

THE  
*Baylands*  
AND  
*Climate Change*

---

WHAT WE CAN DO

BAYLANDS ECOSYSTEM HABITAT GOALS  
SCIENCE UPDATE 2015



THE  
*Baylands*  
AND  
*Climate Change*



THE  
*Baylands*  
AND  
*Climate Change*

---

WHAT WE CAN DO

BAYLANDS ECOSYSTEM HABITAT GOALS  
SCIENCE UPDATE 2015



PREPARED BY  
THE SAN FRANCISCO BAY AREA  
WETLANDS ECOSYSTEM GOALS PROJECT

Copyright © 2015 California State Coastal Conservancy

All rights reserved. No part of this publication may be reproduced, distributed, or transmitted in any form or by any means, including photocopying, recording, or other electronic or mechanical methods, without the prior written permission of the publisher, except in the case of brief quotations embodied in critical reviews and certain other noncommercial uses permitted by copyright law. For permission or to order copies of the printed report, write to the publisher at the address below.

Program Manager, San Francisco Bay Area Conservancy  
California State Coastal Conservancy  
1330 Broadway, Suite 1300  
Oakland, CA 94612  
(510) 286-1015  
[info@baylandsgoals.org](mailto:info@baylandsgoals.org)  
[www.baylandsgoals.org](http://www.baylandsgoals.org)

For photo and illustration credits, see pages 234–5 which constitute an extension of this copyright page.

Please cite this report as:

Goals Project. 2015. *The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update 2015* prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA.

## FOREWORD

---

Climate change is altering the natural world at an accelerating pace, particularly in low-lying coastal areas like San Francisco Bay. Today management of the bay's shores must account for a future of rising sea levels and more extreme weather events while continuing to address the challenges posed by the demands of a growing urban population. Climate-change science has advanced greatly since the 1999 Baylands Ecosystem Habitat Goals were developed, spurring the need for a technical synthesis of climate-change projections and updated recommendations. The findings of this Science Update indicate clearly that restoring a vibrant and functioning baylands ecosystem will make our future shorelines more resilient to these stresses. Baylands restoration is not a luxury but an urgent necessity as ecological change accelerates.

This Science Update documents and celebrates the remarkable progress made toward achieving the 1999 Baylands Ecosystem Habitat Goals over the past decade and a half. Restoration managers have begun to reverse over a century of habitat loss in the baylands, recommitting tens of thousands of acres to the natural world through a comprehensive and adaptive restoration approach that enhances wildlife habitat, recreational opportunities, water quality, and flood protection.

The variety of uncertainties affecting the baylands requires transitioning from a static to a dynamic approach to planning, one that values flexibility and innovation. An increased commitment to long-term collaboration among diverse regional and local constituencies is essential, as is a willingness to study and learn from our inevitable missteps. This Science Update identifies strategies that are within the current experience of restoration managers but also calls for novel actions that are well beyond the scope of previous activities. Such a bold vision—along with improved

monitoring, governance, and financial investment—is required for an estuary that will support a thriving economy and quality of life in the more dynamic environment that the region now faces.

Achieving such a bold vision will require great focus and long-term resolve, and the successes in restoring the estuary to date show that local managers can devise solutions, learn their strengths and



Restoration of the baylands will be increasingly important in the coming century.

weaknesses, and expand actions when policy, funding, science, and regulation align effectively. The Science Update, however, highlights many unmet needs in achieving such an effective alignment. The scope and pace of scientific experimentation and monitoring must increase, relevant policies and regulations must support innovative strategies, and efficient and cost-effective paths to implementation are critical. In addition, it is quite possible that the pace of climate change will be faster than currently projected or that efforts to effectively mitigate its impacts will lag.

Consequently, now is the time to prepare to adapt—to experiment with new ideas and learn what novel techniques can be most effectively scaled up. We must also act quickly to implement the strategies known to work, to give the baylands the best chance to take advantage of current conditions while they last. At the same time, long-term opportunities to envision the shoreline will take decades to realize, and planning must begin now.

This Science Update is a nonregulatory, voluntary effort to point the Bay Area toward a more resilient future, with strategies that were developed over several years by several hundred experts and practitioners in the region. It is a first step on a long journey to learning how to live, work, and play with a changing estuary, an estuary where ecological processes and ecosystems are used to best advantage.

This region has the distinct advantage of a populace that recognizes the critical importance of the San Francisco Bay estuary and baylands to its economy and quality of life. We invite you to participate in this, the journey to our future bay.

*The Baylands Ecosystem Habitat Goals Steering Committee  
October 2015*

# Baylands Goals Science Update

SCIENCE REVIEW PANEL

---

October 2015

The San Francisco Bay ecosystem represents habitat of national and global significance as well as providing important ecosystem services for the region. The 1999 Baylands Ecosystem Habitat Goals report was a seminal document that provided a comprehensive scientific vision for non-tidal and tidal wetland restoration in the baylands ecosystem. This update incorporates new science available since that report and addresses the challenges resulting from the present-day understanding—of climate change and other key drivers—needed to maintain a resilient bayland ecosystem through 2100. The Science Review Panel (SRP) was convened to review the science included in the updated report, identify gaps in the individual chapters, and provide feedback to the Chapter authors and the Steering Committee. The SRP met twice with the Workgroup Chairs to review initial chapter drafts and to discuss issues, concerns, and feedback about our impressions of the scientific concepts, content, and general organization of the individual chapters. The SRP provided a written report and series of recommendations for the entire draft.

The Baylands Goals Science Update includes the work of over 100 scientists who represent an outstanding cross section of expertise and experience in the San Francisco Bay area. A considerable amount of work has been invested in the Baylands Goals Science Update, which reflects the wealth of new information available since 1999. The SRP was able to engage in robust discussions with the Chapter leads about the scientific information in their chapters. We commend all the authors and contributors for their efforts in completing this report, which represents a critically important long-term vision and consensus scientific basis for guiding the development of a resilient ecosystem that can respond to the environmental challenges of the 21st century. We fully expect that as the scientific understanding of these systems and their physical drivers change through continued research and monitoring, further updates will be produced and used in an adaptive management feedback process.



Dr. Glenn R. Guntenspergen (Chair), *U.S. Geological Survey*  
on behalf of:

Dr. Dan Cayan, *U.S. Geological Survey and Scripps Institute of Oceanography*

Dr. Peter Goodwin, *University of Idaho and Delta Science Program*

Dr. James Morris, *University of South Carolina*

Dr. Nils Warnock, *Audubon Alaska*

Dr. Joy Zedler, *University of Wisconsin*



# CONTRIBUTORS

---

## LEAD AUTHORS

### Ensuring a Healthier Bay Shore

Letitia Grenier, *Goals Project, San Francisco Estuary Institute*

Andrew Gunther, *Bay Area Ecosystems Climate Change Consortium*

### Chapter 1—New Understanding: The Baylands and Climate Change, and Chapter 2—New Opportunities: How We Can Achieve Healthy, Resilient Baylands

Letitia Grenier, *Goals Project, San Francisco Estuary Institute*

April Robinson, *San Francisco Estuary Institute*

Jeremy Lowe, *Environmental Science Associates (ESA), San Francisco Estuary Institute*

John Bourgeois, *South Bay Salt Pond Restoration Project*

Wim Kimmerer, *San Francisco State University*

Marilyn Latta, *Coastal Conservancy*

Josh Collins, *San Francisco Estuary Institute*

Donna Ball, *Save The Bay*

Nadav Nur, *Point Blue Conservation Science*

Bruce Herbold, *Independent Consultant*

John Callaway, *University of San Francisco*

Steve Crooks, *Environmental Science Associates*

## SCIENCE COORDINATOR

Letitia Grenier, *Goals Project, San Francisco Estuary Institute*

## PROJECT MANAGEMENT

Matt Gerhart, *Coastal Conservancy*

Nadine Peterson, *Coastal Conservancy*

Andrew Gunther, *Bay Area Ecosystems Climate Change Consortium*

Patricia Hickey, *Independent Consultant*

Brenna Mahoney, *Coastal Conservancy*

## STEERING COMMITTEE

Sam Schuchat, *Coastal Conservancy* (Chair); Joy Albertson, *US Fish and Wildlife Service*; Grant Ballard, *Point Blue Conservation Science*; Chris Barton, *East Bay Regional Park District*; Marina Brand, *Delta Stewardship Council*; Erin Chappell, *California Department of Water Resources*; Steve Chappell, *Suisun Resource Conservation District*; Michael Connor, *East Bay Dischargers Association*; Natalie Cosentino-Manning, *National Oceanic and Atmospheric Administration*; Kristal Davis-Fadtke, *Delta Conservancy*; Naomi Feger, *San Francisco Bay Regional Water Quality Control Board*; Andree Greenberg, *San Francisco Bay Regional Water Quality Control Board*; Robin Grossinger, *San Francisco Estuary Institute*; Beth Huning, *San Francisco Bay Joint Venture*; Judy Kelly, *San Francisco Estuary Partnership*; Tom Kendall, *US Army Corps of Engineers*; Joe LaClair, *San Francisco Bay Conservation and Development Commission*; Carol Mahoney, *Bay Area Flood Protection Agencies Association*; Lester McKee, *San Francisco Estuary Institute*; Mike Monroe, *URS Corporation*; Anne Morkill, *US Fish and Wildlife Service*; Carl Morrison, *Bay Area Flood Protection Agencies Association*; Brad Olson, *East Bay Regional Park District*; Nadine Peterson, *Coastal Conservancy*; Patrick Rutten, *National Oceanic and Atmospheric Administration*; Korie Schaeffer, *National Oceanic and Atmospheric Administration*; Rebecca Smyth, *National Oceanic and Atmospheric Administration Coastal Services Center*; Mendel Stewart, *US Fish and Wildlife Service*; Fari Tabatabai, *retired, US Army Corps of Engineers*; Luisa Valiela, *US Environmental Protection Agency*; Kristen Ward, *National Park Service/Golden Gate National Recreation Area*; Carl Wilcox, *California Department of Fish and Wildlife*; Julian Wood, *Point Blue Conservation Science*; Sam Ziegler, *US Environmental Protection Agency*

## SCIENCE REVIEW PANEL

Glenn Guntenspergen, *US Geological Survey* (Chair); Dan Cayan, *US Geological Survey, Scripps Institute of Oceanography*; Peter Goodwin, *University of Idaho, Delta Science Program*; James Morris, *University of South Carolina*; Nils Warnock, *Audubon Alaska*, Joy Zedler, *University of Wisconsin*

## SCIENCE FOUNDATION CHAPTERS

### Chapter 1: The Dynamic Workings of the Baylands, and Chapter 2: Projected Evolution of Baylands Habitats

**Chairs**—Jeremy Lowe, *Environmental Science Associates (ESA), San Francisco Estuary Institute* and John Bourgeois, *South Bay Salt Pond Restoration Project, Coastal Conservancy*

**Contributing Authors**—Donna Ball, *Save The Bay*; Peter Baye, *Coastal Ecologist*; John Callaway, *University of San Francisco*; Steve Crooks, *Environmental Science Associates*; Letitia Grenier, *Goals Project, San Francisco Estuary Institute*; Robin Grossinger, *San Francisco Estuary Institute*; Roger Leventhal, *Marin Department of Public Works*; Lester McKee, *San Francisco Estuary Institute*; Michelle Orr, *Environmental Science Associates*; Sarah Richmond, *San Francisco Bay Conservation and Development Commission*; Lisa Schile, *University of California Berkeley*; Kathleen Swanson, *US Geological Survey*

**Workgroup Members**—Grant Ballard, *Point Blue Conservation Science*; Julie Beagle, *San Francisco Estuary Institute*; Kristen Cayce, *San Francisco Estuary Institute*; Sarah Lowe, *San Francisco Estuary Institute*; Bruce Jaffe, *US Geological Survey*; Karen Thorne, *US Geological Survey*; Laura Valoppi, *US Geological Survey/South Bay Salt Pond Restoration Project*; Sam Veloz, *Point Blue Conservation Science*; Greg Shellenberger, *US Geological Survey*; Christina Toms, *Environmental Science Associates*

### Chapter 3: Connections to the Bay

**Chairs**—Wim Kimmerer, *San Francisco State University* and Marilyn Latta, *Coastal Conservancy*

**Contributing Authors**—Katharyn Boyer, *San Francisco State University*; Susan De La Cruz, *US Geological Survey*; Ted Grosholz, *University of California Davis*; Maureen Downing-Kunz, *US Geological Survey*; Jessica Lacey, *US Geological Survey*; Jan Thompson, *San Jose State University*;

Chela Zabin, *Smithsonian Environmental Research Center*

**Workgroup Members**—Natalie Cosentino-Manning, *National Oceanic and Atmospheric Administration*; Amy Foxgrover, *US Geological Survey*; Brenda Goeden, *San Francisco Bay Conservation and Development Commission*; Letitia Grenier, *Goals Project, San Francisco Estuary Institute*; Analise Hettinger, *Oregon State University*; Kelley Higgason, *Greater Farallones National Marine Sanctuary*; Judy Kelly, *San Francisco Estuary Partnership*; Noah Knowles, *US Geological Survey*; Rob Leidy, *Environmental Protection Agency*; Korie Schaeffer, *National Oceanic and Atmospheric Administration*; Christina Sloop, *San Francisco Bay Joint Venture*; Caitlin Sweeney, *San Francisco Estuary Partnership*

### Chapter 4: Connections to the Watersheds: The Estuarine–Terrestrial Transition Zone

**Chairs**—Josh Collins, *San Francisco Estuary Institute* and Donna Ball, *Save The Bay*

**Contributing Authors**—Peter Baye, *Coastal Ecologist*; Erin Beller, *San Francisco Estuary Institute*; Roger Leventhal, *Marin Department of Public Works*; Sarah Richmond, *San Francisco Bay Conservation and Development Commission*

**Workgroup Members**—Elizabeth Brusati, *California Invasive Plant Council*; Dylan Chapple, *Save The Bay*; Ron Duke, *H.T. Harvey & Associates*; Xavier Fernandez, *San Francisco Bay Regional Water Quality Control Board*; Brian Fulfrost, *Brian Fulfrost and Associates*; Matt Gerhart, *Coastal Conservancy*; Letitia Grenier, *Goals Project, San Francisco Estuary Institute*; Brenda Grewell, *University of California Davis*; Robin Grossinger, *San Francisco Estuary Institute*; John Klochak, *US Fish and Wildlife Service*; Jon Krause, *California Department of Fish and Wildlife*; Ben Livesy, *San Francisco Estuary Partnership*; Sarah Lowe, *San Francisco Estuary Institute*; Meg Marriott, *US Fish and Wildlife Service*; Nadav Nur, *Point Blue Conservation Science*; Rosa Schneider, *San Francisco Bay Conservation and Development Commission*; Howard Shellhammer, *H.T. Harvey & Associates*; Christina Sloop, *San Francisco Bay Joint Venture*; David Thomson, *San Francisco Bay Bird Observatory*; Laura Valoppi, *US Geological Survey/South Bay Salt Pond Restoration Project*

## Chapter 5: Risks from Future Change for Wildlife

*Chairs*—Nadav Nur, *Point Blue Conservation Science* and Bruce Herbold, *Independent Consultant*

*Contributing Authors*—Josh Ackerman, *US Geological Survey*; Sarah Allen, *National Park Service*; Lauren Barthman-Thompson, *California Department of Fish and Wildlife*; Randy Baxter, *California Department of Fish and Wildlife*; Peter Baye, *Coastal Ecologist*; Valary Bloom, *US Fish and Wildlife Service*; Katharyn Boyer, *San Francisco State University*; Elizabeth Brusati, *California Invasive Plant Council*; Mike Casazza, *US Geological Survey*; Josh Collins, *San Francisco Estuary Institute*; Susan De La Cruz, *US Geological Survey*; Sarah Estrella, *California Department of Fish and Wildlife*; Jules Evens, *Avocet Research Associates*; Denise Greig, *Marine Mammal Center*; Brenda Grewell, *University of California Davis*; Ted Grosholz, *University of California Davis*; Jim Hobbs, *University of California Davis*; Drew Kerr, *Invasive Spartina Project*; Patrick Kleeman, *National Park Service*; Marilyn Latta, *Coastal Conservancy*; Cynthia LeDoux-Bloom, *ManTech International*; Karen Martin, *Pepperdine University*; Peggy Olofson, *Olofson Environmental*; Brian Orr, *University of California San Francisco*; Cory Overton, *US Geological Survey*; Howard Shellhammer, *H.T. Harvey & Associates*; Christina Sloop, *San Francisco Bay Joint Venture*; Cheryl Strong, *US Fish and Wildlife Service*; Ramona Swenson, *Environmental Science Associates*; John Takekawa, *US Geological Survey/Audubon*; Rachel Tertes, *US Fish and Wildlife Service*; Karen Thorne, *US Geological Survey*; Whitney Thornton, *San Francisco State University*; Isa Woo, *US Geological Survey*; Julian Wood, *Point Blue Conservation Science*; Greg Yarris, *US Fish and Wildlife Service/Central Valley Joint Venture*

*Workgroup Members*—Bob Batha, *San Francisco Bay Conservation and Development Commission*; Letitia Grenier, *Goals Project, San Francisco Estuary Institute*; Wim Kimmerer, *San Francisco State University*; John Krause, *California Department of Fish and Wildlife*; Jen McBroom, *Invasive Spartina Project*; April Robinson, *San Francisco Estuary Institute*; Charles “Si” Simenstad, *University of Washington*; Camm Swift, *retired, Natural History Museum of Los Angeles County*

Karen Taylor, *California Department of Fish and Wildlife*; Laura Valoppi, *US Geological Survey/South Bay Salt Ponds Restoration Project*

## Chapter 6: Carbon Sequestration and Greenhouse Gases in the Baylands

*Chairs*—John Callaway, *University of San Francisco* and Steve Crooks, *Environmental Science Associates*

*Workgroup Members*—Dennis Baldocchi, *University of California Berkeley*; Erin Chappell, *California Department of Water Resources*; Steve Deverel, *Hydrofocus*; Judy Drexler, *US Geological Survey*; Letitia Grenier, *Goals Project, San Francisco Estuary Institute*; Robin Miller, *US Geological Survey*; Lisa Windham-Myers, *US Geological Survey*

## MAPS AND SPATIAL ANALYSIS

April Robinson, Kristen Cayce, Pete Kauhanen, Marcus Klatt, Sam Nakata, *all San Francisco Estuary Institute*

## CLIMATE SCENARIOS REVIEW

Patrick Barnard, Dan Cayan, Noah Knowles, Mary Tyree, *all US Geological Survey*

## CASE STUDY AUTHORS

Josh Ackerman, *US Geological Survey*—Forster’s tern and California least tern; Shore birds: Western sandpiper and American Avocet, Diving ducks, Dabbling ducks  
Sarah Allen, *National Park Service*—California red-legged frog, Harbor seal  
Lauren Barthman-Thompson, *Point Blue Conservation Science*—Salt marsh harvest mouse  
Randy Baxter, *California Department of Fish and Wildlife*—Longfin smelt  
Peter Baye, *Coastal Ecologist*—Pacific cordgrass, Plant guild  
Katharyn Boyer, *San Francisco State University*—Pacific cordgrass  
Elizabeth Brusati, *California Invasive Plant Council*—Marsh macroinvertebrates  
Josh Collins, *San Francisco Estuary Institute*—Pacific cordgrass  
Susan De La Cruz, *US Geological Survey*—Diving ducks  
Sarah Estrella, *California Department of Fish and Wildlife*—Baylands shrews

Jules Evens, *US Geological Survey*—Northern harrier, California black rail

Denise Greig, *California Academy of Sciences*—Harbor seal

Ted Grosholz, *University of California Davis*—Pacific cordgrass

C. Alex Hartman, *US Fish and Wildlife Service*—Forster’s tern and California least tern

James Hobbs, *University of California Davis*—Longjaw mudsucker

Drew Kerr, *Invasive Spartina Project*—Pacific cordgrass

Wim Kimmerer, *San Francisco State University*—Northern anchovy, Delta smelt, Dungeness crab, Pacific herring, Oyster beds and reefs, Plankton, Rocky intertidal organisms, Salmon, Submerged aquatic vegetation

Patrick Kleeman, *US Geological Survey*—California red-legged frog

Marilyn Latta, *Coastal Conservancy*—Pacific cordgrass

Cynthia LeDoux-Bloom, *AECOM*—North American river otter

Karin Martin, *Pepperdine University*—California grunion

Nadav Nur, *Point Blue Conservation Science*—Tidal marsh song sparrows

Peggy Olofson, *Olofson Environmental*—Pacific cordgrass

Brian Orr, *University of California San Francisco*—Pacific cordgrass

Cory Overton, *US Geological Survey*—California Ridgway’s rail

Howard Shellhammer, *H.T. Harvey & Associates*—Salt marsh harvest mouse, Baylands shrews

Christina Sloop, *San Francisco Bay Joint Venture*—Vernal pools, Pacific cordgrass

Cheryl Strong, *US Fish and Wildlife Service*—Forster’s tern and California least tern; Shore birds: Western sandpiper and American avocet

John Takekawa, *US Geological Survey*—Diving ducks

Rachel Tertes, *US Fish and Wildlife Service*—California toad

Whitney Thornton, *Invasive Spartina Project*—Pacific cordgrass

Lauren Thompson, *California Department of Fish and Wildlife*—Salt marsh harvest mouse

Karen Thorne, *US Geological Survey*—California black rail

Isa Woo, *US Geological Survey*—Marsh macroinvertebrates

Julian Wood, *Point Blue Conservation Science*—California Ridgway’s rail

Greg Yarris, *US Fish and Wildlife Service*—Diving ducks, Dabbling ducks

#### PLENARY WORKSHOP PARTICIPANTS

Joy Albertson, Sarah Allen, Donna Ball, Mark Boucher, John Bourgeois, Bill Brostoff, Elizabeth Brusati, Kristen Cayce, Erin Chappell, Steve Chappell, Josh Collins, Michael Connor, Natalie Costentino-Manning, Kristal Davis-Fadtke, Jill Demers, Melanie Denninger, Tim Doherty, Ron Duke, Sarah Estrella, Naomi Feger, Arthur Feinstein, Matt Ferner, Brian Fulfrost, Kristin Garrison, Paul Garrison, Matt Gerhart, Brenda Goeden, Wendy Goodfriend, Andree Greenberg, Robin Grossinger, Andy Gunther, Bruce Herbold, Beth Huning, Amy Hutzell, Judy Kelly, Tom Kendall, Wim Kimmerer, John Krause, Marilyn Latta, Cynthia LeDoux-Bloom, Shin-Roei Lee, Roger Leventhal, Len Liu, Erik Loboschefskey, Jeremy Lowe, Carol Mahoney, Michael MacWilliams, Meg Marriott, Jen McBroom, Mike Monroe, Anne Morkill, Nadav Nur, Brad Olson, Michelle Orr, Nadine Peterson, Jenny Quay, Sarah Richmond, Barbara Salzman, Sam Schuchat, Greg Shellenberger, Howard Shellhammer, Pat Showalter, Christina Sloop, Cheryl Strong, Kathleen Swanson, Karen Taylor, Rachel Tertes, Lauren Thompson, David Thomson, Luisa Valiela, Laura Valoppi, Sam Veloz, Laura Wainer, Kristin Ward, Nils Warnock, Maggie Weng, Betsy Wilson, Julian Wood, Katy Zarembo

#### ADDITIONAL REVIEW

The review of draft materials by individuals from the following organizations was greatly appreciated: Alameda County Public Works, Bay Area Open Space Council, Bay Planning Coalition, California State Water Resources Control Board, Cargill, Citizens Committee to Complete the Refuge, San Francisquito Creek Joint Powers Authority, Save The Bay, Sonoma Land Trust, Sonoma Resource Conservation District, The Bay Institute, The Nature Conservancy, US Fish and

Wildlife Service Sacramento Fish and Wildlife Field Office, and US Geological Survey Western Ecosystem Research Center.

#### **ADMINISTRATIVE SUPPORT**

##### **Implementation**

Nadine Peterson, Matt Gerhart, Amy Hutzal, Brenna Mahoney, *all Coastal Conservancy*; Letitia Grenier, *Goals Project, San Francisco Estuary Institute*; Andrew Gunther, *Bay Area Ecosystems Climate Change Consortium*; Patricia Hickey, *Independent Consultant*

##### **Meeting Facilitation**

Mary Selkirk, Gina Bartlett, Marci DuPraw, *all Center for Collaborative Policy*

##### **Communication**

Full Court Press, Warner Chabot, Doug Cordell, Matt Gerhart, Sean Greene, Andrew Gunther, Tony Hale, Beth Huning, Cyril Manning, Nadine Peterson, Melissa Pitkin, Caitlin Sweeney, Caroline Warner, Dick Wayman, Luisa Valiela

##### **Design and Production**

*Design and Layout:* Seventeenth Street Studios  
*Copy Editor:* Karen Seriguchi

#### **FUNDERS**

Major funding provided by the California State Coastal Conservancy and the Gordon and Betty Moore Foundation.

Financial contributions also kindly provided by the San Francisco Estuary Institute, US Army Corps of Engineers, San Francisco Bay Joint Venture, San Francisco Bay Conservation and Development Commission, California Landscape Conservation Cooperative, San Francisco Bay Wildlife Society, San Francisco Bay Regional Water Quality Control Board, and San Francisco Estuary Partnership.

*Please forgive any unintentional omissions.*



# CONTENTS

---

## **Overview** **xxi**

- ▶ **Ensuring a Healthier Bay Shore** **xxii**

## **Chapter 1—New Understanding: The Baylands and Climate Change** **1**

- ▶ **Updating our Vision for the Future** **3**
  - Purpose **4**
  - Intended Use **5**
- ▶ **Relationship to the 1999 Baylands Ecosystem Habitat Goals** **8**
  - Impact of the 1999 Goals Project **8**
  - Process for Developing the Science Update **9**
  - Geographic Scope **11**
  - Baylands Ecosystem **13**
- ▶ **Change in Baylands Habitats over Time** **14**
  - Progress toward the Habitat-Acreage Goals **14**
  - Changes in Habitat Configuration **20**
  - Framing Future Change in the Baylands **24**
  - Future Scenarios Evaluated **25**
- ▶ **The Dynamic Workings of the Baylands** **26**
  - Natural Processes Conferring Resilience on the Baylands **26**
  - Complete Tidal Wetlands **27**
  - Natural Processes Governing the Extent of Marshes **28**
  - Drowning and Accretion **30**
  - Key Physical and Chemical Drivers **33**
- ▶ **Projected Evolution of Baylands Habitats** **40**
  - Tidal Baylands **40**
  - Diked Baylands **42**
  - Considerations for Actions Related to Habitat Evolution **45**

- ▶ **Connections to the San Francisco Bay 52**
  - Future Change in the Bay Connection 54
  - Considerations for Actions Related to the Bay Connection 57
- ▶ **Connections to the Watersheds: The Estuarine-Terrestrial Transition Zone 58**
  - Definition and Description of the Transition Zone 59
  - Transition Zone Ecosystem Services 63
  - Types of Transition Zones 64
  - Considerations for Actions Related to the Transition Zone 66
- ▶ **Risks from Future Change for Wildlife 70**
  - Case Studies 71
  - Impacts on Wildlife 73
  - Summary of Consequences for Wildlife 81
  - Considerations for Actions Related to Wildlife 81
- ▶ **Carbon Sequestration and Greenhouse Gases in the Baylands 86**
  - Carbon Sequestration 86
  - Greenhouse Gas Emissions 88
  - Considerations for Actions Related to Carbon Management 88

## **Chapter 2—New Opportunities: How We Can Achieve Healthy, Resilient Baylands 93**

---

- ▶ **Introduction 95**
- ▶ **Highlights 96**
  - Strategy 1. Restore estuary–watershed connections 96*
  - Strategy 2. Design complexity and connectivity into the baylands 97*
  - Strategy 3. Increase coordination among baylands stakeholders 98*
  - Strategy 4. Create plans that factor in ecological outcomes 100*
  - Strategy 5. Engage the citizenry 101*
- ▶ **Regional Actions 104**
  - 1. Restore estuary–watershed connections 105*
  - 2. Design complexity and connectivity into the baylands 106*
  - 3. Restore and protect complete tidal wetlands systems 107*
  - 4. Restore the baylands to full tidal action 107*
  - 5. Plan for the baylands to migrate 108*
  - 6. Actively recover, protect, and monitor wildlife 109*

7. <i>Develop and implement a comprehensive regional sediment-management plan</i>	<b>112</b>
8. <i>Invest in planning, policy, research, and monitoring</i>	<b>113</b>
9. <i>Develop a regional transition zone assessment program</i>	<b>115</b>
10. <i>Improve carbon management in the baylands</i>	<b>117</b>
<b>► Subregion Visions and Segment Actions</b>	<b>118</b>
Suisun Subregion	<b>121</b>
<i>Segment A: Suisun Marsh East</i>	<b>124</b>
<i>Segment B: Suisun Marsh West</i>	<b>128</b>
<i>Segment C: Contra Costa North</i>	<b>133</b>
North Bay Subregion	<b>137</b>
<i>Segment D: Napa River Area</i>	<b>140</b>
<i>Segment E: Sonoma Creek Area</i>	<b>145</b>
<i>Segment F: Petaluma River Area</i>	<b>150</b>
<i>Segment G: North Marin</i>	<b>155</b>
<i>Segment H: Contra Costa West</i>	<b>160</b>
Central Bay Subregion	<b>165</b>
<i>Segment I: South Marin</i>	<b>168</b>
<i>Segment J: San Francisco Area</i>	<b>173</b>
<i>Segment K: Oakland Area</i>	<b>178</b>
<i>Segment L: Berkeley Area</i>	<b>183</b>
South Bay Subregion	<b>189</b>
<i>Segment M: San Mateo Area</i>	<b>192</b>
<i>Segment N: Redwood City Area</i>	<b>196</b>
<i>Segment O: Mountain View Area</i>	<b>201</b>
<i>Segment P: Coyote Creek Area</i>	<b>206</b>
<i>Segment Q: Mowry Slough Area</i>	<b>211</b>
<i>Segment R: Coyote Hills Area</i>	<b>215</b>
<i>Segment S: Baumberg Area</i>	<b>219</b>
<i>Segment T: Hayward Area</i>	<b>224</b>
Species List	<b>231</b>
Photo Credits	<b>234</b>
Illustration Credits	<b>235</b>

## Online Materials: Appendices and Science Foundation Chapters

The appendices to this report, the Science Foundation Chapters, and related materials are found at [www.baylandsgoals.org](http://www.baylandsgoals.org).

- ▶ **New Understanding—The Baylands and Climate Change: Appendices**
  - Appendix A: Process for Updating the Baylands Goals
  - Appendix B: Change in the Extent of Baylands Habitat
  - Appendix C: Changes in the Configuration of Baylands Habitats
  - Appendix D: Future Scenarios Evaluated
  - Appendix E: Habitat Types
  
- ▶ **Science Foundation Chapters**
  - Chapter 1: The Dynamic Workings of the Baylands
  - Chapter 2: Projected Evolution of Baylands Habitats
    - Appendix 2.1: Vertical Accretion Models of Future Marsh Evolution*
  - Chapter 3: Connections to the Bay
    - Appendix 3.1: Case Studies*
  - Chapter 4: Connections to the Watersheds: The Estuarine–Terrestrial Transition Zone
    - Appendix 4.1: Recommended Definition of the Estuarine–Terrestrial Transition Zone Guiding Principles and Criteria*
    - Appendix 4.2: Profiles of the Transition Zone Types*
    - Appendix 4.3: The Importance of SZ2 in Marsh–Upland Transitions*
  - Chapter 5: Risks from Future Change for Wildlife
    - Appendix 5.1: Case Studies*
  - Chapter 6: Carbon Sequestration and Greenhouse Gases in the Baylands
    - Appendix 6.1: Evaluation of Carbon Dynamics in the Baylands*

## FIGURES, TABLE, AND BOXES

---

### ► Figures

- Figure 1 Change in the extent of baylands habitats over time **9**
- Figure 2 Goals Project area **12**
- Figure 3 Major habitat types **14**
- Figure 4 Baylands habitats c. 1800 **16**
- Figure 5 Baylands habitats in 1998 **17**
- Figure 6 Baylands habitats in 2009 **18**
- Figure 7 Baylands habitats with planned projects **19**
- Figure 8 Tidal marsh patches by size in 2009 **21**
- Figure 9 Core and edge tidal marsh habitat in 2009 **22**
- Figure 10 Total marsh area within each patch-size category for each subregion in 2009 **23**
- Figure 11 Schematic of the complete tidal wetland system **28**
- Figure 12 Analysis of GAP status of undeveloped lands within the footprint of the baylands **30**
- Figure 13 Results from the Marsh98 model showing projected marsh habitat extents under different sea-level rise and sediment supply scenarios for both current tidal areas and potential restoration areas. **43**
- Figure 14 Distribution of modeled habitat types in 2110 from the MEM projects at China Camp marsh for various rates of sea-level rise and suspended-sediment concentrations **44**
- Figure 15 The impact of sea-level rise on managed ponds over time, from the present day to 50 years from now **45**
- Figure 16 Example of a broad natural levee extending into former tidal marsh **47**
- Figure 17 Example of a supratidal area caused by flood deposits of sediment on top of tidal marsh **47**
- Figure 18 Example of a levee realignment, coupled with tidal marsh restoration **50**
- Figure 19 Conceptual phasing of adaptation measures triggered by changes in sea level, rather than a chronological timeline **52**
- Figure 20 Transition zone boundaries corresponding to different ecosystem services **61**
- Figure 21 A typical arrangement of the natural transition zone types in a virtual San Francisco Bay landscape **65**
- Figure 22 Spatial relationships among transition zone types and subzones **65**
- Figure 23 Average percentage of organic matter content in baylands soil **89**

Figure 24	Artist’s rendering of an envisioned future baylands depicting implementation of the regional strategies to promote resilience in the baylands landscape, its habitats, and wildlife	<b>102</b>
Figure 25	Project area with subregions and segments	<b>119</b>
<b>▶ Table</b>		
Table 1	List of case studies	<b>72</b>
<b>▶ Boxes</b>		
Box 1	The Success of the 1999 Baylands Goals	<b>6</b>
Box 2	Mapping the Changing Baylands: Methods and Assumptions for the Baylands Habitat Maps	<b>15</b>
Box 3	Lessons Learned: The Evolution of a Big-Picture Vision of Restoration	<b>31</b>
Box 4	Planning in the Face of Uncertainty: The South Bay Salt Pond Restoration Project Adaptive Management Plan	<b>38</b>
Box 5	Planning to Implement Recommendations for Regional and Subregional Goals	<b>49</b>
Box 6	The Future Shoreline	<b>62</b>
Box 7	Regulatory Challenges and Opportunities	<b>78</b>
Box 8	Challenges to Funding Restoration and Long-Term Monitoring, Maintenance, and Management	<b>90</b>

THE  
*Baylands*  
AND  
*Climate Change*

---

WHAT WE CAN DO

BAYLANDS ECOSYSTEM HABITAT GOALS  
SCIENCE UPDATE 2015

OVERVIEW





# Ensuring a Healthier Bay Shore

## **RESTORE WETLANDS TODAY, FOR THE FUTURE**

The wetlands at the shore of the San Francisco Bay are an integral part of the region's iconic beauty, and they provide numerous benefits for our economy and quality of life. These baylands support abundant wildlife, clean water, open space for recreation, and flood protection. More than 100 scientists who study the bay, its wetlands, and watersheds have concluded that now is the time to ensure that these ecosystems continue to provide such benefits. Sea-level rise and climatic and other changes have brought about a critical moment. The extensive bay marshes and mudflats can be sustained for decades to come, but it will require a bold approach to restoring their natural processes. Meanwhile, we must also accelerate the concerted action of the past two decades to restore tidal habitats.



This page, from top: marshland near San Pablo Bay, a young volunteer. Facing page: endangered salt marsh harvest mouse; a stream channel wall; cities around San Francisco Bay.

Much progress has been made on restoring San Francisco Bay's tidal wetlands since the *Baylands Ecosystem Habitat Goals* report was released in 1999. This science update to that report provides guidance for sustaining a healthy and vibrant shore. Carrying out its recommendations will help meet state and federal objectives for the conservation of endangered and threatened species. And it will implement federal strategies (*Tidal Marsh Ecosystem Recovery*) and state plans (*Safeguarding California*) to withstand the impacts of climate change.



## A BAY SURROUNDED BY WALLS AND CONCRETE?

Projections show that if we don't act, rising seas and greater erosion will cause the baylands to shrink. We would lose the protection these wetlands provide to our shoreline by buffering storm waves, and the cost-effectiveness of a natural infrastructure that adjusts as sea levels rise. The bay would fundamentally change, with hardened edges and little vegetation.

Eventually, this damage would be irreversible. The region would be obliged to construct and maintain more sea walls and levees, and larger ones. (In places where wetlands are not naturally sustainable, other forms of sea level rise adaptation will be required in any case.) The baylands would eventually retract to narrow strips at the base of these structures or disappear altogether. Water quality could degrade as the baylands would no longer absorb excess nutrients from wastewater or filter contaminants. The diversity and abundance of native animals and plants would be drastically reduced. Several endangered species found only in San Francisco Bay could go extinct, and millions of migratory waterbirds would lose critical feeding and wintering grounds.



*“This report tells us what we need to do today to ensure a healthy San Francisco Bay into our future. If we have the courage to act now and follow scientific recommendations, we can secure much of what is most precious about living in the Bay Area, and ensure the gratitude of our grandchildren.”*

Sam Schuchat, Executive Officer,  
California Coastal Conservancy;  
Chair, Baylands Ecosystem Habitat Goals  
Update Steering Committee





## HOW DID WE GET TO THIS POINT?

The forces that control the balance of land and water in San Francisco Bay are changing. The sea level is rising, weather patterns are shifting, and the sediment supply that has helped nourish the baylands since the Gold Rush appears to have been exhausted. Without enough sediment to sustain bay wetlands as sea levels rise—especially coupled with a greater frequency of extreme storms, flooding, droughts, and heat waves—most of the marshes are projected to be damaged or destroyed by 2100 unless we intervene now.

Our response to these events will be fundamental to the fate of wildlife populations. We will either choose to actively support population recovery after a disaster or exacerbate the harm with inappropriate responses. Higher average temperatures, a greater intrusion of seawater into the bay, and new invasions by exotic species will also affect natural communities.

This pivotal moment comes after nearly two centuries of habitat loss and degradation as well as the modification of key natural processes such as freshwater flows, tidal exchange, flood-plain productivity, and invasion by nonnative species. Our levees, flood-control channels, roads, railways, storm drains, garbage dumps, and sewage treatment systems have all been built at the edge of the bay. This alteration of the shore has left a legacy of fragmented habitats with small and stressed native wildlife populations and fixed, inflexible systems for controlling water and sediment flows. Neither our critical human-built infrastructure nor the remaining natural habitats are expected to be resilient to coming changes without significant new investment in adaptation and resilience strategies.



*“Rising sea level, more extreme weather events, and other impacts of climate change are already altering our region’s ecosystems, and this will accelerate in coming decades. By using our new scientific understanding to highlight important actions for visionary management, this document provides a vital basis for sustaining the iconic beauty and valuable services of our remarkable baylands for future Bay Area residents.”*

Carl Wilcox, California Department of Fish and Wildlife, project co-chair and contributing author of *Baylands Ecosystem Habitat Goals* report (1999)

This page, from top: bicyclists on a levee; assessing health of baby tern. Facing page, top: volunteers put in marsh plants.

## NEW APPROACHES, NEW POLICIES

To arrive at a future with functioning, dynamic baylands, we must act immediately. Resilience to sea-level rise depends on natural processes that work over years and decades. We need to adjust our policies to encourage the rapid restoration and enhancement of the natural infrastructure that cost-effectively protects people and property while also supporting native plants and animals.

## STRATEGIES FOR A HEALTHY SHORE

The scientists that developed this report suggest regional strategies to maintain healthy baylands and the benefits they provide. These strategies are summarized below and listed in full in the second chapter of the report.

### Restore complete baylands systems.

To achieve and maintain the Baylands Goals (100,000 acres of tidal marsh and the targets for other habitat types), we should maximize baylands resilience. This means restoring complete wetland systems with their many interconnected habitat types, along with the physical processes that sustain them. Reconnecting the baylands to nearby open lands is also crucial to provide wildlife with refuge during high-water events and for



Below: Artist's conceptual rendering shows a future Bay Area shoreline that has successfully accommodated significant sea-level rise through the restoration of baylands and the processes that sustain them. Reconnected waterways provide adequate sediment and freshwater to sustain marshes, while diverse connected marsh habitats allow wildlife to flourish and migrate near urban areas. Gradually sloping undeveloped areas also provide space for marshes to move inland as the sea level rises. These restored baylands enhance the lives of millions of people, protect built infrastructure, return wildlife to our communities, and improve water quality.





the baylands to move landward as sea levels rise. Diverse, connected baylands habitats will foster diverse wildlife populations that can survive extreme conditions, move where they need to go, and evolve with the changing environment. Management techniques can be refined to prevent further subsidence, increase organic matter accumulation, reduce greenhouse gas emissions, and sequester more carbon. Even though they are not naturally resilient systems, artificially managed ponds are a valuable component of future baylands ecosystems to support waterbirds and compensate for the extreme loss of wetlands across California.

*“These updated Goals provide an urgently needed roadmap to secure the future of the San Francisco Bay region during this time of rapid change. Produced by leading scientists, managers, and decision makers, these practical, climate-smart recommendations will guide habitat restoration and management to sustain wildlife and people for decades to come.”*

Ellie Cohen, President and CEO,  
Point Blue Conservation Science;  
co-founder, Bay Area Ecosystems  
Climate Change Consortium

### **Accelerate restoration of complete baylands systems by 2030.**

Restore tidal flows to strategic areas and manage sediment to establish tidal marsh ecosystems. Tidal marshes that are established by 2030 are more likely to flourish and provide ongoing benefits when the sea-level rise accelerates in the middle of this century. To achieve this goal, the planning, permitting, and construction of restoration projects on currently available lands must be accelerated.

This page, from top: salt ponds in the south bay; scientist prepares a native oyster restoration experiment. Facing page: volunteers plant willows; children study the bay.

### **Plan ahead for the dynamic future.**

Create regional policies for the shore that anticipate change over time, using projections of sea-level rise and expected shifts in habitat types, locations, and connectivity. Baylands can better sustain themselves as sea levels rise if they can migrate landward. We should prepare for this migration by conserving the transition zone between the baylands and adjacent lands.

Develop and implement a comprehensive regional plan to reuse suitable dredged, excavated, or naturally occurring



sediment. This sediment could come from the bay, local rivers and streams, flood control channels, reservoirs, and other sources.

Prepare for the likely increases in extreme weather events such as floods and drought. Extreme events will inevitably cause damage, but they will also provide opportunities to rebuild more-resilient shores. We can buffer wildlife populations against extreme events and prevent extinctions by monitoring them and taking protective action at strategic moments.

### Increase regional coordination.

Creating a resilient and healthy shore will be more successful if the responsible agencies and interested stakeholders collaborate to build consensus, identify barriers to action, solve problems, and promote shared learning and aligned benefits from individual projects. Regionally coordinated research, monitoring, and implementation are critical for rapid innovation and large-scale, complex restoration. This approach will foster the adoption of the most promising techniques for restoration and management, build understanding for and support of necessary new policies, and establish coalitions to obtain the public funding required for a healthy future shore.

THE SUCCESS we have already achieved with baylands restoration provides us with the opportunity to continue this work. But this opportunity is available only if we act now. Restoring the baylands is a necessary part of creating a resilient and healthy shore that supports our economy and maintains the remarkable natural heritage of the Bay Area.



*“The recommendations provided by over 100 of the region’s leading scientists are invaluable for helping managers, scientists and decision-makers continue to make progress in restoring our valuable wetlands. We now know we must accelerate our restoration efforts, and adopt new watershed and in-bay management practices to ensure there is sufficient sediment for the baylands to continue to provide a multitude of beneficial functions with our rising seas.”*

Michael Monroe, lead author and project co-chair for the *Bayland Ecosystem Habitat Goals* report (1999)





## ABOUT THIS SCIENCE UPDATE

This report is an update to the 1999 *Baylands Ecosystem Habitat Goals* that for the first time set comprehensive restoration goals for the San Francisco Bay estuary. It synthesizes the latest science— particularly advances in the understanding of climate change and sediment supply— and incorporates projected changes through 2100 to generate new recommendations for achieving healthy baylands ecosystems.

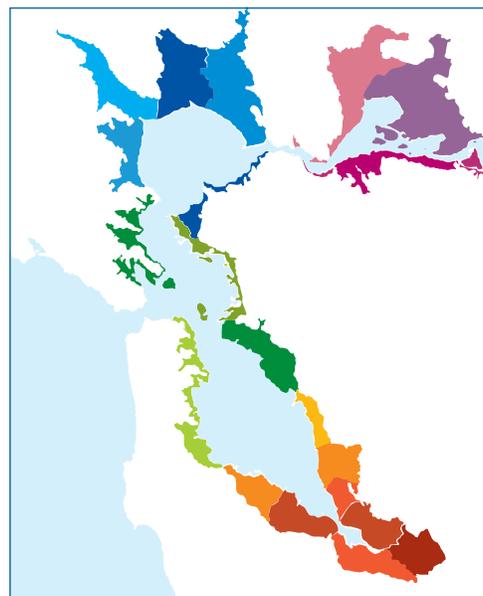
The habitat acreage goals set in 1999 remain the same. Recommendations have been updated—and many new restoration approaches are suggested—for the region, its major subregions, and local shorelines. These actions must be integrated with civic and economic planning to arrive at appropriate implementation strategies. This report provides technical information that policy makers and others can use in deciding how to maximize ecosystem health.

## TO OBTAIN THE REPORT

Access the full Science Update at [www.baylandsgoals.org](http://www.baylandsgoals.org).

Available on the website are PDFs of the full report, maps, and appendices, as well as Science Foundation chapters that provide the technical background to the report.

For inquiries, please contact [info@baylandsgoals.org](mailto:info@baylandsgoals.org).



The report provides updated recommendations for the region, its major subregions, and local shorelines.



Top: Mud Slough; above: endangered Ridgway's rail