate models to assess cause and effect relations.

The product of this step should be a determination of: (1) what is stressing the environmental quality of the wetlands system (such as residential development in the watershed stimulating erosion which vastly increases the sediment input to the wetlands and (2) how these stresses can be controlled (such as performance standards on site preparation, check dams, and sediment traps).

D3. Calculating each property owner's amount of wetlands and developable uplands

As Figure 1 illustrates this step consists of overlaying the ownership map with the map indicating wetlands, degraded wetlands and uplands. As previously pointed out, the greater the percentage of developable land for each property owner, the lower the difficulty in designing a politically and economically acceptable wetlands restoration plan.

E. Design of a restoration site plan

The three previous lines of analysis converge at this point. This "bring-it-all-together" step is certainly the most challenging and difficult step of the entire process.

One component of my project for the Conservancy was the preparation of guidelines to assist in designing a restoration site plan. These site plan restoration guidelines are based on: review of existing literature and consultation with academicians, consultants and government staffers who have conducted research or have been involved in the management of California coastal wetlands. The final set of these guidelines is included in the project report to the Coastal Conservancy (Sorensen 1982).

The Coastal Conservancy's Los Cerritos Enhancement Plan is serving as a prototype for developing and testing the restoration site planning process. It is expected that four discrete components will comprise the Los Cerritos site restoration plan, as well as other restoration site plans.

The first and most basic component is a set of specific objectives to be achieved by the restoration site plan. The objectives should be sufficiently specific to clearly support the other three components as well as to enable program monitoring and evaluation (steps H and I).

A second component should be a map indicating:

- the location of the different wetland habitat or environmental types (such as tidally-influenced pickleweed marsh)
- the location of the different types of activities that

will be allowed in the wetlands

- the location and type of buffer areas between the wetland areas and developed upland areas
- the types and densities of land use that will be permitted on the uplands

A third component should be a set of performance standards to control activities in the wetlands, the buffer area, and the uplands so impacts will not be generated that would adversely effect achieving the specific objectives of the restoration site plan.

A program to implement the site plan should be the fourth component. This program would include: the roles of the institutions that will develop and implement the plan, the anticipated budget necessary to restore the site *and* maintain the site, and local or state legislation that may be necessary.

Figure 1 also indicates that in this step consideration is given to offsite creation of new wetlands in compensation for filling (and developing) degraded wetlands. This provision of the Coastal Act and the Coastal Commission's guidelines allows additional flexibility in the design of a restoration site plan. If a land owner has degraded wetlands on the property (as determined by DFG) these degraded wetlands may be completely filled provided another site is converted into wetlands that provide greater resource values than those values lost by filling the degraded wetlands. This is the approach now proposed by Ponderosa Homes for 25 acres of degraded wetlands in the City of Seal Beach. The most suitable offsite compensation for the filling is creating at least 50 acres of new wetlands adjacent to the Anaheim Bay wetlands system.

F. Assessment of the restoration plan

As the diagram illustrates, this step assesses the plan or plan alternatives from three perspectives:

- Resource values enhanced by the plan
- Cost to government and other institutions to implement the plan
- Cost and benefit assessment by the land owners or developers with vested interest in the restoration site.

This assessment step could be merged with the previous plan design steps since the two activities are expected to be conducted as an interactive exercise. In other words, in the design step, it is expected that those involved in planning will take the three assessment factors into account in order to produce a realistic and workable product. It is also expected that a negative findings in any one of these three assessments would force alterations in the design of the plan.

G. Public review and comment

It is anticipated that there will be a significant level of public participation from the very outset of the process. For example, the Long Beach Planning Department has formed a citizens advisory committee to review and comment on the design of the Los Cerritos Plan. Step G indicates the formal public review and comment stage required before local and state (and in some cases federal agencies) can take action in approving or denying the restoration plan.

H. Implement plan and monitor changes

Implementation will have at least two stages: (1) restoration and development activities to achieve the plan objectives and (2) monitoring the wetland's environmental quality indicators to determine if these objectives are being achieved. Experience with the southern California wetlands indicates that the restoration and development stage will often be done in a series of phases over a number of years. This is particularly true in existing oil field areas as long as the price of oil and the field's supply makes pumping oil more profitable than residential or commercial development.

The diagram also illustrates that knowledge gained from plan implementation and monitoring should be fed into the ongoing state-wide and regional analyses of wetland resources.

I. Program evaluation

Implementation and monitoring also lead into program evaluation. It is expected that state agencies involved in wetlands management will establish an ongoing program to evaluate the success or failure of their efforts. It is hoped that the academic community would also be part of the evaluation program to both prevent or minimize the biases that inherently occur when agencies review their own efforts *and* to provide advances in the state of the art.

Panel Discussion

Margaret Race, *Stanford University, Stanford, CA:*

First of all, I'd like to say that I view the presented paper as one that seems to apply best to an individual situation, a flowchart from the beginning of an individual project until its completion and evaluation. I'd like to step back and take a view of the overall strategy of wetlands restoration and interject some views as a biologist.

First, some specific comments about several proposals in the paper. Jens mentioned the importance of *quid pro quo* exchanges of property, especially in light of all of the budget cuts that we have seen. He feels that private sector exchanges and mitigation may be more important in the future. I would urge caution in the application of these techniques to the private sector and cite some work done in Tampa Bay on other restoration projects.

There have been conferences in Tampa Bay for the past eight or nine years looking at wetlands restoration. Among the papers in recent years have been reports on the lack of success of private sector restoration projects. (Fehring *et al.* 1979). The more successful projects seem to be those that were mitigation or restoration projects undertaken by government agencies. Projects undertaken by individual developers have often resulted in failure. The original wetland resource has been bartered away during the mitigation and permitting process, and a degraded habitat created at the new "restoration" site. One should be careful in urging an exchange of habitats, a *quid pro quo* treatment of these restoration sites. We must distinguish between the difference in the private sector and the government sector in their ability and effectiveness o follow a project to completion.

Jens also mentioned the importance of both restoring and maintaining these sites. What is required initially is a clear statement of goals. Are we trying to maintain the static nature of a marsh or do we want to incorporate dynamics? Are we trying to set up a marsh for maximum species diversity? Maximum primary productivity? Are we going to let storm damage remain unrepaired? What should we do about succession that eventually may change the marsh? All of these questions have to be discussed in the initial stages when project goals and objectives are identified. To determine whether we have met those objectives we really have to set up monitoring programs. We have already heard the need for that. I agree with the other panels that monitoring of a one or two-year nature is insufficient.

It may be better to use our funds for long term monitoring studies. We don't need to document over and over the first two years of post-construction vegetation establishment. We should study restored marshes as they mature to determine their long term success. That is, after all, what we're after. If we're striving to replace one kind of wetland with another, or if we're trying to restore and maintain wetlands for a long period of time, we need to ask the question about their long term persistence. And we must also address the quality vs quantity issue, as Jens mentioned.

In the case of wetland restoration, it may be that the management agencies are a quantum step ahead of the scientists. There is a tremendous lack of scientific information on the technology of actually creating these salt marshes on the Pacific Coast. Jens mentioned in the paper the importance of guidelines that various agencies are putting together right now. I realize that many of these guidelines are based upon our best information to date. But we must be careful to distinguish between our best educated guess on the technology, the experimental evidence we have now, and compare that with what we actually know as fact. It does appear that hydrology is very important. We know certain things about the requirements of many species of plants and animals. But many ideas about restoration are no more than best guesses from past experience and to equate those ideas with guidelines somehow makes it seem as if we have a set of rules, a set of best ways to approach the particular problem.

We may, in fact, have that in some cases. But we might find ourselves having many more experimental projects that don't work as well. And if a developer can come to us and say, "I followed the guidelines and I did everything you said and I still failed," what position are we in? Are we urging developers and individual interests to foot the bill for a very expensive experiment? We have to ask that question because we don't want to see the backlash that could result. That woud cause a complete loss of all of the strides we have made in wetlands protection. If people can turn back to us and say, "You have just made us go through a very expensive experiment that didn't work; I'm not going to do it any more; let's change the laws and regulations," we may all be in trouble.

Finally, I will take the usual academic approach and say it's obvious to me there is a need for continued research in various areas, continued communication and transfer of information between academic institutions, agencies, consultants of all sorts. I think this conference has made strides in that direction.

Nona Davis, *ESA/Madrone Associates, Novato, CA:*

Jens' flowchart appears to be based on the Los Cerritos case and his experience in that case. It is a hybrid flowchart which encompasses everything from setting regional goals down to a specific progam on a specific marsh. I don't know whether he intended to encompass such a broad planning framework. I would like to comment on three points concerning the overall flowchart, and throw out a few ideas that may raise some questions following the end of this session.

First of all, with regard to the identification of candidate "wetlands" for enhancement or restoration I feel that the inventory that Susa presented yesterday is very comprehensive. We should bear in mind however that there are many instances of marginal or transitional wetlands—for example, some of the lands to which Howard Shellhammer referred that have value in their present unrestored condition. These marginal and frequently less than optimum situations need to be considered in our setting of regional goals for restoration. At the Riparian Symposium last fall (UC, Davis) I referred to similar less than optimal riparian sites in the Delta as "surrogate" riparian communities.

Perhaps we could apply the same term to some less than optimal wetland sites that nevertheless are useful wildlife habitats and should be part of comprehensive regional goals and restoration planning. These might include, for example, seasonally flooded agricultural lands. In the Delta, that habitat is the closest approximation for waterfowl to the pristine tidal marsh condition prior to reclamation. We could also include areas such as oxidation ponds and ditches, although the mosquito control people would not want us to enhance ditches; in fact, they (ditches) provide a very important adjacent wetland habitat to coastal and estuarine transitional wetlands and agricultural lands. Flood basins, ruderal edges, and seasonal marshes which are virtually isolated from any kind of tidal connection; these are all examples of marginal wetlands and adjacent habitats that we need to keep in mind when setting regional goals.

Incidentally, I have always objected to the term "degraded," which worked its way into the lexicon of marsh restoration as an absolute term. Degraded actually represents a wide range of conditions, many of which can be exploited in their present state and left as habitat adjacent to the wetlands that presently exist or are considered for restoration.

As a second point, I would like to comment on the question of quality of restoration versus quantity. Probably one of the major difficulties that we face in dealing with a specific wetland and talking with the regulatory agencies, the resources agencies, the landowners or the applicants, local government planners and so forth, is arriving at some kind of working consensus as to the definition of a wetland—what is "dry" and what is "wet". What constitutes, shall we say, a "quality restoration" of habitat value? Until we resolve the question of consistency in determining what is a wetland and what is a dry land within a given area, and arrive at a working consensus or basis for asking compensation for loss or mitigation of damage, we are going to continue to frustrate the local planning agencies that have a direct and broad public interest responsibility, in contrast to the more specialized interest and responsibilities of the state and federal agencies.

A third point. In the process of actually working on development/restoration projects in transitional wetland sites, with landowners, with applicants, and with local governments (which in many instances are an *in lieu* applicant), we have become increasingly familiar with the responsibility of local governments to carry out general plans that are broad purpose rather than specialized. Plans often contain conflicting policies with respect to use of shoreline lands. You can understand that often the adversary role that is set up is not between local government and the applicant but rather it's a three or four-way kind of confrontation, involving also state and federal agencies with wetland programs and policies. A very valuable educational process can be incorporated into the actual planning of a restoration project—developing its goals, planning the distribution of land use, and describing the functions of restorable areas. Bringing all the parties into this and treating it as an educational process as well as a negotiating process, providing them with a range of alternatives from which we can arrive at some kind of working consensus, I feel is an essential part of the implementation of wetland restoration.

James Schooley, *California State University, Hayward, CA:*

There are several of Jens' opening comments concerning the need to develop regional guidelines and goals that I would like to expand upon.

In Jens' flowchart, one of the middle steps (E) was to consider creating a new wetland "offsite" to compensate for the filling of a degraded wetland. If the "offsite" options are to be seriously considered in planning, the need to establish clear regional goals is extremely important. I would suggest that the "offsite" designation be expanded to include the entire state rather than just a region. I realize it may be politically difficult, but I would urge that landowners who are required to finance an offsite restoration be required to fund the highest priority restoration in the state. As an example, a developer with a project in San Francisco Bay might be required to support a restoration in Humboldt County. All of this would require very well-defined state goals for marsh restoration.

The second point I would like to make concerns monitoring costs. I agree with many of the points made by Dr. Race. If we only have a small amount of money for monitoring, it should be stretched out for long term studies. Additionally, monitoring costs paid by the developer should be pooled to fund a few selected sites. Perhaps we could coordinate our efforts and monitor selected sites, considered to be critical marsh developments, on a long term basis. I believe we now spend extensive monies monitoring many restoration sites for too short a period of time to provide the data necessary to help design future restorations.

And finally, it is extremely important for us to communicate within groups such as this, but also to let the public know what we are trying to accomplish and how decisions are made concerning the state wetlands. The use of a flowchart, as Jens has developed, will be very helpful in communicating with those who have a strong vested interest in the wetlands as well as the general public trying to determine how we are protecting their public interests.

Roger Barnhart, *California Cooperative Fishery Unit, Arcata, CA:*

It is clear to me that biological input is necessary far beyond collecting base-line data and monitoring changes during the wetland restoration process. A biologist's input in regional analyses is important. As Jens mentioned, data on species diversity, population counts are needed. Unique requirements of various organisms, rare and endangered, will also be needed to assess the quality and quantity of habitat available. Jens Sorenson mentioned 12 discrete wetland systems present in Los Angeles and Orange counties alone. Biologists were needed to help define these 12 systems and will be needed for other areas of the California coast. Of course, similar data will be required to define the wetland system for a site specific plan in more detail.

Susa Gates' inventory of the various wetland projects in the state was very interesting. We do have a choice in what we restore but we may not always want to restore what was there historically. I was interested in Bob Jones' comments about this subject and I agree that although it may not always be preferable to do so, in some cases it may be possible to key into a recreational or commercial species and develop habits for that species to make projects more acceptable to the public.

I was glad to see Jens Sorenson's mention of "quantity versus quality" and I agree that the two are not equal when considering wetland resource values. Categories of habitat units lost and gained and overall habitat productivity, perhaps expressed as net primary production attained or lost should be emphasized not number of compensated acres. Naturally, the biologist will play an important part in these determinations—biological judgments will be needed and certain biological decisions required.

In wetland planning involving private ownership, net costs to develop wetlands should include non-market values for fish and wildlife as well as the usual economic values. I'm not sure we have acceptable procedures to establish non-market values. Again, the biologist can provide information to aid in this process. There are some attempts already—the U.S. Fish and Wildlife Service has a Habitat Evaluation Procedures method which may be adaptable to the marsh restoration process. Again, a habitat and fauna classification system, to be of real value, will have to include more than measures of amount or quantity of habitat types and associated fauna present, but will need to include some measure of quality.

I believe the biologist should be a member of the multi-disciplinary team which designs the restoration site plan for some of the reasons mentioned above. The biologist should be involved not only in establishing base line information but in monitoring changes which occur during restoration and providing information to evaluate the success of the project. I must also mention the ever-occurring problem of time constraints. A good restoration plan strategy should provide adequate time to develop baseline information and sufficient time to monitor environmental changes due to the project. Conversely, one of the panelists mentioned that time delays do cost money. But I am hoping that in most cases a compromise that is suitable to both sides can be worked out. In Humboldt Bay, for instance, we were able to delay the breaching of the dike for about a year in order to develop more baseline information with very little increase in cost.

Thomas Dickert, *University of California, Berkeley, CA:*

I have been conducting research on the linkage between land use intensity in the estuarine watershed and its impact on wetlands. There is a need to look at land use intensity in a much different way than as planners look at it in units per acre. Units per acre is not a very good measure of land use intensity as it relates to the hydrologic impacts on the estuarine regime. And there's a need to look for measures of land use intensity and classifications of land use that will allow one to look at the causal linkages between land use intensity in the watershed and the resulting impacts within the wetland area.

The importance of time is a critical factor in wetland analysis, a critical factor in impact analysis generally, and has been neglected almost entirely. There is a need to establish a baseline over which to measure change. An ideal baseline would be one which could be defined for wetlands in California using fairly extensive coring and sediment dating, but would be very expensive. It probably would have to be confined to small areas. A practical baseline, which we have found useful in our work in Elkhorn Slough, and now on the north coast, is one which is based on aerial photography and other records. Unfortunately, we have been unable to use anything in the Elkhorn case and the Humboldt case earlier than about 1930 because of the spurious nature of the plan maps that occur prior to that date, but useful baseline data can be set.

Finally, I'd like to reiterate one point that was alluded to by the last speaker, concerning the question of values and cost benefit analysis. I would be very cautious about the use of cost benefit analysis in this area, primarily because there has been no significant theoretical advances made in this area of environmental economics for at least a decade. And generally, environmental economics still relies mainly upon neoclassical economics as a theoretical base. Thus, try as they might, they are unable to come up with a satisfactory answer as to how much the demands of environmental protection have created economic scarcity or slowed down economic growth. Further, questions of species loss cannot be fully costed out because of questions concerning ethics, sensibilities, and other overriding concerns. Therefore, unless we are simply interested in values which can be translated into, for example, so many pounds of duck meat, cost benefit analysis will probably not be a very useful technique in this instance. The Coastal Act is not specific in terms of saying that we have to show benefits in terms of resource value. It says that the habitats will be protected.

Audience Participation

MANUEL ROSALES (Cabrillo Marine Museum): There seems to be a creeping assumption that monitoring is expensive. What component of monitoring makes it expensive? Once a reasonable protocol has been established, an academician or someone as a consultant is only necessary for the interpretation and quality control. The actual sampling itself can be done by lay people and by people of lesser expertise.

DR. RACE: I'm not so sure that it is expensive. Obviously, it's labor-intensive. I think the problem is that monitoring is seen as an after-effect, not as something that's integrated into the planning and the development of the project. As long as it remains separate, we feel we've got to keep defending the need for monitoring.

In the long run, monitoring is cost-effective. We should be monitoring so we can say, "Look, our best empirical data shows that we are getting better." Right now monitoring is not included in any of the initial planning costs, and I don't know why it's not included.

DR. SCHOOLEY: My point is that two years of a monitoring program isn't tremendously expensive except you have to pay for tool-up and tool-down time. To try to piece together a series of short term studies to provide a long term look at what happens in marshes can be rather inefficient. Long term studies of a few restorations might be preferred.

WAYNE TYSON (Regrowth Associates): My question is how can you be talking about converting degraded substandard wetlands to permanent urban uses at the same time you have a directive from the state legislature to increase wetlands by 50 percent.

DR. SORENSEN: First, we can create new wetlands. For example, in the Anaheim Bay Area, we could easily create 80 acres of freshwater marsh by flooding agricultural fields periodically.

The other proposition you're making is that the developers might fill a substantial amount of degraded wetlands. I don't see that happening. I see a reconfiguration, like in the Los Cerritos situation, where the uplands are easier to develop, so you come out with the same total net acreage of wetlands. So I actually see the total wetlands acreage being increased maybe by 10 to 15 percent. I don't see it shrinking in southern California.

JAMES McGRATH (California Coastal Commission): I would suggest that anything that happens in the watershed and proximity of a wetland has an effect on the wetland. If that effect is adverse, it should be mitigated. The people who caused that effect should be made to pay. In that way, through economic strategies that deal with the development of the watershed and adjacent property you can generate sufficient funds to restore wetlands without becoming involved in the *quid pro quo*. An example is Los Penasquitos Lagoon, where the landowner owns the lagoon surface and the surrounding hillsides. In this case they intend to do restoration work in the lagoon in exchange for high density development areas.

MR. TIEGER: Although there are alternatives, but would you care to suggest which legislature is going to pass the laws to give the authority to the agency to implement those strategies.

MR. McGRATH: I believe that the existing legislation provides the authority.

DR. DICKERT: The idea of compensation has been brought up several times, which I see as the difficulty in our work in Elkhorn. Essentially, the problem is trying to trace the drain back to the property owner to find out whose sediment got into the wetlands. I view that as a totally impossible task and I would not encourage you to pursue that course of action with respect to any hydrologic processs unless the entire watershed is owned by one landowner.

KAREN GLATZEL (City of Eureka): Although I agree regional wetlands restoration goals are important, I have great concern for the methodology and more importantly, the lack of a forum to develop these goals. You can't develop regional goals starting from the state level. To effectively restore and enhance wetlands, we must look at the land use development that is going to occur at the local level and then project the type of wetlands that will be impacted. That's the only way that I think that it will work. This is a question put to everyone here. What kind of forum should we use to develop these goals?

DR. SORENSEN: In a report I am preparing for the Coastal Conservancy, I'll be making recommendations on the habitat and environmental priorities for 13 wetland systems in L.A. and Orange Counties considering their inherent resource characteristics, the mix of resources at the regional level, what is scarce, what is relatively abundant, what are the stresses on the system, and what are the private ownership patterns—taking all that into account, I will develop specific recommendations for habitat priorities. That then, would be used as a basis of a dialogue. If Fish and Game does not like the priorities, then they can express that, hopefully in some other form than, "Well, we don't like it". Why don't they like it? Other agencies—the Coastal Commission and Fish and Wildlife Service would also be involved. Because it's based on the regional inventory that I have done, it forms a discussion paper which state and local communities can look at.

ANN SANDS (Planktonics): I am more familiar with riparian areas, but I question the concept that you can take a large degraded marsh and let half of it go and then have 50 percent of it be better than what you would have had if you had restored the whole thing. In riparian systems, the concept applies that the smaller the parcel

is, the less diverse and you begin to lose species that have needs for large feeding areas. How can we justify the destruction of a large parcel and trying to save just a little bit, when we could save it all?

DR. SORENSEN: Margaret Race and I were discussing the concept of an island biogeography and how this applies to wetland priorities, and maybe Margaret could follow up on this, about size versus quality.

DR. RACE: I don't know that we have any data to look at that. No one has done the studies to look at species diversity with different configurations of restored areas and that is obviously a very basic research need.

What you brought up is consistent with my concern for taking another look at the whole idea behind restoration and mitigation. Are we in the long run doing the right thing? It may be the political climate we have to deal with, getting half each time—but is there any point at which "Thou shall not take any more"? We need a lot more basic data before we answer that question.

Contributed Poster Session: Abstracts

Time is Running Out for New Chicago

Janet Carter and Mike Boylan, ***U.S. Fish & Wildlife Service, San Francisco Bay National Wildlife Refuge, Newark, CA***

New Chicago Marsh surrounds the Environmental Education Center of San Francisco Bay National Wildlife Refuge located in the Alviso district of San Jose. One of the largest remaining marshes in the south Bay, 200-acre New Chicago has been diked-off for many years and is now badly dessicated. Characteristic marsh species have been displaced by upland species such as ring-necked pheasants, burrowing owls, ground squirrels and feral dogs.

The U.S. Fish & Wildlife Service is considering proposals to restore New Chicago as a healthy marsh. Its inclusion within San Francisco Bay National Wildlife Refuge provides great potential not only for wildlife enhancement but for environmental education and wildlife-oriented recreation opportunities such as birding and photography as well.

Methods Used to Evaluate Fish Utilization of a Salt Marsh Restoration Site in Humboldt Bay, California

Robert Chamberlain, ***California Cooperative Fishery Research Unit, Humboldt State University, Arcata, CA***

Humboldt Bay is an important embayment in California which provides habitat for approximately 96 fish species and is a nursery area for many organisms including English sole, dungeness crab, Pacific herring and northern anchovy. The 1979 construction of Woodley Island Marina disrupted approximately 3000 feet of mud flats and adjacent salt marshes. A mitigation area adjacent to Freshwater Slough consisting of diked pasture land was selected to replace the lost habitat. In December, 1980, the 16-acre pasture was returned to tidal flushing by breaking the existing dike.

The research and methods presentd by slides and tape in this poster session intends to estimate the fish abundance, density and species composition at the restoration site and to compare the results to an undisturbed salt marsh and to the waters adjacent to Woodley Island in order to determine if adequate mitigation has been accomplished. The project received its original support from Sea Grant and is now funded by the California Cooperative Fisheries Research Unit. Preliminary sampling began in December, 1980; the major field effort started in mid-July, 1981 and will continue through July, 1982. The marshlands are covered with a dense vegetation making non-destructive sampling difficult. To sample these marsh flats, three portable 2m x 2m drop traps were constructed. These traps take a quantitative sample by rapidly enclosing a $4m^2$ area of water which is then seined with a specially designed plankton net that filters the entire trapped water column. Drop trap samples indicate that the dominate species in the restoration marsh is the threespine stickleback, *Gasterosteus acculeatus*. As many as 63 larval, juvenile, and adult fish have been collected in a single sample in the restoration marsh. To date, no fish have been collected in the comparative marsh by drop traps.

The channel, created where the dike was breached, is being sampled bimonthly during high tide for larval and juvenile fishes moving into and out of the marshes. This sampling was conducted using a modified channel net with a ½ meter plankton net sewn into the center. This same method is also employed in the second slough at the comparative marsh. During sampling, water flow and physio-chemical measurements are made to later assist in determining how they relate to fish density. As many as 1500 larvae and juveniles have been collected in a single 45 minute sample at the restoration site.

In August 1981, a monthly seining program was initiated in the restoration marsh using a fine-mesh beach seine. Many short-hauled seines are made at various locations throughout the marsh and one monthly standardized seine to facilitate comparison. The short-hauled seines usually collect juvenile and adult threespine stickleback, juvenile arrow gobies, *Clevelandia ios*, and tidewater gobies, *Eucyclogobius newberryi*. Staghorn sculpin, *Leptocottus armatus*, have also been collected. The standardized seines have captured juvenile topsmelts, *Anthernops affinis*, juvenile smelts, Osmerids, and other unidentified juveniles. In September 1981, gut content analysis of fish collected in the restoration marsh by beach seining was begun by marine advisory agent Chris Toole.

The adjacent source water for the marshes and the channel in front of Woodley Island are sampled monthly with a 16-foot otter trawl and a 1.0m plankton net fitted with a flow meter. Both devices are towed a standard, timed, 1000 feet to enable comparison and assist in evaluation.

Wetland Treatment System Design for Surface Runoff Pollution Control

Emy Chan, Gary S. Silverman, Taras A. Bursztynsky, ***Association of Bay Area Governments, Berkeley, CA;*** **Peter Koos,** ***East Bay Regional Park District, Oakland, CA***

Wetland treatment systems for surface runoff pollution control are an attractive management option that can combine multiple uses such as pollutant removal, flood control, wildlife habitat and recreation into a single facility. Many existing wetlands currently provide one or more of these uses; however, few such systems have been specifically designed on a large scale to optimize pollutant removal and maintain all of these multiple uses. Important design considerations are the hydraulic capacity, pollutant removal capability, plant-sediment-water relationships, cost effectiveness and application constraints.

The Coyote Hills Marsh/Treatment Facility is being designed to demonstrate urban runoff treatment through wetlands creation. It forms the current focus of the San Francisco Bay Areawide 208 Water Quality Management Program to show local jurisdictions that wetlands treatment systems can be more cost-effective than conventional public works practices and at the same time provide multiple benefits to the local community. The facility is being designed over a 24 ha. agricultural open space area adjacent to San Francisco Bay in Fremont. It drains approximately 11 km^2 of completely urbanized land and the marsh can be expanded as further lands become urbanized. It contains four marsh systems of various lengths, configurations and depths to test the effectiveness of various detention times and depths.

Design and operation parameters for a marsh/treatment fcility were drawn from an extensive nationwide literture survey on the use of wetlands for water pollution control. Data were compiled on the ratio of wetland size to contributory watershed area, pollutant removal versus various wetland detention-contact times, optimum flow patterns and water depths, selection of vegetation types for pollutant removal and habitat creation, criteria for waterfowl enhancement and mosquito abatement, management techniques and wetlands construction costs.

Environmental Resource Management: Wetland Protection and Restoration

Michael G. Clayton, ***EDAW, Inc., San Francisco, CA***

Wetlands are one of nature's most fragile of ecosystems constituting an invaluable resource. They provide fisheries and wildlife habitat, recreational areas and open space. By their very nature, wetlands are often found near the highly urbanized coastal areas and thus are subject to a disproportionate degree of environmental stress and deterioration. In the 20 years between 1947 and 1967, approximately two-thirds of the estuarine wildlife habitats in the State of California were lost due to dredging and filling.

EDAW's goal in Environmental Resource Management is to achieve a balance between the competing needs of resource preservation and recreational/educational use. The translation of this goal into resource management plans provides the means essential for the effective protection and administration of our shrinking wetland resources. The three case studies presented here are intended to demonstrate the role of this process in wetland protection and restoration.

San Francisco Bay National Wildlife Refuge Master Plan

The Refuge encompasses over 16,000 acres of salt ponds, tidal mudflats, salt marshes, open water and uplands of south San Francisco Bay. Its location is especially unique in that it provides a nesting and feeding area on the Pacific Flyway within one of the largest metropolitan regions in the United States. The Refuge plan has three objectives: (1) preservation and enhancement of wildlife habitats; (2) objectives of migratory waterfowl and other wildlife; and (3) provision for recreation and environmental education opportunities. Achievement of these goals depends on balancing habitat sensitivities with proposed specific uses and facilities. The planning process combined assessment methodology with the constraint-opportunity approach in order to arrive at an appropriate balance.

Suisun Marsh Protection Plan

Suisun marsh comprises almost ten percent of the remaining natural wetlands of California. It provides winter habitat for waterfowl and a number of rare and endangered species. This study focused on the land use, topography and climate of the area as part of the development of a plan to protect the marsh ecosystem and its wildlife values. The land use inventory included zoning, existing land uses, and a composite of general plans, potential development and land ownership. All environmental factors were mapped and synthesized to develop the initial Fish and Wildlife plan. The final land use element and protection program was completed by the Department of Fish and Game and the San Francisco Bay Conservation and Development Commission.

Nisqually National Wildlife Refuge Conceptual Plan

The Nisqually National Wildlife Refuge is situated at the southern end of Puget Sound in Washington State. The Refuge contains 3,700 acres of primarily flat river delta within the Pacific Flyway and offers a diversity of unique ecosystems particularly beneficial to migratory waterfowl. The conceptual development plan for the refuge focuses on safeguards to protect the ecological, recreational, cultural, scientific and economic values of these game and non-game migratory birds and their habitats. The plan both modifies the existing refuge habitat and provides special features such as trails, interpretive stations, observation stations, an environmental education center and a hunters' check station, designated for both educational and recreational uses.

Selected Restoration Strategies in San Francisco Bay: Four Examples

K.C. Cuneo, *ESA/Madrone Associates, Novato, CA*

The historic tidelands of San Francisco Bay have undergone modification of tidal regime and land forms in varying degree as a result of diking and other human actions and land uses in diked lands. Restoration strategies, to be successful, must respond not only to specific sets of conditions governed by location on the Bay shoreline and history of use, but also to regional habitat objectives and to local political and planning constraints. Four current and proposed wetland restoration projects demonstrate some of the diverse conditions and issues which are evident in the San Francisco Bay shoreline. (Illustrations drawn from Muzzi Marsh; Marin Country Day School Shoreline; Hayward Marsh; E. San Rafael Mitigation Plan.)

Considerations for Restoration of an Endangered Species: Salt Marsh Bird's Beak, *Cordylanthus Maritimus* ssp. *Maritimus*

Patrick Vance Dunn, *Department of Biology, San Diego State University, San Diego, CA*

Salt marsh bird's beak, *Cordylanthus maritimus* ssp. *maritimus*, should be included in the revegetation-restoration of southern California coastal salt marshes, because it is an endangered species with dwindling numbers. *Cordylanthus* is also one of only three native halophytic annuals occurring in southern California marshes. *Cordylanthus* is unusual in several aspects; it is a hemiparasitic plant and its distribution is patchy both spatially and temporally, as represented by the failure of three established colonies at the Tijuana estuary in 1981.

My study of *Cordylanthus* at Tijuana Estuary during 1981 identified several aspects of the basic ecology of the plant which are important for any attempt at restoration. The three colonies studied occurred within an extremely narrow elevational range of 0.9 ft., from 6.3 to 7.2 ft. above MLLW, which is near the high extreme of the marsh at Tijuana. The mean densities of seedlings (75 m^2) and mature plants were also determined, (190 m^2), suggesting seeding and transplanting densities.

Germination requirements and other life history characteristics were also investigated in an attempt to determine factors limiting the distribution of *Cordylanthus*. Two explanations were developed, limitation by dispersal or by a restrictive habitat. These ideas led to a model for upper marsh functioning based largely on the large seasonal variation in soil salinity found in the *Cordylanthus* colonies. The fresh water input of winter rains lowers the upper marsh soil salinity to brackish levels which allows the germination and seedling growth of *Cordylanthus* in the early spring. Through summer there is a steady increase in soil salinity caused by tidal inundation and evaporation of sea water. At this time *Cordylanthus* probably benefits most from being a hemiparasite.

Big Canyon Marsh Restoration Upper Newport Bay

EDAW, Inc., *Newport Bech, CA*

Under contract to the County Sanitation Districts of Orange County, EDAW, Inc. prepared the conceptual design for the restoration of a 7-acre freshwater marsh at the mouth of Big Canyon adjacent to the Upper Newport Bay Ecological reserve in Orange County, California. Historically, the project site was believed to have been a salt- and brackish marsh complex to which tidal flow had been interrupted by the construction of a diked road across the canyon mouth. More recently, the site had been used to deposit and stockpile spoils dredged from the Bay following severe floods and sedimentation that occurred in 1969.

The restoration project was the turn-key element of a mitigation program required for a Coastal Commission permit to construct a gravity line sewer in the same area as proposed by the Sanitation Districts. Marsh restoration was primarily intended to enhance and expand available habitat for the light-footed clapper rail, an endangered species occurring in the Upper Bay. Recent investigations had found freshwater marshes adjacent to saltmarshes to be important foraging areas for this species. Significant benefits to many other wildlife, particularly migratory waterfowl and shorebirds, are also expected.

In addition to the jurisdictional involvement of the California Coastal Commission, the project site is owned by The Irvine Company and is within the City of Newport Beach. Throughout the project's planning, close contact and coordination with these entities, as well as the State Department of Fish and Game, U.S. Fish and Wildlife Service and public interest groups was required and maintained.

Subsequent to agreement of all parties involved to the conceptual design, precise engineering drawings were prepared by the Sanitation Districts and sent out for bid. A contractor was selected and construction began in early September, 1981. Marsh construction, which included reconfiguration of the dredge spoils pile and modification of on-site drainage, was completed in early November 1981 and the area is now functioning as viable wildlife habitat. Revegetation has been allowed to occur on its own.

In its present form, the area is a shallow pond with dense marsh vegetation on one side only. Consequently, its use is limited to foraging and loafing birds. Recolonization and the establishment of a more extensive vegetative cover representative of complete restoration is expected to occur within 3 to 4 years.

Muzzi Marsh Restoration, a Mitigation Project

Phyllis Faber, ***California Wetland Coalition, Mill Valley, CA***

In 1976 a 200-acre parcel of diked and partially filled marshland on the San Francisco bayfront was purchased by the Golden Gate Bridge, Highway and Transportation District as a mitigation for development of a nerby ferry terminal facility. 135 acres were restored to tidal activity to mitigate dredging 83 acres of mudflat necessary to deepen a ferry access channel; 65 acres were used as a spoils disposal site. Four years after the dikes were breached natural recovery of the marsh was impressive: pickleweed *Salicornia virginica*, covered over 50 percent of the site and in one 20-acre study area, cordgrass, *Spartina foliosa*, increased by 790 percent between the third and fourth year of tidal activity. Active feeding of large flocks of shorebirds, herons and egrets indicate increases in invertebrate and fish populations.

Salt Marsh Restoration From Salt Evaporation Ponds: Vegetation Establishment and Sediment Properties

Michael Josselyn and Rick Perez, ***Department of Biological Sciences, San Francisco State University, San Francisco, CA***

The Hayward marsh restoration is a 200-acre site in south San Francisco Bay that has been created on the site of a former solar evaporation pond system. Prior to dike breaching, sediment salinities ranged between 9 to 181 ppt and small patches of *Salicornia virginica* were present along drainage canals. Following tidal flooding, surface sediment salinities dropped within ten months, ranging between 10 and 22 ppt. Vegetation establishment occurred by three mechanisms: airborn seeds, floating seeds, and vegetative growth from drift plant fragments. Examples of these dispersal mechanisms are found in *Cotula coronopifolia*, *Spergularia marina*, and *Salicornia virginica*, respectively. Establishment of new plants is limited by sediment scouring, adequate seed or fragment stock, distance of seed dispersal, and season.

Naturally Restored Wetlands

Paul R. Kelly, ***California Department of Fish and Game, Yountville, CA;***
Roy W. Lowe, ***Fish and Wildlife Service, Newark, CA;***
Thomas E. Harvey, ***Biosystems Analysis, Inc., San Francisco, CA***

Salt marsh restoration plans should first consider the simplest, most inexpensive means of regaining maximum productivity, *i.e.* the natural restoration of tidal influence. Many former tidelands have the potential for rapid regeneration of flora and fauna without the "benefit" of water control structures, excavation, dikes, designers or biologists. Examples of naturally restored wetlands and their wildlife values are reviewed.

Cabrillo Salt Marsh Construction

Los Angeles Harbor Department and EDAW, Inc., ***Newport Beach, CA***

The Los Angeles Harbor Department will construct a 5-acre salt marsh in the proposed West Channel/Cabrillo Beach Recreational Complex (WCCBRC) of the Port of Los Angeles. The conceptual plan for the salt marsh was developed by EDAW, Inc. in association with Santina Thompson as a cooperative effort with the WCCBRC Citizens Advisory Committee, state and federal wildlife agencies and the Los Angeles Harbor Department. EDAW, Inc./Santina Thompson have prepared the preliminary design, construction drawings and development specifications for the salt marsh construction.

Creation of the salt marsh is required by the U.S. Army Corps of Engineers as biological compensation for filling of two slips in the Port. Additionally, the overall goals of the construction of the Cabrillo salt marsh include:

- To enhance fishery resources by providing viable fishery habitat.
- To develop and enhance an intertidal wetland ecosystem.
- To protect and enhance native plant and wildlife species.
- To improve the public's understanding and appreciation of wildlife and tideland ecology.
- To provide an area for *in situ* studies of wildlife and marsh management techniques.
- To develop the salt marsh as an integral part of the new Cabrillo Museum educational experience and as an integral element of the proposed Recreational Complex.

Presently the site supports vegetative elements of a salt marsh without a well-developed community character. Additionally, the shore-water interface is very limited. As planned, the project will involve a total reconfiguration and expansion of the existing marsh area. Major features of the planned marsh include: an inlet/outlet which allows tidal influence and flushing; maximum screening and limited access from adjacent areas; an observation platform to permit interpretive use; a bird island surrounded by a permanent tidal lagoon; and the distinct zonation of intertidal and subtidal habitats.

A unique feature of the project is the attempt to apply standard commercial landscaping methods, which permit the project's construction to be bid and built by commercial contractors using common labor procedures. Commercial landscaping methods have been adapted to the salvaging, storage and transplanting of native salt marsh species. The use of hydroseeding and provision of a temporary supplemental irrigation system are expected to result in the rapid development of the salt marsh.

The Cabrillo salt marsh project is scheduled to begin construction in Spring 1982 and to be completed by the end of Summer 1982.

Fish Utilization of Tijuana Estuary: Applications for Wetland Restoration

Chris Nordby, ***Department of Biology, San Diego State University, San Diego, CA***

In an attempt to determine preference of fishes for spawning habitat, fish eggs and larvae were sampled bimonthly at Tijuana Estuary in main channels, tidal creeks and nearshore waters. Larval composition differed among the three habitats. Greater than 90 percent of the larvae collected from the main channel were gobies. Sixty percent were of a goby complex composed of three species: arrow goby, shadow goby and cheekspot goby. Longjaw mudsucker comprised the remaining 30 percent. Less abundant in the main channels were silversides and queenfish. Tidal creeks were dominated by longjaw mudsuckers, silversides, northern anchovy and the goby complex. The nearshore habitat was dominated by the goby complex, queenfish, white croaker, northern anchovy and silversides.

Eggs were more abundant in nearshore waters but all three habitats were similar in percent relative abundance. Main channel dominants included croakers, Pacific sardine, northern anchovy, sanddabs, topsmelt and California tonguefish. Northern anchovy, croakers, topsmelt and sanddabs were the most abundant taxa collected from the tidal creeks. In the nearshore habitat croakers, Pacific sardine, sanddabs, northern anchovy and Pacific mackerel were dominants.

Comparisons of community similarity based on relative abundance showed larval similarities of 35 percent for tidal creeks and main channels while main channels and nearshore were 50 percent similar. The comparison for eggs revealed tidal creeks and main channels to be 45 percent similar while main channels and nearshore were 90 percent similar.

It is suggested that channel morphometry and substrate-type affects the spawning preference in adults and the subsequent distribution of eggs and larvae. Straight, steep-banked dredged channels were associated with increased tidal velocities. The increased tidal velocities can inhibit burrow construction and maintenance of the dominant gobies. Firm substrates also inhibit burrow formation. High tidal velocities have been associated with translocation of eggs and larvae, a major cause of mortality in these species (Brothers 1975). Topsmelt eggs and larvae were positively associated with aquatic algae mats, particularly *Enteromorpha* species. These algae were more dense in low tidal velocity channels. It is suggested that longjaw mudsucker, topsmelt, northern anchovy and staghorn sculpin utilized the tidal creeks as spawning areas and that longjaw mudsucker and staghorn sculpin used such habitats as nurseries as well. Deeper creeks appeared to be utilized to a greater extent than shallower creeks. As fishes appear to demonstrate preferences for different substrates and channel morphometries these factors should be considered in planning wetland restoration projects.

Bolsa Chica — A Coastal Wetland Restoration Project

Harold Novick and Ron Hein, ***California Department of Fish and Game, Long Beach, CA***

The Bolsa Chica wetland is located near the city of Huntington each in southern California. Historically, it was an estuary comprising about 2300 acres of saltwater marsh with an adjacent large freshwater marsh of undetermined size. For approximately 80 years, human activities have altered and destroyed this coastal wetland. The most significant alteration was the construction of a dam with one-way tidegates across the major tributary, Freeman Creek, by owners of the Bolsa Chica Gun Club in 1899. This dam prevented tidal waters from nourishing the lowlands except for approximately 50 acres in Outer Bolsa Bay. With this altered water regime, marsh communities changed in the lowlands with a few areas transitioning to uplands and most others to a high saltmarsh community dominated by pickleweed, *Salicornia virginica*. Farming, oil development and later urban development encroached upon this historic wetland of which only 852 acres now remain.

In 1973, the State received title to 327.5 acres in a land trade agreement with the private landowner. The Department of Fish and Game dedicated the area as the Bolsa Chica Ecological Reserve and is responsible for its management. In 1978, the Department constructed containment levees, least tern nesting islands and public use facilities and restored tidal influence to 150 acres of this historic wetland. This project, in addition to 50 acres of relatively undisturbed saltmarsh in Outer Bolsa Bay comprises a 200-acre tidal system. Presently, an additional 85 acres of non-tidal wetlands are in the planning stages for restoration to tidal influence.

The restoration project has been most successful for fish and wildlife. Before the project, three species of fish were found in the area; now three years later 32 species have been observed and numbers continue to increase. Species utilizing the Reserve for spawning and foraging include topsmelt, California killifish, yellowfin croaker, round stingray, striped mullet and others. Bird species diversity and abundance have increased significantly with daily populations exceeding 7,000 in midwinter. Similarly, endangered species use has increased, particularly brown pelican and California least tern, the latter now nesting here.

While the status of the Bolsa Chica Ecological Reserve is secure, those remaining historic wetlands outside of State ownership are not. The private landowners have expressed a strong desire to develop this area. The California Coastal Commission and local government will ultimately determine the allowable land-uses for Bolsa Chica.

Restoration of Estuarine Habitat at the Mouth of Redwood Creek, Humboldt County, California

Cindy L. Ricks, *Oregon State University and Redwood National Park, Arcata, CA*

The mouth of Redwood Creek is located approximately 4.0 river km west of Orick, California. The relatively narrow floodplain is periodically inundated due to steep basin gradients, intense storms and rapid runoff characteristic of the region. The series of damaging floods in 1950, 1953, 1955, and 1964 prompted channelization of Redwood Creek in the vicinity of Orick. The downstream portion of the levee bypasses the last meander and diverts the flow directly to the ocean. Deleterious effects of restructuring the channel include loss of riparian vegetation, accumulation of sediment in areas which were previously viable fish-rearing habitat and isolation of productive slough areas.

Prior to channelization, high flows kept the south meander open and created an eddy against the cliffs on the north side of the mouth. Presently, sand is transported into the sloughs under conditions of high ocean swells during high tides. Waves propagate into the north slough and wash over the sand spit into the south slough. Aggradation of 1.3 -2.7 meters of sand has been measured along a transect in the south slough since the 1966 survey by the Army Corps of Engineers. The crest of the sand spit or berm has grown by 1.4-1.8 meters. This barrier prevents saltwater intrusion by overwash across most of the spit. Estuarine conditions develop only following periods of high ocean swells in late summer or early fall when saltwater enters through the mouth outlet or washes over the low berm on the north side.

High summer swells may also cause migration of the mouth outlet and effectively close the estuary. The volume of water increases, flooding backwater areas and adjacent pasturelands. Frequent backwater flooding is a relatively recent problem and may be a direct result of aggradation in the sloughs. High water levels induce local ranchers to break the sand berm prematurely, sweeping fish and invertebrate fauna out to sea. Thus, peak juvenile salmonid migration does not coincide with high invertebrate productivity which is dependent on estuarine conditions, substrate stability and algae growth.

Sediment which has accumulated in the sloughs must be flushed out or excavated in order to aid restoration of the natural aquatic habitat. Interdisciplinary studies will provide baseline data on water quality, anandromous salmonid migration, distribution and abundance of fish food organisms and historic and present patterns of inundation, sediment accumulation, and general estuarine morphology. Upon the conclusion of these studies, Redwood National Park will consider the feasibility of developing rehabilitation alternatives for the estuary.

Salt Marsh Restoration: Handmaking a Natural Habitat

Douglas Spicher, *Department of Biological Sciences, San Francisco State University, San Francisco, CA*

A salt marsh restoration usually involves returning natural tidal flow to an area which has been diked or restricted in some way. A major goal of a restoration is the reestablishment of plants within a marsh, and the restoration design should begin with a comprehensive plan which recognizes all geologic, hydrologic, and biologic problems and attempts to resolve them as they relate to each other. Since marsh plants are adapted to a certain range of conditions, early consideration must be given to soil elevations within the planned restoration and the types of soil conditions, particularly salinity and pH, which will be found at those elevations. Circulation and sedimentation patterns will affect both soil conditions and elevation and, depending on the hydrological design, the diversity of the marsh. These variables dictate which of the various planting methods, seeds, seedlings, sprigs, or plugs, can be used, and since each method has its own associated cost these methods should perhaps be considered in the beginning plan.

This poster reviews information regarding California salt marshes and considers variables affecting plant establishment such as hydrology of the marsh, soil substrate conditions, marsh diversity, and planting methods as well as planting costs. Each of these are explained in further detail as to how they are important to marsh plants; culminating with identifying methods of planting *Spartina foliosa* and their related costs and assessing procedures involved when confronted with various marsh conditions.

Examples of Marsh Restoration Design Practice in San Francisco Bay: A Controlled Level Marsh in Corte Madera

Philip B. Williams, *Philip Williams & Associates, San Francisco CA*
H. Thomas Harvey, *Harvey & Stanley Associates, Alviso, CA*

The Hahn Corporation is presently planning to construct a shopping center on an area of diked wetland between U.S. Highway 101 and Muzzi Marsh. Mitigation required for the filling of approximately 20 acres of the site is the restoration of the remaining 34 acres as a healthy salt marsh. Severe hydraulic design constraints on marsh restoration included the use of the area as a floodwater retention basin, subsidence of the marsh plain surface, future sedimentation, poor quality urban runoff, and a constricted half mile long channel linking the marsh to the Bay.

The poster display describes an integrated marsh management design prepared for and adopted by the Town of Corte Madera under the direction of Dr. Williams with the assistance of Professor Harvey, Tito Patri, principal of the Planning Collaborative, landscape architects, Gary Page, ornithologist for the Point Reyes Bird Observatory, and Ted Rust, principal of Rust & Weinstein, economical and environmental policy planners. The overall design concept for the marsh restoration is to integrate the use of the marsh as a flood basin and as a means of improving water quality, while restoring the salt marsh vegetation and enhancing wildlife and waterfowl habitat. It achieves this by utilizing the marsh as a flood basin during the winter months and then allowing limited tidal inflows during the summer, regulated by an automatic slide gate to restrict water levels to those suitable for extensive growth of cordgrass on the existing marsh plain. Other features of the design include grading to restore a more natural tidal drainage system, provision of open water and mud flat fringes for waterfowl, landscaping and design of tidal channels to control intrusion onto the marsh, separation of 3 acres of the marsh to act as a stormwater runoff pollutant trap during the winter months, and upgrading of pump station and outlet structures.

An interesting feature of the design is the projection of ultimate siltation within the marsh and in the connecting slough using 'regime' plots for tidal slough channel geometry based on surveys of adjacent natural sloughs. These plots relate tidal prism to slough depth and width.

The restoration plan also identifies an implementation program, schedule, and costs. The restoration is expected to begin early in 1982.

Examples of Marsh Restoration Design Practice in San Francisco Bay: A Brackish Marsh on Coyote Creek Slough

Philip B. Williams, ***Philip Williams & Associates San Francisco, CA***
H. Thomas Harvey, ***Harvey & Stanley Associates, Alviso, CA***

The development of 552 acres of former marshland for the Warm Springs International Park at the southern extremity of San Francisco Bay will require the filling of areas of seasonal wetland. As mitigation for this loss, the developer is proposing to manage approximately 265 acres of the site as a marsh. The site is unique in San Francisco Bay in that it offers the opportunity for creating an extensive contiguous area of tidal alkali bulrush marsh. This is because it is located upstream of Artesian Slough, which is the discharge point for the San Jose Sewage Treatment Plant, and salinity levels in Coyote Creek Slough are typically less than 6 ppt. The site is also notable for its extreme tidal range and high siltation potential. Major design constraints on the marsh restoration design include the desire by the developer to use much of the diked area as a borrow pit; the need to preserve and enhance an existing 25-acre pickleweed area that is a potential habitat for the salt marsh harvest mouse; and the need to provide sufficient stormwater retention capacity for the development's flood protection.

The poster display describes a conceptual design prepared for the developer, Fremont International Partners, by Cathy Merrill and Tony Wright of Thompson and Wright, architects and planners, Dr. Williams, and Professor Harvey. The design separates the marsh restoration into two areas: approximately 200 acres of the site will be opened to unrestricted tidal action to ultimately create an alkali bulrush marsh. Initially, the area will be excavated and then graded so as to provide an extensive perimeter around three separate basins at a suitable elevation for the establishment of alkali bulrush. As the construction of the development proceeds, these three basins would be opened in turn. The very high siltation rates will establish mud flats and a tidal slough system in the basins, so that the alkali bulrush will invade onto the mudflats from the surrounding perimeter. About 65 acres of marsh will be excavated as a flood retention basin, supplemented by an existing 25-acre pickleweed area which will be kept undisturbed. Periodic inundation of the 65 acres will take place during the summer by manually operated slide/flap gates.

The conceptual plan also includes landscaping and requirements for public access.

The plan is now in the process of being submitted for approval to regulatory agencies. Following this, a detailed design will be prepared.

Habitat Considerations for Light-Footed Clapper Rails in Marsh Design

Richard Zembal, ***U.S. Fish & Wildlife Service, Laguna Niguel, CA, and***
Barbara W. Massey, ***Long Beach, CA***

The recovery of the endangered light-footed clapper-rail *Rallus longirostris levipes*) (LFCR) is totally dependent on restoration, creation, and proper management of coastal wetlands.

Censusing of the known populations throughout the state revealed 203 pairs of LFCR distributed in 11 marshes from Carpenteria to Tijuana Estuary in 1980 and 173 pairs in 15 marshes in 1981. The observed distribution and relative densities of the LFCR along with more intensive study (initiated in 1979) of the populations at Anaheim Bay and Upper Newport Bay led to some conclusions concerning the species' habitat requirements with obvious implications for marsh design and management.

LFCR were found in order of decreasing abundance in marshes with abundant dense cordgrass (*Spartina foliosa*), in pickleweed (*Salicornia virginica*)-dominated marshes with little or no cordgrass, and in brackish to freshwater marshes with dominant freshwater reeds (*Scirpus* spp. and *Typha* spp.). Dense cordgrass provides a highly preferred habitat but all of a marsh and its environs are utilized, including adjacent upland slopes. A most productive situation is apparently provided by a large marsh comprised of numerous habitats as exemplified at Upper Newport Bay, where nearly half of the LFCR in the state were detected in 1980. LFCR do occur, however, in very small marshes with nearly monotypic vegetational cover.

A large portion of the LFCR's diet is apparently provided via the high invertebrate productivity associated with most marshes, particularly those with a good tidal prism. It appears, however, that ample water-free foraging habitat must be available on a regular, possibly daily, basis. Populations of LFCR have disappeared from several marshes that were (and mostly still are) periodically subjected to closed ocean entrances and subsequent prolonged flooding. Additionally, LFCR have not been detected in those coastal brackish to freshwater marshes comprised totally of emergent needs.

Nesting sites must be densely vegetated and high enough to afford protection from high tides and isolated enough in the marsh to be effectively protected from upland predators. Tidal creeks are effective nesting site isolators and also provide important foraging habitat and major thoroughfares. Nests are placed preferentially in tall cordgrass but large numbers are also located in upper saltmarsh vegetation and stands of freshwater reeds, particularly during years of poor growth by cordgrass. The scarcity of suitable nesting habitat appears to be a major limiting factor for several populations of the LFCR. Further development and implementation of techniques for establishing cordgrass and encouraging lush growth are needed along with the provision of protected upper marsh hummocks and/or fringing stands of freshwater reeds. A pilot project for establishing nesting hummocks at Anaheim Bay has been initiated by the authors.

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