

# ON THE EDGE:

## Protecting California's Fish and Waterfowl from Global Warming

NATIONAL WILDLIFE FEDERATION

PLANNING AND CONSERVATION LEAGUE FOUNDATION

2008



CONFRONTING GLOBAL WARMING

# Report

# Acknowledgements

This report is the culmination of the efforts of numerous individuals without whom it could not have been completed.

At the National Wildlife Federation, we especially thank David Dittloff, Patty Glick, Doug Howell, Doug Inkley, John Kostyack, Matt Little, Steve Malloch, Felice Stadler, Tim Warman, and Aileo Weinmann for their many valuable contributions. At the Planning and Conservation League Foundation, we are indebted to Barb Byrne, Monica Hunter, Mindy McIntyre, Justin Saydell, Traci Sheehan, and Erick Watkins.

We also appreciate the constructive assistance of Josh Ackerman, U.S. Geological Service; Gary Adams, California Striped Bass Association; Sam Davidson, Trout Unlimited; Kim Delfino, Defenders of Wildlife; Conner Everts, Southern California Watershed Alliance; Jeffrey Mount and Peter Moyle, University of California at Davis; Jan Randall, San Francisco State University; Mark Rockwell, Northern California Federation of Fly Fishers; Rudy Rosen, Ducks Unlimited; and Mark Drew, Scott Feierabend, Wende Micco, Jeff Shellito, Brian Stranko, and Tony VanHouten, California Trout. Barbara Raab Sgouros and Lee Ann Rhodes Lawlor skillfully handled the design and layout of the report.

The National Wildlife Federation is grateful to Jay J. and Sigrid E. Wimberly for the establishment of the Jay J. Wimberly Wildlife Fund, which helped make this report possible. NWF also acknowledges support for efforts to combat global warming in California, and throughout the Western states, from the Energy Foundation, the Surdna Foundation, the Wallace Global Fund, and the New York Community Trust. The Planning and Conservation League Foundation thanks the Lisa and Douglas Goldman Fund and the Richard and Rhoda Goldman Fund.

## **On the Edge: Protecting California's Fish and Waterfowl from Global Warming**

April 2008

Prepared by:

Sarah Skikne, Global Warming Program  
Consultant, Planning and Conservation  
League Foundation

Amanda Staudt, Global Warming Scientist,  
National Wildlife Federation

Matt Vander Sluis, Global Warming  
Program Manager, Planning and  
Conservation League Foundation

© 2008 by the National Wildlife Federation.  
All rights reserved.  
Larry J. Schweiger  
President and Chief Executive Officer  
National Wildlife Federation

**Cover photo: Fishing in the East  
Walker River in front of the  
Sweetwater Mountains, of the  
Eastern Sierra Nevada.**

Photo by: Ronald G. Guerra



# Contents



|                |   |
|----------------|---|
| Foreword ..... | 2 |
|----------------|---|

|                         |   |
|-------------------------|---|
| Executive Summary ..... | 3 |
|-------------------------|---|

## I. California's Changing Climate Impacts Fish, Waterfowl, and Their Habitats ..... 9

|   |    |
|---|----|
| Altered Precipitation and Snowmelt Patterns ..... | 10 |
|---|----|

|  |    |
|--|----|
| Warmer Water in Rivers and Streams ..... | 10 |
|--|----|

|   |    |
|---|----|
| Increasing Sea Level and Storm Surges ..... | 11 |
|---|----|

|   |    |
|---|----|
| Warmer and More Acidic Ocean Conditions ..... | 12 |
|---|----|

## II. Special Places Under Pressure ..... 13

|  |    |
|--|----|
| <b>Sierra Nevada:</b> Declining Snow Pack<br>Impacts Fish Downstream ..... | 14 |
|--|----|

|   |    |
|---|----|
| <b>Klamath River Basin:</b> Uncertain and<br>Overstretched Water Supplies ..... | 15 |
|---|----|

|  |    |
|--|----|
| <b>Central Valley:</b> Low Streamflows<br>Threaten Waterfowl ..... | 17 |
|--|----|

|   |    |
|---|----|
| <b>Sacramento-San Joaquin Delta:</b><br>Encroaching Seas and Altered Freshwater Inflows ..... | 19 |
|---|----|

|   |    |
|---|----|
| <b>South Coast:</b> Rising Seas and<br>Urbanization Squeeze Species ..... | 21 |
|---|----|

## III. A Plan of Action for California Fish and Wildlife ..... 22

|  |    |
|--|----|
| Reduce Global Warming Pollution to<br>Avoid the Worst Potential Outcomes ..... | 23 |
|--|----|

|  |    |
|--|----|
| Create a New Water Management Regime<br>that Benefits Humans, Fish, and Wildlife ..... | 24 |
|--|----|

|   |    |
|---|----|
| Help Fish and Wildlife Survive Those<br>Climate Changes that Are Inevitable ..... | 25 |
|---|----|

|                |    |
|----------------|----|
| Endnotes ..... | 26 |
|----------------|----|

# Foreword



www.wildflyproductions.com

My first love growing up was the great outdoors. I spent countless days creeping along the creek bank in the woods near my parents' house, seeking out fish and frogs, the tracks of bear, deer, and turkey, and the opportunity to experience unique moments in the wild, such as a rare glimpse of a mountain lion. Today I take my two daughters into California's outdoors to relive through them the same wonder and awe that I felt as a child.

That's why I got involved in California Trout eight years ago. By better managing the habitats that make fishing possible, and by encouraging young people to get involved in fishing, the people of California can maximize the long-term value of this healthy, sustainable activity.

However, without decisive action to address global warming, all the hard-fought progress made by so many to protect and restore California's diverse habitats could be lost. **Indeed, our sportsman's heritage is at risk.** Unless we address the root causes of global warming, rising sea levels will destroy critical wetlands and render current shorelines unrecognizable. More intense storms will increase sediment and nutrient runoff. Warmer water will change the entire ecology of California, pushing out cold-water fish species and disrupting the precarious balance that supports a multitude of wildlife species.

The issue cuts across all income levels, all political boundaries, and all religious beliefs. If you care about your hunting, fishing, or wildlife watching opportunities, you're affected. **Like it or**

**not, global warming is the defining issue of the 21st century.**

The single most important conservation action we can take is to minimize the impacts of global warming in California. We can steer clear of the worst impacts by taking action now to reduce our global warming pollution by at least two percent per year. And, we can take steps to help California's people, fish, and wildlife cope with those climate changes that are already inevitable. For example, California Trout, Trout Unlimited, and the Federation of Flyfishers are assisting the California Department of Fish and Game and the U.S. Forest Service in a collaborative effort to protect and restore the California golden trout. These on-the-ground activities will be increasingly important to give fish and wildlife a fighting chance to survive global warming.

We don't have time to waste. And, it will require the action of all of us. **On the Edge offers a plan of action that can help preserve the natural splendor of California.** We at California Trout look forward to working with the National Wildlife Federation and the Planning and Conservation League Foundation to put this plan into action.

I hope and believe that we will be successful, and I hope you'll join me and the many organizations working on global warming to ensure our success. Our children and grandchildren are counting on us.

Sincerely,

A handwritten signature in black ink that reads "Brian R Stranko".

Brian Stranko  
Executive Director, California Trout

Founded in 1971, California Trout was the first statewide conservation group to focus on securing protections for California's unparalleled wild and native trout diversity. Working with local communities, business partners, and government agencies, California Trout employs conservation science, education, and advocacy to craft effective solutions for California's water resources and fisheries. Among its many current initiatives, California Trout is now leading the effort to save the official state fish, the California golden trout.

# Executive Summary



U.S. Fish and Wildlife Service

Global warming is affecting California's water. Diminishing snowpack in the Sierra Nevada and Cascades, more variable river flows, and rising sea levels mean that fresh water will be ever more scarce. At risk are river, wetland, and coastal habitats that are home to treasured fish, waterfowl, and other birds. California is on the brink of losing some of its most prized outdoor traditions, such as fishing for Chinook salmon on the Klamath River, hunting pintail ducks in the Central Valley, and sighting the Western snowy plover and other birds in the marshes and beaches of the southern coast.

This report summarizes the latest scientific research as it provides a tour through some of California's iconic landscapes, revealing how global warming is stressing fish, waterfowl, and their habitats. Many of these ecosystems are already fragile, having withstood years of pressure from human activities. Left unchecked, global warming will magnify these pressures, fundamentally changing California's diverse natural systems. Fortunately, it is not too late to take action to reduce global warming and help prepare California's fish and wildlife to cope with those climate changes already put into motion by our past pollution.

## CALIFORNIA OUTDOOR ACTIVITIES BY THE NUMBERS

**1.3 million acres** in state parks,  
attracting about **80 million visitors**  
each year<sup>1</sup>

**2.1 million** visitors to national parks  
in California<sup>2</sup>

**40** National Wildlife Refuges<sup>3</sup>

**1,100 miles** of coastline with **450**  
beaches<sup>4</sup>

**1,894 miles** of rivers designated as  
“wild” or “scenic”<sup>5</sup>

**8.1 million** wildlife watchers in 2006<sup>6</sup>

**1.7 million** anglers<sup>6</sup>

**284,000** hunters<sup>6</sup>

**1 out of every 14** residents hunts  
or fishes<sup>6</sup>

**\$4.6 billion** spent by wildlife  
watchers in 2006<sup>6</sup>

**\$3.6 billion** spent by hunters and  
anglers in 2006<sup>6</sup>

**54,700 jobs** supported by hunting  
and fishing industries in 2006<sup>7</sup>



U.S. Fish and Wildlife Service

**Lesser Scaup hen in the Lower Klamath National Wildlife Refuge.**

# California is Blessed with Superb Habitats for Fish and Waterfowl

For generations, California has been known for some of the richest aquatic habitats in America, from the famed trout streams in the north, to the wetlands and estuaries teeming with waterfowl in central California, to the tremendous birdwatching opportunities at beaches in the south. The absolute splendor of California's natural beauty and wildlife inspired early conservationists such as John Muir, Ansel Adams, and President Theodore Roosevelt.

Today, wild fish and waterfowl remain a fundamental part of

California's cultural, economic, and ecological heritage. These species support hunting and fishing industries that contribute billions of dollars to the state's economy each year. They sustain the spiritual and physical well-being of the state's Native American tribes. They serve a critical role in the state's diverse ecosystems and are indicators of the overall health of our lakes, rivers, wetlands, and estuaries. And, they are a cherished piece of the natural world to be passed on from one generation to the next.



# Conservation Efforts Have Helped Protect and Restore California's Aquatic Habitats

The expansion of urban and agricultural areas in California over the past century has placed tremendous pressure on fish, waterfowl, and their habitats. For example, as of 2003, 91 percent of California's wetlands had been lost, primarily due to conversion for agricultural uses.<sup>8</sup> Fish and wildlife have suffered. Among the states, California has the second largest number of federally listed threatened and endangered species, with 179 plants and 130 animals.<sup>9</sup>

Over the past century, major steps

have been taken to protect and restore California's fish, wildlife, and their habitats. In many cases, hunters and anglers have provided important leadership and financial support, contributing to the creation of 40 National Wildlife Refuges, 1.3 million acres of state parks, 1,894 miles of protected rivers and streams, and other public lands across California. In addition, the sporting community has helped spur some of our most important conservation policies and programs.



Library of Congress Prints and Photographs Division

**Theodore Roosevelt and John Muir on Glacier Point, Yosemite Valley, California in 1906.**



Tom Weseloh

**Tom Weseloh holding a large salmon he caught in November 2007.**

# Global Warming Puts California's Rivers, Wetlands, and Coast at Risk

Global warming is already affecting aquatic habitats across California. Average snowpack in the Sierra Nevada has decreased by 11 percent since 1950 and peak river flows are as much as four weeks earlier in spring. Sea levels along the California coast have risen by 4 to 8 inches over the last century. These and other climate changes are projected to continue and to have a significant impact on many of California's most popular fish and waterfowl species:

- **More rain and less snow during winter** will increase the risk of winter floods that destroy prime habitat and scour away the gravel nesting sites of salmon, trout, and steelhead.
- **Less mountain snowpack that melts earlier each year** will cause summer water shortages that constrict cold-water fish habitat, hamper fish migrations, increase salinity in the Sacramento-San Joaquin Delta, and increase pressure to divert water from rivers and

wetlands critical for waterfowl and fish.

- **Warmer water in rivers and streams** will increase fish disease rates, lower oxygen levels, and reduce growth rates, strength, and swimming ability for cold-water species. By 2090, 25 to 41 percent of California streams currently suitable for trout may be too warm.
- **Increasing sea level and storm surges** will erode beaches and inundate coastal estuaries and wetlands. An additional 8.5 to 35 inches of sea-level rise is projected for California by the end of the 21<sup>st</sup> century if greenhouse gas emissions continue unabated.
- **Warming ocean waters** could restrict the ability of some fish, such as Chinook salmon, to return to their historic river systems in California to spawn.
- **More acidic ocean waters** are expected to alter the ocean food chain, of which salmon are a top level predator.

## FISH AND WATERFOWL AT RISK ACROSS CALIFORNIA

**SIERRA NEVADA** Average snowpack in the Sierra Nevada is projected to decrease by as much as 12 to 47 percent by mid-century. As deep, cold pools become increasingly shallow and warm, most steelhead trout habitat and potentially all spring-run salmon habitat may disappear.

**KLAMATH RIVER BASIN** A projected 66 percent decrease in the snowpack of the Cascades would greatly reduce the snowmelt feeding the basin during summer. Combined with increasing water demands for irrigation, low river flows would spell disaster for fish in the Klamath River Basin.

**CENTRAL VALLEY** Hotter, drier summers with low stream flows will threaten waterfowl species that breed there over the summer and will increase irrigation costs, threatening rice farming and the habitat it provides to migratory waterfowl that overwinter in the Central Valley.

**SACRAMENTO-SAN JOAQUIN DELTA** Rising sea levels combined with less freshwater contributions from snowmelt could lead to extensive saltwater inundation of key fish and waterfowl habitat. Diving ducks such as canvasbacks and ruddy ducks—which already are experiencing habitat loss from dredging, levees, and other development—will be hit especially hard.

**SOUTH COAST** As sea level rises, beaches will be eroded and coastal wetlands and estuaries that abut developed areas will be blocked from moving inland. Habitat for the Western snowy plover, light-footed clapper rail, California least tern, and other species prized by birdwatchers will be especially at risk.

Aquatic species are especially at risk because the fresh water they require for survival is in high demand. Higher atmospheric temperatures will increase evaporation rates, increasing the water demand of certain agricultural crops and water-intensive landscaping. In addition, without improvements in water management, accommodating growth in California will increase the strain on already overstretched water supplies. California's fish and waterfowl face an increasingly inhospitable future unless strong protections are put in place.





# Decisive Action Now Can Minimize Global Warming Impacts and Help Fish and Wildlife Survive

We can change the forecast for fish and wildlife in California. Success will require a holistic, forward-looking approach to conservation—one that goes beyond traditional treatments for current ills and prepares wildlife for those threats that loom in the future. The following three-pronged strategy provides meaningful actions that California officials and residents can take to help forge a better future for fish and wildlife.

## **1. REDUCE GLOBAL WARMING POLLUTION TO AVOID THE WORST POTENTIAL OUTCOMES.**

We must curb global warming pollution in order to limit the magnitude of changes to the climate and natural ecosystems. Reductions on the order of two percent per year, or 20 percent per decade, are essential to meet an 80 percent reduction by the middle of this century, required to avoid the worst impacts of global warming.

Fortunately, California has taken the first bold step by enacting precedent-setting legislation, the Global Warming Solutions Act of 2006, which requires annual statewide greenhouse gas emissions to be reduced to 1990 levels by 2020. Now, California's officials, wildlife agencies, local governments, and residents need to ensure that real emission reductions are achieved. California must continue to lead the western region and the nation in developing comprehensive and aggressive greenhouse gas reduction policies.

## **2. CREATE A NEW WATER MANAGEMENT REGIME THAT BENEFITS HUMANS, FISH, AND WILDLIFE.**

Water management will become increasingly challenging in California as freshwater becomes scarcer and less predictable. Accommodating population growth could increase urban water demands, potentially

leaving less and less water for fish and waterfowl. Responding to these challenges through traditional energy-intensive water management strategies, such as water pumping and dam construction, will harm wildlife and will not satisfy water demands. A new strategy, focusing on the enormous untapped potential of water-use efficiency and water recycling, will help reconcile these competing demands in a more cost-effective manner while preserving crucial water for fish and waterfowl.

## **3. HELP FISH AND WILDLIFE SURVIVE THOSE CLIMATE CHANGES THAT ARE INEVITABLE.**

Even as global warming pollution is cut, California's wildlife will experience some impacts due to climate changes already put into motion by past pollution. Now is the time to start taking projected climate changes into account in managing our wildlife

refuges, rivers, wetlands, and coasts. California officials should secure adequate funding for wildlife agencies to tackle this large new challenge, revise permitting processes to ensure species can survive under future climate changes, and support research efforts to improve our understanding of how global warming will affect wildlife.

The time for action is now, because many of the decisions we make today—from where and how we build our homes, businesses, and roads, to the sources of our water and energy—will have a significant impact on California's fish, waterfowl, and other wildlife for decades to come.



Howard Kern

## CALIFORNIA'S OFFICIAL STATE FISH AT INCREASED RISK FROM GLOBAL WARMING

The beautiful golden trout is well known as California's officially designated state fish. Native to two small watersheds of the high Sierra, the golden trout is listed as a State Species of Special Concern<sup>10</sup> and designated by the U.S. Forest Service as a Sensitive Species.<sup>11</sup>

The golden trout has been severely impacted by hybridization with non-native rainbow trout and habitat degradation from grazing. While hybridization is currently the most significant problem for golden trout, global warming is a potentially serious threat as temperatures increase and Sierra snowpack declines. Although the golden trout is native to high mountain waters, even these areas are susceptible to increasing water temperatures, which have been recorded as high as 77 degrees Fahrenheit. At these temperatures, golden trout stop feeding.<sup>12</sup>

Restoration of golden trout habitat will be important to buffer against the potential impacts of global warming on water supply and water temperature. Conservation efforts are focusing on removing non-native fish and restoring stream-side habitats.<sup>13</sup> The Western Native Trout Initiative Strategic Plan points to the need to improve the current status of all western native trout to help them withstand the pressures of global warming.<sup>14</sup>



U.S. Army Corps of Engineers

**Yolo Basin Wetland, Davis  
Wetland Project.**

# I. CALIFORNIA'S CHANGING CLIMATE IMPACTS FISH, WATERFOWL, AND THEIR HABITATS

California's treasured river, wetland, and coastal ecosystems will feel the heat from global warming. Regional studies project that, by the end of this century, average air temperatures in California will be 3.0 to 10.4 degrees Fahrenheit greater than those in 2000, depending on the magnitude of greenhouse gas emissions.<sup>15</sup> These increasing air temperatures will be accompanied by a suite of other climate changes—altered precipitation patterns; warmer water in rivers, lakes, and oceans; higher sea level; and more intense droughts, floods, storms, and heat waves—with impacts on the viability of habitats across the state.<sup>16</sup> Unless we take action to curb greenhouse gas emissions, global warming may transform aquatic habitats too rapidly for fish, waterfowl, and other birds to adapt.



Tom Weseloh



# Altered Precipitation and Snowmelt Patterns

One of the most certain threats posed by global warming to California's freshwater supply is the loss of mountain snowpack, which feeds many of the state's streams and rivers. Climate projections indicate that rising temperatures will cause more precipitation to fall as rain rather than snow. Associated with this, average snowpack in the Sierra Nevada is projected to decrease by 12 to 47 percent by mid-century.<sup>17</sup> This shift will lead to more frequent flooding and heavy streamflows in the winter and spring, followed by decreased freshwater flows during the summer.

Shallower streams and lower flows will create problems especially for aquatic species that migrate through heavily impacted areas. Low summer flows during salmonid rearing and downstream migration are linked to poor survival and return rates in the Central Valley. Stronger winter flood events may wash away the gravel beds that salmon, trout, and steelhead use for nesting sites.<sup>18</sup> Furthermore, changes in water flow will disrupt the movements of migrating fish that use water conditions to control their development, time their migrations, and orient themselves to navigate effectively.<sup>19</sup>



Mountain stream in Sequoia National Park.

## Warmer Water in Rivers and Streams

Cold-water fish are very sensitive to increases in water temperature. Prolonged exposure to water temperatures approaching 70 degrees Fahrenheit is lethal for some fish species, including the state's prized salmon, steelhead, and trout.<sup>20</sup> Even small increases in temperature can reduce growth rates and increase susceptibility to disease. Warmer water holds less dissolved oxygen, which can lead to reduced survival in juvenile salmonids. Higher stream temperatures can also decrease the quantity of preferred invertebrate food sources—such as mayfly, stonefly and caddisfly nymphs—and increase predation on juvenile salmon and trout.<sup>21</sup>

Temperatures in California's rivers and streams are already higher than historical levels, due to factors such as diversion of water, low summer flows,

loss of shade along riverbanks, and warming of sluggish waters behind dams. For example, Klamath water temperatures increased 3.6 degrees Fahrenheit from 1962 to 2001 and the average length of the main-stem river with cool summer temperatures declined by about 20 miles. Mean temperatures in the lower Klamath are now approaching 70 degrees Fahrenheit during July and August.<sup>22</sup>

Global warming will exacerbate the rise of water temperatures in California's rivers and streams.<sup>23</sup> By 2090, 25 to 41 percent of suitable California streams may be too warm for trout.<sup>24</sup> Coldwater fish that do survive despite stressful warmer conditions will likely have lower growth rates.<sup>25</sup> In addition, fish seeking cooler waters will be limited by dams and other diversions that block upstream access.



Mark Rockwell

**"Being part of the fishing community for the past 45 years, I am acutely aware of how vital water is to our fisheries. Reduced summer water flows, higher temperatures, and decreased snow pack will challenge every one of our 11 cherished wild and heritage trout species. We have to act now to minimize the effects of global warming and find new ways to provide water rather than simply relying on the old paradigm of dams and diversions."**

**MARK ROCKWELL**

*Mark Rockwell Fishing Guide Services & Federation of Fly Fishers*

# Increasing Sea Level and Storm Surges

As ocean temperatures increase and polar and glacial ice melts, sea levels around the globe are steadily rising. California's coastline and estuaries are already seeing rising sea levels. Average increases of 4 to 8 inches have been measured at tide gauges over the past century, about the same as the average global rate of sea-level rise. An additional 8.5 to 35 inches of sea-level rise is projected for California by the end of this century if greenhouse gas emissions continue unabated.<sup>26</sup> If the melting of the Antarctic and Greenland ice sheets accelerates during the coming decades as new studies suggest, sea-level rise along California's coast could be considerably greater.<sup>27</sup>

Much of the year-to-year variability in sea level along California's coast is due to tides, climate fluctuations such as El Niño, and wind-driven waves caused by strong storms. Indeed, the worst coastal damages in the past happened when major storms coincided with high tides during El Niño conditions. Sea-level rise will exacerbate such events, allowing for greater storm surges and larger

waves.<sup>28</sup> Furthermore, global warming is projected to cause stronger El Niño events and more intense storms.<sup>29</sup>

As sea levels rise, suitable habitat for coastal fish and wildlife will be

reduced, especially in areas with significant coastal armoring and other development. For example, in the Sacramento-San Joaquin Delta, there will be an increased potential for floodwaters to damage or flow over the tops of man-made levees, inundating waterfowl habitat with saltwater<sup>30</sup> and making these waters unsuitable for the invertebrates, marsh grasses, and other food that waterfowl need.

## CLIMATE CHANGES IN ALASKA AND CANADA WILL AFFECT CALIFORNIA WATERFOWL



Most of the migratory waterfowl that overwinter in California return to breeding grounds in Alaska and Canada each summer. Alaska alone has more than 90 million acres of wetlands, and over half of its breeding waterfowl population winters in the Pacific Flyway.<sup>40</sup> These northern regions are experiencing especially rapid warming; temperatures in Alaska rose 3.6 to 5.4 degrees Fahrenheit

from 1954 to 2003.<sup>41</sup> Migratory waterfowl will likely be impacted by continued warming, although it is hard to pinpoint how because they are able to move over large distances in search of suitable habitat. Changes in these arctic regions could affect California waterfowl in a number of ways:

- As permafrost thaws, lakes and ponds will drain into groundwater aquifers, leading to a loss of waterfowl habitat in some areas and the formation of new habitat in others. Since 1950, a warming regional climate and melting permafrost have been correlated with a substantial reduction in the surface area and total number of shallow ponds in Alaskan Boreal Forest regions.<sup>43</sup>
- Warmer conditions may shift the timing of waterfowl reproduction. In 1990, arctic geese were hatching about 30 days earlier than they were in 1950, coinciding with increasing average temperatures during the same period.<sup>44</sup>
- Many migratory waterfowl species are known to choose more northern wintering grounds during warm years.<sup>45</sup> With warmer winters, waterfowl may not need to fly as far south from Canada or Alaska to find suitable wintering habitat, or they may migrate south to California later in the year.



## ALTERED WILDFIRE PATTERNS

The effects of global warming are already being seen in altered wildfire patterns, with catastrophic effects for many people living in California. Warmer temperatures and earlier snowmelt have increased the duration and intensity of the wildfire season across the western United States. From 1987 to 2003, the region experienced a nearly fourfold increase in major wildfires and over a sixfold increase in the area of forest burned compared to the average for 1970 to 1986. Some of the greatest increases have been seen in California's Sierra Nevada, southern Cascades, and Coast Ranges, especially during years with early springs.<sup>37</sup>

These trends are projected to continue in the future. If winter rain increases, more vegetation in the grasslands and chaparral in the southern part of the state could provide increased fuel for fires. Some models project that wildfires in Southern California will increase by 30 percent toward the end of the century. In Northern California, forest fires could increase by up to 90 percent as hotter and drier conditions increase the flammability of vegetation.<sup>38</sup>

Increasing fire frequency and severity will affect aquatic and other California habitats in the coming decades. Wildfires, especially those that are more intense, often lead to landslides, flooding, and erosion. The resulting increased siltation degrades stream water quality,<sup>39</sup> impacting the fish and waterfowl that rely on these habitats.



U.S. Air Force photo by Senior Master Sgt. Dennis W. Goff

**Simi Valley fire in Southern California, October 2003.**

to the region's coast.<sup>33</sup> Such ocean changes have been one factor implicated in the unprecedented 2008 collapse of the salmon fisheries on the U.S. west coast.<sup>34</sup>

Oceans are also becoming more acidic because about half of the carbon dioxide emitted to the atmosphere from burning fossil fuels ultimately ends up being dissolved in the ocean. Ocean pH has already decreased by 0.1 units since the 1800s and could drop by another 0.14 to 0.35 units over the 21st century.<sup>35</sup> This acidification may have wide-ranging impacts on complex marine food webs. For example, higher acidity erodes calcium in the shells of small invertebrates that are at the beginning of the salmon food chain.<sup>36</sup>

## Warmer and More Acidic Ocean Conditions

Global warming is making oceans warmer and more acidic, shifting the range of viable habitat for some fish species and impacting the marine food web. These ocean changes affect many popular fish in California, such as salmon and steelhead, that spend up to 90 percent of their lives in the Pacific Ocean before returning to spawn in California rivers.<sup>31</sup>

The temperature of the upper part of the world's oceans has risen about 0.5 degrees Fahrenheit since the

1950s due to human activities.<sup>32</sup> As this ocean warming continues, those species whose southernmost habitat lies along the California coast may soon find that waters there are too warm and be forced to stay in cooler waters further north. Higher ocean temperatures and changes in wind patterns can also diminish nutrient upwelling from the deep ocean, thereby reducing important food sources for salmon. And, warmer waters can attract salmon predators



## II. SPECIAL PLACES UNDER PRESSURE

California's broad range of landscapes offers an impressive bounty of fish, waterfowl, and other birds. With stunning natural vistas spanning forested mountains, wetlands, and an expansive coastline, there is no shortage of special places in California. In the following section, we explore how global warming may impact five key regions and the fishing, waterfowl hunting, and birdwatching opportunities they offer. Starting in the Sierra Nevada, we next examine the Klamath Basin in the northern part of the state, then head south through the Central Valley and the Sacramento-San Joaquin Delta, and finally look at impacts on the South Coast.

The ecosystems in these regions share many of the same challenges. All have been profoundly affected by human development pressures. Dams and other water diversions have modified rivers and altered water flows to most aquatic habitats. Agriculture has transformed much of the landscape. Urbanization has destroyed or altered huge areas of natural habitats.

Conservation efforts have done much to preserve wild lands and ensure healthy habitats for fish, waterfowl, and other birds. Yet, many natural ecosystems are on the brink of collapse. Global warming could push them over the edge unless decisive action is taken to reduce greenhouse gas emissions and help fish and wildlife survive those changes that are now unavoidable due to past pollution.





Vince King

**Global warming is already afoot in the Sierra Nevada. The monthly minimum air temperature has increased by about 5.4 degrees Fahrenheit over the past 100 years in middle-elevation Sierra Nevada.<sup>58</sup> At Tahoe City, the percent of precipitation falling as snow has decreased from 52 percent in 1911 to 34 percent in 2006.<sup>59</sup> And, average snowpack in the Sierra Nevada has decreased by 11 percent since 1950.<sup>60</sup>**

shallower and warmer.

These changes in temperature and water flow threaten the fish of the Sierra Nevada. As deep, cold pools become increasingly shallow and warm, most steelhead habitat and potentially all spring-run salmon habitat may disappear.<sup>49</sup> The downstream reach of brown and rainbow trout on the Tule River could decline severely due to changes in stream flow timing and water temperature.<sup>50</sup> Salmon and rainbow trout that spawn and rear below dams of foothill reservoirs or at associated hatcheries may decline.<sup>51</sup> Increasing winter flows, flooding, and landslides<sup>52</sup> will increase erosion and sedimentation, lower water quality, and damage nesting sites. Such increases in peak flow can be especially detrimental to the eggs of brown and brook trout.<sup>53</sup> Because many Sierra Nevada aquatic systems are already impaired by dams, water diversions, livestock grazing, mining, forestry practices, and urban development,<sup>54</sup> fish populations in the region will be less able to recover from the projected effects of global warming.

Less snow in the mountains will also have wide-ranging impacts on fish and wildlife in other regions of the state that depend on snowmelt. The Sierra Nevada and Cascades supply about 40 percent of the surface-water runoff flows to the Central Valley<sup>55</sup> and help replenish groundwater basins



## Sierra Nevada:

### DECLINING SNOW PACK IMPACTS FISH DOWNSTREAM

The Sierra Nevada region is the poster child for how changes in temperature can impact water reliability. Temperatures in the region are expected to rise 2 to 2.5 degrees Fahrenheit within 50 years, causing more precipitation to fall as rain rather than snow and the snowpack melt to commence earlier in the season.<sup>46</sup> By midcentury, snowpack is projected to decrease by 12 to 47 percent from historic levels and water flows into Sierra Nevada

reservoirs could decrease by 25 to 30 percent. If global warming continues unabated, snowpack loss of 70 to 90 percent could become a reality by the end of the century.<sup>47</sup> Stream flows in the Sierra Nevada region and downstream are likely to reach annual maximums earlier in spring, and decrease sooner in the summer. In fact, some permanent streams may only hold water part of the year<sup>48</sup> and those streams that remain may be



throughout California. In effect, the snowpack serves as the region's largest natural water reservoir. Global warming will reduce the capacity of this reservoir, presenting challenges to water management strategies that depend on it.

Without new policies in place that accommodate changes to the state's natural hydrology, pressure may build to increase water diversions and exports in the Sierra Nevada and foothills, further affecting the region's habitats. Increased water conservation, watershed planning, mountain meadow restoration, and more comprehensive flood policies can help us better manage this changing hydrology and ensure cool, clean water is available for wildlife.

**Coldwater fish thrive in the rivers originating in the Sierra Nevada. Historically, one to three million Chinook salmon (pictured here) spawned each year in the western Sierra, with some ascending up to 6,000 feet in elevation.<sup>56</sup> Today, recreational fishing in the Sierra Nevada is valued at approximately \$200 million annually.<sup>57</sup>**



U.S. Fish and Wildlife Service



## Klamath River Basin:

### UNCERTAIN AND OVERSTRETCHED WATER SUPPLIES

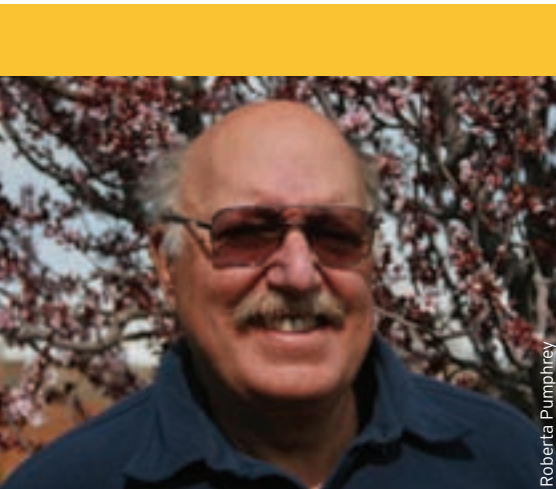
The Klamath River Basin has been blessed with ample water supplies and prime habitat for salmon, steelhead, trout, and countless waterfowl. With runoff from nearby mountains—including the Coastal Ranges, the Trinity Alps, and the Marble, Salmon, and Russian Mountains—combined with up to 100 inches of annual rainfall in the lower part of the basin, the Klamath has earned a reputation for phenomenal aquatic habitats.<sup>61</sup> Historically sustaining the third largest salmon and steelhead run on the West Coast, the basin and adjacent coast of northern California still support one-third of California's Chinook, most of California's Coho salmon and steelhead, and all of California's coast cutthroat trout.<sup>62</sup>

Although 80 percent of the Klamath basin's wetlands have been drained to support agriculture, the region remains a major spring and fall stopover spot for Pacific Flyway waterfowl, including tens of thousands of white-fronted, snow, Ross's, and Canada geese, tundra swans, northern pintails, mallards, American wigeon, and other ducks. The area also supports among the most prolific breeding populations of ducks, herons, egrets, terns, avocets, white-faced ibis,

geese, and grebes, as well as the largest population of wintering bald eagles in the lower 48 states.<sup>63</sup>

Yet, water in the Klamath region is in high demand, and fish and waterfowl often end up paying the price. The region now has chronic low water flows, higher water temperatures, and poor water quality. Dams and water diversions, mining operations, logging practices, livestock grazing, and agricultural channel and berm construction have reduced riparian vegetation and shade, helping to earn the Klamath River "impaired" status under the Clean Water Act because of high temperatures.<sup>64</sup> Fish in the region have been pushed to the brink: between the 1950s and 1990s, salmon and steelhead populations declined 80 percent.<sup>65</sup> Coho salmon, an indicator of overall watershed health, were listed as threatened under the federal Endangered Species Act in 1997.<sup>66</sup>

Low summer water flows on the Klamath River and its tributaries will be increasingly common because of global warming. With a 3.8 degrees Fahrenheit warming, snowpack in the Cascades is projected to decrease by 66 percent, greatly reducing the snowmelt feeding the basin in the summer.<sup>67</sup> As the air temperature



Roberta Pumphrey

**"I want people like me, who have enjoyed more than forty years of wild trout fishing in places like the backcountry of Sequoia and Kings Canyon, to be able to pass their love of the Sierra experience onto their grandchildren. But if we allow global warming to alter the natural systems upon which our beautiful trout depend—from stream-flow patterns and spawning habitat to the composition and stability of insect populations—I'm concerned that those opportunities may not exist for tomorrow's anglers."**

#### PETE PUMPHREY

*Fishing Guide in Bishop, California and writer for California Fly Fisher Magazine*



increases, so too will summertime evaporation of water from the Klamath, further diminishing water supplies.<sup>68</sup>

Global warming will exacerbate trends of increasing water temperatures in the Klamath River basin, affecting the region's fish populations. Chronic temperatures above just 59 degrees Fahrenheit in the Klamath River are associated with reduced swimming ability, increased vulnerability to disease, and low growth rates.<sup>69</sup> High water temperatures also lower the amount of oxygen available for fish and can cause juvenile Coho salmon to leave prematurely for the Pacific when ocean conditions are unfavorable.<sup>70</sup>

Existing dams and diversions will prevent fish from escaping to cooler upstream habitats and continue to affect water temperatures, quality, strength, and timing. Even fish that do not migrate to the ocean, such as redband and rainbow trout and Klamath smallscale sucker, move widely and may be negatively affected by limitations on their movement.<sup>71</sup>

Furthermore, as rising air temperatures heighten agricultural



U.S. Fish and Wildlife Service

and landscape water demands, the decreasing availability of freshwater could raise the cost of supplying water to Klamath Basin rivers.<sup>72</sup> Without proper management, less water means more competition for this scarce resource and a greater chance that fish and waterfowl will lose out. Anglers in a region once known for large coldwater fish may instead be limited to catching smaller and less healthy fish, while some areas may become entirely unsuitable for fishing.

**In 1908, President Theodore Roosevelt created the Lower Klamath National Wildlife Refuge, the nation's first refuge for waterfowl like this Gadwall duck.**

## THE KLAMATH KILL - HARBINGER OF THINGS TO COME?



Northcoast Environmental Center

The vulnerability of local fish to changes in water flows was dramatically illustrated by the fish kills on the Klamath and Trinity Rivers in September 2002. Due to water diversions for irrigation during a severe drought, flows at several locations were between 11 and 64 percent of historic averages.<sup>73</sup> This made the year's somewhat large run of salmon more susceptible to disease

by increasing water temperatures, increasing crowding, hampering fish passage and upstream migration cues, and increasing the spread of disease. The result was the largest known adult salmon kill in the Klamath River, affecting primarily fall-run Chinook salmon, as well as Coho salmon, steelhead, and others. According to a report by the California Department of Fish and Game, 34,000 to 79,000 fish died before spawning.<sup>74</sup>



# Central Valley:

## LOW STREAMFLOWS THREATEN WATERFOWL

California's Central Valley is an important winter getaway for waterfowl, despite the fact that more than 95 percent of the Central Valley's wetlands have been destroyed or highly modified.<sup>75</sup> With over 205,000 acres of managed wetlands, as well as dry grain fields, flooded rice fields, and tule-reed and cattail marshes, 60 percent of the migratory waterfowl of the Pacific Flyway choose to stop over or spend the winter in the region. That is 5.5 million ducks and geese, still one of the largest concentrations of wintering waterfowl in the world.<sup>76</sup>

Fortunately, many of the remaining wetland patches in the Central Valley are protected in State Wildlife Management Areas and Federal National Wildlife Refuges, through private duck clubs, or conservation easements, most of which are managed primarily for wildlife. Nonetheless, the future for waterfowl in the Central Valley is uncertain. Ducks Unlimited lists this region as the second most important and threatened waterfowl habitat in the country.<sup>77</sup>

Global warming threatens to further



Dick Overstreet



U.S. Fish and Wildlife Service

**The Merced National Wildlife Refuge provides important habitat for lesser sandhill cranes, Ross's geese, northern pintails, cackling geese, and a wide variety of shorebirds.<sup>83</sup>**

**"Any California waterfowler who has spent the last twenty years in a duck blind is well aware of how early December's cold streaks were practically clockwork, along with huge clouds of green-winged teal. Most hunters in the Central Valley will now tell you that such conditions don't seem to arrive until far later in the winter, and have been replaced with balmy shooting days that hardly require a jacket. What used to 'turn on' in the first week of December seems to now be occurring in January, and the traditional migratory push from northern California climates to the Central Valley seems to be more sluggish.**

**Then there are the impacts on California's water. If we don't get serious about global warming, it will become extraordinarily difficult to provide for the needs of both wintering migratory waterfowl and resident wildlife, not to mention wildlife food production in the spring and summer."**

### **DAVID L. WIDELL**

*General Manager and Director of Governmental Affairs, Grassland Water District, and an avid hunter (pictured with his son Ty Widell)*





U.S. Fish and Wildlife Service

California's Central Valley is wintertime habitat for all of the world's Aleutian cackling geese and Tule White-fronted geese, 80 percent of the continent's Ross's geese, 33 percent of the continent's tundra swans and Pacific white-fronted geese (pictured here), and 80 percent of the Pacific Flyway's northern pintail ducks.<sup>84</sup>

diminish waterfowl habitat in the Central Valley by changing water availability and seasonality, thereby increasing competition from agriculture and urban water uses.<sup>78</sup> At risk is the habitat of resident species—such as the mallard, cinnamon teal, gadwall, and wood duck—that require access to permanent water bodies,<sup>79</sup> as well as those waterfowl that over-winter in the region.

Because wildlife refuges in the Central Valley often depend on return flows from agriculture,<sup>80</sup> they are anticipated to lose supplies as the rising price of limited water supplies provides an incentive to transfer agricultural water to urban areas. The winter waterfowl habitat provided by flooded rice fields in the Central Valley faces similar pressures. Greater competition for water will likely raise irrigation costs for rice farmers.<sup>81</sup> In addition, higher summer temperatures could reduce rice yields and increase rice sterility, further decreasing the

profitability of rice farming in California.<sup>82</sup> These factors, combined with a growing human population, may cause land to be taken out of agricultural production, where it provides at least some habitat value, and converted into urban environments, with little or no habitat value.

### Birdwatching at San Luis National Wildlife Refuge.



U.S. Fish and Wildlife Service



## WILL THERE BE CHINOOK IN THE CENTRAL VALLEY?

Historically, up to 600,000 spring-run Chinook salmon inhabited 6,000 river-miles in the Central Valley, including the Sacramento River as far as Mount Shasta City and Fall River. The San Joaquin River supported a population of 50,000 to 200,000 spring-run Chinook. However, water diversions and dams eliminated spring-run Chinook in the San Joaquin River, and by 1997, Central Valley populations had declined to less than 1 percent of historic levels, with only 20 percent of historic habitat still accessible. Today, all Chinook runs are limited to about 300 river-miles, mostly in the main stem of the Sacramento River.<sup>85</sup>

Global warming is a major long-term threat facing Central Valley salmon, including all runs of Chinook.<sup>86</sup> Warming will shorten the period when fall-run Chinook have access to sufficiently cool habitats, particularly affecting fish in the San Joaquin River and its tributaries.<sup>87</sup> Winter- and spring-run salmon, already the most harmed by dams, are especially likely to be affected by global warming because they depend on rivers and streams for rearing habitat in the warm summer months.<sup>88</sup> If air temperatures rise 3.6 degrees Fahrenheit, the Tuolumne and Merced Rivers and Butte Creek will become too warm for spring-run Chinook.<sup>89</sup> If air temperatures rise about 9 degrees Fahrenheit, expected if global warming pollution continues unabated, it is doubtful whether any Central Valley Chinook will be able to survive.<sup>90</sup>

The 2008 collapse of the Sacramento River's fall-run Chinook is a testament to the instability and vulnerability of Central Valley Chinook. Although it is not yet known what specific conditions caused the collapse, scientists have implicated insufficient river flow and disruptions in marine food sources caused by warm ocean waters.<sup>91</sup> Such threats to salmon populations and fishing will be more frequent with global warming.



Tom Weseloh



## Sacramento-San Joaquin Delta:

### ENCROACHING SEAS AND ALTERED FRESHWATER INFLOWS

Fish and waterfowl flourish in coastal estuaries where freshwater flows into the ocean. Fortunately for wildlife enthusiasts, California is home to the largest estuary on the west coast of North and South America: the Sacramento-San Joaquin Delta. Located just east of the San Francisco Bay area where California's two largest rivers converge, the Delta is comprised of more than 700,000

acres of waterways, wildlife habitat, reclaimed farmland, and agricultural towns. Tens of thousands of waterfowl use freshwater areas of the Delta as important resting, feeding, and breeding habitat in their migration along the Pacific Flyway.<sup>92</sup> Over 40 fish species live or pass through the Delta, including catfish, sturgeon, steelhead, and striped bass.<sup>93</sup>

These conditions, coupled with the

Delta's proximity to large urban population centers, provide some of the best access to hunting and fishing opportunities in the western United States. The Delta's Suisun Marsh area alone is home to 158 private duck clubs as well as public hunting areas.<sup>94</sup> In 2000, visitors made approximately 2.13 million boating trips through the hundreds of miles of lazy sloughs and channels of the Delta.<sup>95</sup>



Vince King

### **The Sacramento National Wildlife Refuge includes seasonal marshes, permanent ponds, and riparian habitats for waterfowl.**

Many of the Delta's habitats are at risk from changes in precipitation patterns due to global warming. Increased winter flooding and reduced inflows of Sierra Nevada snowmelt from the Sacramento and San Joaquin Rivers in spring and summer will stress the Delta's delicate food web. Decreasing freshwater flows in summer will also increase the Delta's salinity in that critical period of the year.<sup>96</sup> Diving ducks such as canvasbacks and ruddy ducks, which have already lost habitat from dredging, levees, and other development, will be hit especially hard by these changes in salinity.<sup>97</sup>

Sea-level rise threatens to further constrict habitat for fish and waterfowl in the Delta. Higher sea levels will inundate waterfowl habitat with saltwater, making these waters unsuitable for the invertebrates, marsh grasses, and other food that

waterfowl need, while urbanization at the Delta's edge will prevent wetlands from shifting upland.<sup>98</sup> The extensive habitat maintenance efforts by hunting clubs and other organizations<sup>99</sup> could be undermined by such saltwater inundation.

In addition, rising waters increase the potential for floodwaters to damage or flow over the tops of the Delta's 1,100 miles of fragile earthen levees.<sup>100</sup> A 2005 study estimated a 64 percent chance of catastrophic failure of multiple delta levees by 2050 due to earthquakes and extreme flood events.<sup>101</sup> The chance of such a catastrophe is even higher when factoring in the effects of global warming.

Warmer water will also stress coldwater fish that pass through the Delta to spawn. For instance, reduced levels of dissolved oxygen will be increasingly common as water

temperatures rise. In the lower San Joaquin River at the eastern edge of the Delta, low levels of dissolved oxygen have caused salmon and steelhead kills, created barriers to salmon migration, and interfered with striped bass, sturgeon and shad migration and spawning.<sup>102</sup>

As conditions in the Delta worsen, the ability of fish to shift their habitat to cooler locations will be impaired by dams and other diversions that block upstream access.





## South Coast:

### RIISING SEAS AND URBANIZATION SQUEEZE SPECIES

Southern California's coastal habitats offer numerous opportunities for birdwatching, hunting, and fishing. With 13,000 acres of coastal wetlands, many species of ducks, geese, and other birds—such as the California least tern, Western snowy plover, light-footed clapper rail, and California brown pelican—find essential breeding, feeding, and nesting habitat in the region.<sup>103</sup> These coastal wetlands are also important habitat for more than 60 fish species.<sup>104</sup>

Unfortunately, Southern California has more flood-control dams, debris basins, and miles of cemented stream channels than any other region in the country. Such changes have fragmented watersheds and altered natural flow patterns, devastating aquatic species. Southern California is now home to more threatened and endangered species than any other

region in the continental United States, in large part because of degraded aquatic habitats. For example, steelhead in the region have declined from a population of tens of thousands to about 200 to 300 fish today.<sup>105</sup>

The fish, waterfowl, and other birds that reside in Southern California's coastal habitats will feel the squeeze from global warming. Rising sea levels and more intense winter storms will inundate wetlands and estuaries and erode coastal beaches.<sup>106</sup> The many wetlands and estuaries that abut developed areas will be blocked from moving inland, threatening the species that depend on them. Those beaches that are protected with sand replenishment programs will face increasing costs for more and more replacement sand.<sup>107</sup>



Monte Stennett

**The salt marshes of the Upper Newport Bay Ecological Reserve in Southern California are home to the endangered light-footed clapper rail. In 1985, only 142 breeding pairs remained, largely because the birds' salt marsh habitat had become increasingly degraded and disconnected by coastal development in the region. Restoration efforts increased the population to 350 breeding pairs by 2004, but sea-level rise now poses a new threat.**<sup>108</sup>



U.S. Fish and Wildlife Service

**The Sweetwater Marsh, part of the San Diego National Wildlife Refuge Complex, provides sanctuary to burrowing owls, shorebirds, egrets, and herons.**





# III. A PLAN OF ACTION FOR CALIFORNIA FISH AND WILDLIFE

Even though the problems posed by global warming seem daunting, practical solutions are available. We can ensure that California's treasured natural heritage and sporting legacy will endure by (1) reducing global warming pollution, (2) creating a new water management regime for California, and (3) taking steps to help wildlife survive those changes that are now considered inevitable because of past pollution. Policy makers in California and Washington, D.C., organizations engaged in natural resource management, and individuals can all play a critical role in advancing meaningful solutions to improve the forecast for California wildlife.

Effectively managing California's natural resources in the face of global warming is a major challenge for the next decade and beyond. California must call upon its legacy of effective conservation activities—from 1.3 million acres set aside in state parks to the hundreds of restoration and conservation projects undertaken by organizations such as California Trout, Ducks Unlimited, and the California Conservation Corps. However, failure to explicitly consider global warming as part of these efforts will make it much more difficult, if not impossible, to meet conservation goals.

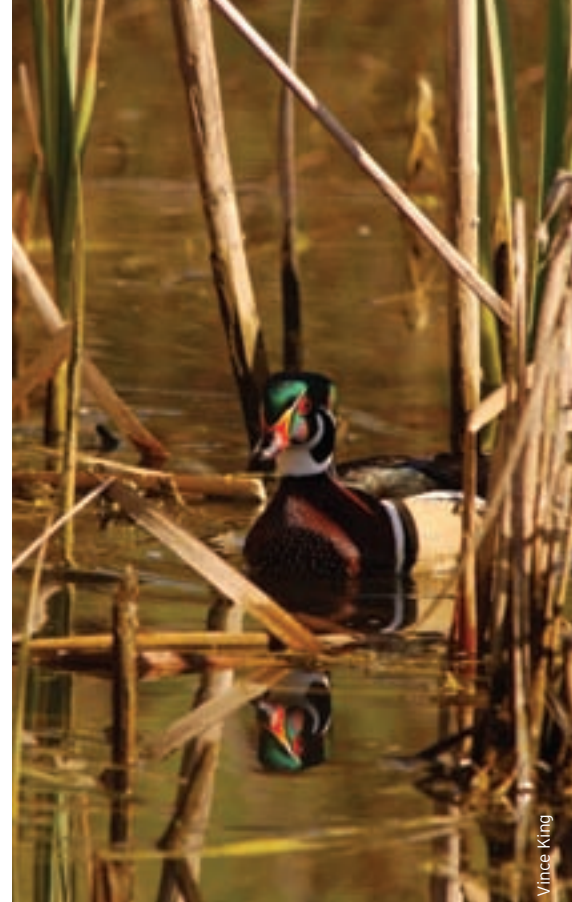
# Reduce Global Warming Pollution to Avoid the Worst Potential Outcomes

We must curb global warming pollution in order to limit the magnitude of changes to the climate and natural ecosystems. Reductions of at least two percent per year, or 20 percent per decade, are essential to meet an 80 percent reduction by the middle of this century, required to avoid the worst impacts of global warming. Fortunately, California has taken the first bold step by enacting precedent-setting legislation, the Global Warming Solutions Act of 2006, which requires annual statewide greenhouse gas emissions to be reduced to 1990 levels by 2020. Now, California's elected officials, wildlife agencies, local governments, and individuals need to ensure that real emission reductions are achieved. California also must continue to lead the western region and the nation in developing comprehensive and aggressive greenhouse gas reduction policies.

- **California officials should ensure that regional and national greenhouse gas reduction efforts succeed** in achieving real emission reductions and providing the public benefits and protections required by the Global Warming Solutions Act of 2006.
- **California's wildlife agencies should identify and promote policies that reduce greenhouse gas emissions while providing wildlife benefits.** These include water management policies that cut energy usage while reducing the strain on California's rivers, lakes, and streams, as well as land-use policies that reduce vehicle travel and protect habitat.
- **Local agencies should incorporate global warming reduction mandates into their legally-binding policy documents,** including their General Plan and Environmental Impact Reports.

## WHAT CAN YOU DO?

- **CONTACT** your Senator or Representative and ask them to support federal legislation that cuts greenhouse gas emissions. Check out [www.nwf.org/globalwarming](http://www.nwf.org/globalwarming) to learn more.
- **REDUCE GREENHOUSE GAS EMISSIONS** in your home. Check out National Wildlife Federation's Good Neighbor website at [www.nwf.org/goodneighbor](http://www.nwf.org/goodneighbor) for ideas.
- **GET INVOLVED** in your local government by commenting on plans made available for public review. To find out how, contact the National Wildlife Federation's California affiliate, the Planning and Conservation League, at (916) 444-8726.



Vince King



U.S. Fish and Wildlife Service





Vince King

# Create a New Water Management Regime that Benefits Humans, Fish, and Wildlife

Managing water for wildlife will become increasingly challenging in California as freshwater becomes scarcer and floods more frequent. Responding to these challenges through traditional energy-intensive water management strategies such as water pumping and dam construction will only harm wildlife.

Furthermore, such strategies will increase global warming pollution given that water use accounts for 19 percent of the electricity and 30 percent of the natural gas consumed in California, as well as 88 billion gallons of diesel fuel use per year. One of the most effective ways to both combat global warming and protect water for fish and wildlife is to simply use water more efficiently.<sup>109</sup> A new strategy for managing California's water demands is needed to ensure that fish and waterfowl can survive.

- **Water agencies should integrate global warming into California water planning** by choosing demand, supply, and reliability management strategies based upon projected changes to the state's hydrology.
- **Water agencies should aggressively develop and implement sustainable and climate-resilient water management strategies**, including increasing water-use efficiency,

water recycling, and cleaning up polluted groundwater.

- **The State should implement a "water demand neutral" standard for new developments in California** to ensure that all new growth is accommodated without increasing demand on our rivers and streams. The standard should leverage California's significant potential in water-use efficiency, water recycling, and other climate-resilient water supplies.

## WHAT CAN YOU DO?

- **GET INVOLVED** in your local agency's update of their Urban Water Management Plan. Urge them to develop climate-resilient local water supplies rather than water transfers or continued reliance on imported water. The next plans must be completed by 2010.
- **CONSERVE WATER** in your home and yard. Check out [www.nwf.org/water](http://www.nwf.org/water) for ideas.



Tom Wiseloh



# Help Fish and Wildlife Survive Those Climate Changes that Are Inevitable

Even as global warming pollution is cut, California's wildlife will experience some impacts due to climate changes already put into motion by past greenhouse gas emissions, and many species are already in trouble due to existing land and water use practices. Now is the time to start taking projected climate changes into account in managing our wildlife refuges, rivers, wetlands, and coasts. Wildlife agencies especially need to consider global warming in their efforts to monitor habitats, restore degraded ecosystems, educate the public, and issue and enforce permits to protect endangered species and threatened habitats.

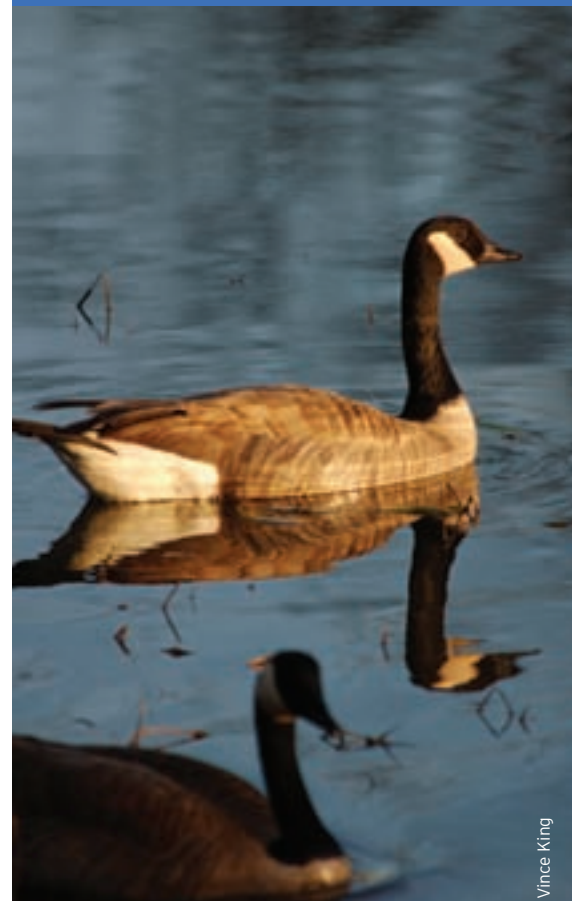
- **California officials should design global warming pollution reduction programs so that major polluters pay and some of the revenue generated is allocated for fish and wildlife conservation.** The revenue should supplement, not supplant, existing budgets for natural resource management, recognizing the new threat to fish and wildlife posed by global warming.
- **The California Department of Fish and Game, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service should revise their permitting processes and their land and wildlife management plans** to ensure that California's wildlife and habitats can survive as climate changes become more pronounced.
- **California's wildlife agencies should partner with universities, research institutions, and nongovernmental organizations to develop a state strategy to address the most critical science gaps** to best manage California's wildlife and natural resources under new climate regimes. This information should build on the strong foundation of the

California Environmental Protection Agency's biennial science report *Our Changing Climate* and be used to refine the proposals in the state's Wildlife Action Plan.

- **State and federal land management agencies should reduce other stresses on fish and wildlife** to help improve the habitats that will be increasingly important as the climate changes. For instance, many wildlife management areas and refuges do not currently have sufficient water supplies; these areas should receive the resources they need to provide real refuge from global warming and other environmental pressures.

## WHAT CAN YOU DO?

- **HELP A HUNTING, FISHING, OR BIRDPWATCHING ORGANIZATION** with a habitat conservation project or join them in advocating for improved wildlife habitat and management. Your actions can make a real difference in increasing the resilience of habitats in the face of global warming.



Vince King

**It is time to tap the pioneering spirit that built California and forge ahead to protect wildlife and stop global warming. Hunters, anglers, and other outdoor enthusiasts have been the foundation for conservation in California. We must continue that tradition as the challenges grow significantly greater.**

# Endnotes

<sup>1</sup> California Department of Parks and Recreation, "The California State Park System Statistical Report: 2006/07 Fiscal Year" (Sacramento, CA: 2007). Available at: [www.parks.ca.gov/pages/795/files/06-07%20statistical%20report\\_onlinefinalfinal.pdf](http://www.parks.ca.gov/pages/795/files/06-07%20statistical%20report_onlinefinalfinal.pdf).

<sup>2</sup> National Park Service Public Use Statistics Office, "NPS Stats" [www.nature.nps.gov/stats/park.cfm](http://www.nature.nps.gov/stats/park.cfm).

<sup>3</sup> U.S. Fish and Wildlife Service, "Refuge List by State: California" [www.fws.gov/refuges/profiles/ByState.cfm?state=CA](http://www.fws.gov/refuges/profiles/ByState.cfm?state=CA).

<sup>4</sup> California Beaches, [www.beachcalifornia.com](http://www.beachcalifornia.com).

<sup>5</sup> National Wild and Scenic Rivers System, "Wild and Scenic Rivers by State" [www.rivers.gov/wildriverslist.html#ca](http://www.rivers.gov/wildriverslist.html#ca). (accessed March 24, 2008).

<sup>6</sup> U.S. Fish and Wildlife Service (FWS), *2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation State Overview* (Washington, DC: U.S. Department of Interior, July 2007).

<sup>7</sup> Southwick Associates, *Sportfishing in America: An Economic Engine and Conservation Powerhouse*. Produced for the American Sportfishing Association with funding from the Multistate Conservation Grant Program (2007); Southwick Associates, *Hunting in America: An Economic Engine and Conservation Powerhouse*. Produced for the Association of Fish and Wildlife Agencies with funding from Multistate Conservation Grant Program (2007).

<sup>8</sup> U.S. Geological Survey, "National Water Summary on Wetland Resources. U.S. Geological Survey Water-Supply Paper 2425" Available at: [water.usgs.gov/nwsum/WSP2425/index.html](http://water.usgs.gov/nwsum/WSP2425/index.html) (accessed March 9, 2008).

<sup>9</sup> U.S. Fish and Wildlife Service, "USFWS Threatened and Endangered Species System (TESS), California listed species," Available at: [ecos.fws.gov/tess\\_public/StateListing.do?state=CA&status=listed](http://ecos.fws.gov/tess_public/StateListing.do?state=CA&status=listed) (accessed March 9, 2008).

<sup>10</sup> Moyle, P.B., R.M. Yoshiyama, J.E. Williams, and E.D. Wikramanayake. *Fish Species of Special Concern in California (Second Edition)*, Prepared for the State of California, The Resources Agency, Department of Fish and Game, Inland Fisheries. (University of California at Davis: 1995). Available at: [www.dfg.ca.gov/habcon/info/fish\\_ssc.pdf](http://www.dfg.ca.gov/habcon/info/fish_ssc.pdf).

<sup>11</sup> Steen, H.K., *The U.S. Forest Service: A History* (Seattle, WA: University of Washington Press, 2004).

<sup>12</sup> Stephens, S.J., C. McGuire, and L. Sims, *Conservation Assessment and Strategy for the California Golden Trout (Oncorhynchus mykiss aguabonita) Tulare County, California* (California Golden Trout Working Group, 2004). Available at: [www.tucalifornia.org/cgtic/GTCAssessmnt&Strategy9-04.pdf](http://www.tucalifornia.org/cgtic/GTCAssessmnt&Strategy9-04.pdf)

<sup>13</sup> Stephens et al., 2004.

<sup>14</sup> Western Native Trout Initiative (WNTI). *Western Native Trout Initiative: A Plan for Strategic Action*. (2008) Available at: [www.westernnativetrout.org/media/pdf/A-Plan-for-Strategic-Action.pdf](http://www.westernnativetrout.org/media/pdf/A-Plan-for-Strategic-Action.pdf)

<sup>15</sup> Cayan, D., et al., *Scenarios of Climate Change in California: An Overview*, (Sacramento, CA: California Climate Change Center, 2006a) Available at: [www.climatechange.ca.gov/biennial\\_reports/2006report/index.html](http://www.climatechange.ca.gov/biennial_reports/2006report/index.html).

<sup>16</sup> Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: The Physical Science Basis, Summary for Policymakers* (Geneva: IPCC Secretariat, 2007). Available at: [www.ipcc.ch](http://www.ipcc.ch).

<sup>17</sup> Luers, A.L., et al., *Our Changing Climate: Assessing the Risks to California* (California Energy Commission report CEC-500-2006-077, July 2006). Available at: [www.climatechange.ca.gov/biennial\\_reports/2006report/index.html](http://www.climatechange.ca.gov/biennial_reports/2006report/index.html)

<sup>18</sup> Lindley, S.T., et al., "Framework for Assessing Viability of Threat-



Vince King

ened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin" *San Francisco Estuary and Watershed Science* 5 (2007): Art. 4. Available at: [repositories.cdlib.org/jmie/sfews/vol5/iss1/art4/](http://repositories.cdlib.org/jmie/sfews/vol5/iss1/art4/)

<sup>19</sup> Williams, J. "Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California" *San Francisco Estuary and Watershed Science* 4 (2006): Art. 2. Available at: <http://repositories.cdlib.org/jmie/sfews/vol4/iss3/art2/>

<sup>20</sup> National Research Council (NRC), *Endangered and Threatened Fishes in the Klamath River Basin: Causes of Decline and Strategies for Recovery* (Washington, DC: National Academies Press, 2004). Available at: [books.nap.edu/catalog.php?record\\_id=10838](http://books.nap.edu/catalog.php?record_id=10838)

<sup>21</sup> Washington State Department of Ecology (WSDE), *Effects of Elevated Water Temperatures on Salmonids* (Olympia, WA: State of Washington, 2000). Available at: [www.ecy.wa.gov/biblio/0010046.html](http://www.ecy.wa.gov/biblio/0010046.html); Lindley et al., 2007.

<sup>22</sup> Barthelow, J.M. "Recent Water Temperature Trends in the Lower Klamath River, California" *North American Journal of Fisheries Management* 25 (2005): 152-162.

<sup>23</sup> Poff, N.L., M.M. Brinson, and D.W. Jay, *Aquatic Ecosystems and Global climate change: Potential Impacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States* (Arlington, VA: Pew Center on Global Climate Change, 2002). Available at: [www.pewclimate.org/docUploads/aquatic.pdf](http://www.pewclimate.org/docUploads/aquatic.pdf).

<sup>24</sup> O'Neal, K., *Effects of Global Warming on Trout and Salmon in U.S. Streams* (Washington, DC: Defenders of Wildlife and National Resources Defense Council, 2002). Available at: [www.defenders.org/resources/publications/index.php](http://www.defenders.org/resources/publications/index.php)

<sup>25</sup> Yates, D., et al., "Climate Warming, Water Storage, and Chinook Salmon in California's Sacramento Valley" *Climatic Change* (accepted February 2008).

<sup>26</sup> Cayan, D., et al., *Projecting Future Sea Level* (Sacramento, CA: California Climate Change Center, 2006b). Available at: [www.climatechange.ca.gov/biennial\\_reports/2006report/index.html](http://www.climatechange.ca.gov/biennial_reports/2006report/index.html).

<sup>27</sup> Chen, J.L., C.R. Wilson, and B.D. Tapley, "Satellite Gravity Measurements Confirm Accelerated Melting of Greenland Ice Sheet" *Science* 313 (2006): 1958-60; Otto-Bliesner, B.L., et al., "Simulating Arctic Climate Warmth and Icefield Retreat in the Last Interglaciation" *Science* 311 (2006): 1747-50; Overpeck, J.T., et al., "Paleoclimatic Evidence for Future Ice-sheet Instability and Rapid Sea-level Rise"

Science 311 (2006): 1747-50; Rignot, E., and P. Kanagaratnam, "Changes in the Velocity Structure of the Greenland Ice Sheet" Science 311 (2006): 986-90.

<sup>28</sup> Cayan et al., 2006b.

<sup>29</sup> IPCC, 2007.

<sup>30</sup> Cayan et al., 2006b; California Department of Water Resources (DWR) and California Department of Fish and Game (DFG), *Risks and Options to Reduce Risks to Fishery and Water Supply Uses of the Sacramento/San Joaquin Delta: A Report Pursuant to Requirements of Assembly Bill 1200*, Laird (Sacramento, CA: 2008).

<sup>31</sup> O'Neal, 2002.

<sup>32</sup> Barnett, T.P., D.W. Pierce, and R. Schnur, "Detection of anthropogenic climate change in the world's oceans" Science 13 (2001): 270-74.

<sup>33</sup> Pearcy, W.G., *Ocean Ecology of North Pacific Salmonids* (Seattle, WA: University of Washington Press, 1992).

<sup>34</sup> Taugher, M., "Panel to consider ban on California salmon fishing; Population collapse inspires drastic talk" San Jose Mercury News, March 10, 2008.

<sup>35</sup> IPCC, 2007.

<sup>36</sup> Turley, C., et al., "Reviewing the impact of increased atmospheric CO<sub>2</sub> on oceanic pH and the marine ecosystem" *Avoiding Dangerous Climate Change*, Schellnhuber, H.J., N. Nakicenovic, T. Wigley, and G. Yohe, Eds., (Cambridge, UK: Cambridge University Press, 2006).

<sup>37</sup> Westerling, A.L., et al., "Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity" Science 313 (2006): 940-943.

<sup>38</sup> Luers, et al., 2006.

<sup>39</sup> Fried, J.S., M.S. Torn, and E. Mills, "The impact of climate change on wildfire severity: a regional forecast for northern California" *Climatic Change* 64 (2004): 169-191.

<sup>40</sup> U.S. Fish and Wildlife Service-Alaska, "Migratory Bird Management: Waterfowl" [alaska.fws.gov/mbmp/mbm/waterfowl/waterfowl.htm](http://alaska.fws.gov/mbmp/mbm/waterfowl/waterfowl.htm) (Accessed March 24, 2008).

<sup>41</sup> Arctic Climate Impact Assessment (ACIA), *Impacts of a Warming Arctic* (New York, NY: Cambridge University Press, 2004).

<sup>42</sup> Ibid.

<sup>43</sup> Riordan, B., D. Verbyla, and A.D. McGuire, "Shrinking ponds in subarctic Alaska based on 1950-2002 remotely sensed images" *Journal of Geophysical Research* 111 (2006): G04002, doi:10.1029/2005JG000150.

<sup>44</sup> LaRoe, E.T., and D.H. Rusch, "Changes in Nesting Behavior of Arctic Geese," in *Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems*, ed. LaRoe, E.T., et al. (Washington, DC: U.S. Department of the Interior, National Biological Service, 1995), 388-389.

<sup>45</sup> Nichols, J.D., K.J. Reinecke, and J.E. Hines, "Factors Affecting the Distribution of Mallards Wintering in the Mississippi Alluvial Valley" *The Auk* 100 (1983): 932-946; Hepp, G.R., and J.E. Hines, "Factors Affecting Winter Distribution and Migration Distance of Wood Ducks From Southern Breeding Populations" *The Condor* 93 (1991): 884-891.

<sup>46</sup> California Department of Fish and Game (DFG), *California Wildlife: Conservation Challenges. California's Wildlife Action Plan*.

(Sacramento, CA: California Resources Agency, 2007). Available at: [www.dfg.ca.gov/wildlife/wap/report.html](http://www.dfg.ca.gov/wildlife/wap/report.html)

<sup>47</sup> Cayan et al., 2006a.

<sup>48</sup> DFG, 2007.

<sup>49</sup> California Department of Water Resources (DWR), *Progress on Incorporating Climate Change into Planning and Management of California's Water Resources* (Sacramento, CA: California Resources Agency, 2006) Available at: [baydeltaoffice.water.ca.gov/climatechange.cfm](http://baydeltaoffice.water.ca.gov/climatechange.cfm)

<sup>50</sup> Jager, H.I., W. Van Winkle, and B.D. Holcomb, "Would Hydrologic Climate Changes in Sierra Nevada Streams Influence Trout Persistence?" *Transactions of the American Fisheries Society* 128 (1999): 222-240.

<sup>51</sup> DWR, 2006.

<sup>52</sup> Wilkinson, R., *The Potential Consequences of Climate Variability and Change for California: A Report of the California Regional Assessment Group for the U.S. Global Change Research Program* (Santa Barbara, CA: University of California, Santa Barbara, 2002) Available at: [www.usgcrp.gov/usgcrp/nacc/california.htm](http://www.usgcrp.gov/usgcrp/nacc/california.htm)

<sup>53</sup> Erman, D.C., et al., "Effects of winter floods on fishes in the Sierra Nevada" *Canadian Journal of Fisheries and Aquatic Sciences* 45 (1988): p. 2195-2200; Bratovich, P.M., et al., *Fish Populations of Mammoth Creek, Mono County, California* (1988 - 2007) (Mammoth Lakes, CA: Mammoth Community Water District, 2007). Available at: [www.mcwd.dst.ca.us/ProjectsReports/MammothCreek.htm](http://www.mcwd.dst.ca.us/ProjectsReports/MammothCreek.htm).

<sup>54</sup> Sierra Nevada Ecosystems Project (SNEP), *Final Report to Congress, Summary of the Sierra Nevada Ecosystem Project Report* (Davis, CA: University of California, Centers for Water and Wildland Resources, 1996). Available at: [ceres.ca.gov/snep/pubs/](http://ceres.ca.gov/snep/pubs/).

<sup>55</sup> DFG, 2007.

<sup>56</sup> DFG, 2007; SNEP, "Chapter 8: Watersheds and Aquatic Biodiversity" *Final Report to Congress, vol. 1, Assessments and Scientific Basis for Management Options*.

<sup>57</sup> SNEP, "Chapter 23: Economic Assessment of the Ecosystem" *Final Report to Congress, vol. III, Assessments, Commissioned Reports, and Background Information*.

<sup>58</sup> Thorne, J.H., et al., *The Development of 70-Year-Old Wieslander Vegetation Type Maps and an Assessment of Landscape Change in the Central Sierra Nevada* (Sacramento, CA: California Energy Commission, PIER Energy-Related Environmental Program, 2006). Available at: [www.climatechange.ca.gov/biennial\\_reports/2006report/index.html](http://www.climatechange.ca.gov/biennial_reports/2006report/index.html)

<sup>59</sup> Tahoe Environmental Research Center (TERC), *Tahoe: State of the Lake Report 2007* (Davis, CA: University of California, 2007).

<sup>60</sup> Mote, P. W., "The West's Snow Resources in a Changing Climate" *Testimony before the U.S. Senate Committee on Commerce, Science, and Transportation*, May 6, 2004.

<sup>61</sup> NRC, 2004.

<sup>62</sup> DFG, 2007.







Vince King

<sup>63</sup> FWS, "Lower Klamath National Wildlife Refuges Complex" [www.fws.gov/klamathbasinrefuges](http://www.fws.gov/klamathbasinrefuges) (accessed Feb. 2, 2008).

<sup>64</sup> DFG, 2007; California Environmental Protection Agency State Water Resources Control Board, "2006 Clean Water Act Section 303(d) List of Water Quality Limited Segments" [http://www.swrcb.ca.gov/tmdl/303d\\_lists2006.html](http://www.swrcb.ca.gov/tmdl/303d_lists2006.html) (accessed Feb 1, 2008).

<sup>65</sup> DFG, 2007.

<sup>66</sup> NRC, 2004.

<sup>67</sup> DWR, 2006.

<sup>68</sup> NRC, 2004.

<sup>69</sup> Bartholow, 2005.

<sup>70</sup> DWR, 2006; DFG, 2007.

<sup>71</sup> DFG, 2007.

<sup>72</sup> Tanaka, S.K., et al., "Climate Warming and Water Management Adaptation for California" *Climatic Change* 76 (2006): p. 361-387.

<sup>73</sup> NRC, 2004; FWS, *Klamath River Fish Die-off September 2002: Causative Factors of Mortality* (Washington, D.C.: U.S. Department of the Interior, 2003) Available at: [www.fws.gov/sacramento/ea/news\\_releases/2003%20News%20Releases/Causative%20Factors%2011-07-03public.pdf](http://www.fws.gov/sacramento/ea/news_releases/2003%20News%20Releases/Causative%20Factors%2011-07-03public.pdf).

<sup>74</sup> FWS, 2003; NRC, 2004.

<sup>75</sup> Central Valley Joint Venture (CVJV), *Central Valley Joint Venture 2006 Implementation Plan - Conserving Bird Habitat* (Sacramento, CA: U.S. Fish and Wildlife Service, 2006).

<sup>76</sup> Ibid.

<sup>77</sup> Ducks Unlimited, "Central Valley / Coastal California" [www.ducks.org/conservation/initiative25.aspx](http://www.ducks.org/conservation/initiative25.aspx) (accessed Feb. 22, 2008).

<sup>78</sup> Ibid.

<sup>79</sup> Ducks Unlimited, "Wildlife Resources of the Central Valley, California. Birds - Part I: Permanent and Summer Residents" *Valley Habitats: A Technical Guidance Series for Private Land Managers in California's Central Valley*. Available at: [ceres.ca.gov/ceres/calweb/DU/Valley\\_Habitats5.html](http://ceres.ca.gov/ceres/calweb/DU/Valley_Habitats5.html)

<sup>80</sup> Inkley, D.B., et al., *Global climate change and wildlife in North America*. Wildlife Society Technical Review (Bethesda, MD: The Wildlife Society, 2004). Available at: [www.nwf.org/nwfwebadmin/binaryVault/Wildlife\\_Society\\_Report2.pdf](http://www.nwf.org/nwfwebadmin/binaryVault/Wildlife_Society_Report2.pdf)

<sup>81</sup> Ibid.

<sup>82</sup> Cavagnaro, T., L. Jackson, and K. Scow, *Climate Change: Challenges and Solutions for California Agricultural Landscapes* (Sacramento, CA: California Climate Change Center, 2006). Available at: [www.climatechange.ca.gov/biennial\\_reports/2006report/index.html](http://www.climatechange.ca.gov/biennial_reports/2006report/index.html)

<sup>83</sup> U.S. Fish and Wildlife Service, "Merced National Wildlife Refuge" [http://www.fws.gov/pacific/refuges/field/CA\\_merced.htm](http://www.fws.gov/pacific/refuges/field/CA_merced.htm)

<sup>84</sup> Great Valley Center, *The State of the Great Central Valley of California. Assessing the Region via Indicators: The Environment*

2000-2005 (Modesto, CA: Great Valley Center, 2005).

<sup>85</sup> DFG, 2007; Yates et al., 2008.

<sup>86</sup> Williams, 2006.

<sup>87</sup> Ibid.

<sup>88</sup> Yates et al., 2008.

<sup>89</sup> Lindley et al., 2007.

<sup>90</sup> Williams, 2006.

<sup>91</sup> Bailey, E., "Salmon may be off-limits" *Los Angeles Times*, March 15, 2008; Fimrite, P., "Threat of closing jolts fishing industry" *San Francisco Chronicle*, March 13, 2008; Taugher, M., "Panel to consider ban on California salmon fishing; Population collapse inspires drastic talk" *San Jose Mercury News*, March 10, 2008; Kay, J., "Scientists try to explain dismal salmon run" *San Francisco Chronicle*, March 24, 2008.

<sup>92</sup> Lund, J., et al., "The Future of the Delta as an Aquatic Ecosystem" *Envisioning Futures for the Sacramento-San Joaquin Delta* (San Francisco, CA: Public Policy Institute of California, 2007). Available at: [www.ppic.org/main/publication.asp?i=671](http://www.ppic.org/main/publication.asp?i=671)

<sup>93</sup> DWR, *Suisun Marsh Monitoring Program Reference Guide Version 2* (Sacramento, CA: California Resources Agency, 2000). Available at: [www.iep.ca.gov/suisun/dataReports/index.html](http://www.iep.ca.gov/suisun/dataReports/index.html)

<sup>94</sup> DWR, 2000.

<sup>95</sup> Lund, 2007.

<sup>96</sup> Knowles, N., and D.R. Cayan, "Elevational Dependence of Projected Hydrological Changes in the San Francisco Estuary and Watershed" *Climatic Change* 62 (2004): 319-336.

<sup>97</sup> Inkley et al., 2004.

<sup>98</sup> Boesch, D.F., et al., *The Potential Consequences of Climate Variability and Change on Coastal Areas and Marine Resources: A Report of the National Coastal Areas and Marine Resources Sector Team for the U.S. Global Change Research Program* (Silver Spring, MD: National Oceanic and Atmospheric Administration Coastal Ocean Program, 2000). Available at: [www.cop.noaa.gov/pubs/das/das21.pdf](http://www.cop.noaa.gov/pubs/das/das21.pdf)

<sup>99</sup> DWR, 2000.

<sup>100</sup> Lund et al., 2007; Cayan et al., 2006b.

<sup>101</sup> Mount, J., and R. Twiss, "Subsidence, Sea Level Rise, and Seismicity in the Sacramento-San Joaquin Delta" *San Francisco Estuary and Watershed Science* 3 (2005): Art. 5. Available at: [repositories.cdlib.org/jmie/sfews/vol3/iss1/art5/](http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art5/)

<sup>102</sup> Jassby, A.D., and E.E. Van Nieuwenhuysen, "Low dissolved oxygen in an estuarine channel (San Joaquin River, California): mechanisms and models based on long-term time series" *San Francisco Estuary and Watershed Science* 3 (2005): Art. 2. Available at: [repositories.cdlib.org/jmie/sfews/vol3/iss2/art2/](http://repositories.cdlib.org/jmie/sfews/vol3/iss2/art2/)

<sup>103</sup> California Coastal Conservancy (CCC), *Southern California Wetlands Recovery Project Regional Strategy* (Santa Barbara, CA: California Coastal Conservancy, 2001). Available at: [www.scwrp.org/regional\\_strategy.htm](http://www.scwrp.org/regional_strategy.htm) (accessed Feb. 23, 2008); DFG, 2007.

<sup>104</sup> CCC, 2001.

<sup>105</sup> DFG, 2007.

<sup>106</sup> Cayan et al., 2006b.

<sup>107</sup> Luers et al., 2006.

<sup>108</sup> DFG, 2007.

<sup>109</sup> Krebs, M., "Water-Related Energy Use in California" Presentation before the Assembly Committee on Water, Parks and Wildlife, February 20, 2007. Available at: <http://www.energy.ca.gov/2007publications/CEC-999-2007-008/CEC-999-2007-008.PDF>





INSPIRING AMERICANS TO PROTECT WILDLIFE FOR OUR CHILDREN'S FUTURE.



**National Wildlife Federation**  
11100 Wildlife Center Drive  
Reston, VA 20190  
703-438-6000  
[www.nwf.org](http://www.nwf.org)

**Planning and Conservation  
League Foundation**  
1107 9th Street, Suite 360  
Sacramento, CA 95814  
916-313-4515  
[www.pcl.org](http://www.pcl.org)

