

The California Current Marine Bird Conservation Plan

Executive Summary Report



Photo: Dave Gardner, PRBO Conservation Science

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The California Current Marine Bird Conservation Plan Executive Summary Report

*A summary of knowledge and recommendations
for the conservation of marine birds and their habitats throughout
the California Current Large Marine Ecosystem.*

Version 1.0

**Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum**

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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Photos: David Gardner and Eric Preston

CONSERVATION PLAN AUTHORS

Lead Editors:

Kyra L. Mills, William J. Sydeman and Peter J. Hodum

Correspondence:

Brenna Langabeer Schlagenhauf
Program Coordinator, PRBO Marine Ecology Division
4990 Shoreline Highway
Stinson Beach, CA 94970
E-mail: blangabeer@prbo.org

Authors:

Sue Abbott, PRBO Conservation Science
Christine Abraham, PRBO Conservation Science
Luis Bourillón, Comunidad y Biodiversidad
Russell Bradley, PRBO Conservation Science
Ellie Cohen, PRBO Conservation Science
Gregg Elliott, PRBO Conservation Science
Meredith Elliott, PRBO Conservation Science
David Gardner, PRBO Conservation Science
Andrew Hagen, PRBO Conservation Science
Laird Henkel, HT Harvey and Associates Ecological Consulting
David Hyrenbach, Duke University
Brad Keitt, Island Conservation
Brenna Langabeer Schlagenhauf, PRBO Conservation Science
Derek Lee, PRBO Conservation Science
Aileen Miller, PRBO Conservation Science
Kyra Mills, PRBO Conservation Science
Ken Morgan, Canadian Wildlife Service
Maura Naughton, U.S. Fish and Wildlife Service
Scott Newman, Wildlife Trust
Nadav Nur, PRBO Conservation Science
Eduardo Palacios, ProNatura
Peter Pyle, PRBO Conservation Science
Jennifer Roth, PRBO Conservation Science
Jose Angel Sanchez-Pacheco, Island Conservation
Michelle Schuiteman, PRBO Conservation Science
William Sydeman, PRBO Conservation Science
Julie Thayer, PRBO Conservation Science
Pete Warzybok, PRBO Conservation Science
Shaye Wolf, Island Conservation
Peggy Yen, PRBO Conservation Science

Reviewers:

Dan Anderson, University of California, Davis
Vernon Byrd, U.S. Fish and Wildlife Service
Don Croll, University of California, Santa Cruz
Shannon Fitzgerald, NOAA Fisheries-National Marine Fisheries Services
Mark Hipfner, Canadian Wildlife Service
Ken Morgan, Canadian Wildlife Service
Ken Warheit, Washington Dept. Fish and Wildlife

Data Contributions:

California Cooperative Oceanic Fisheries Investigations (CalCOFI)
California Department of Fish and Game (CDFG)
Canadian Wildlife Service (CWS)
Island Conservation Ecology Group (ICEG)
NOAA Fisheries—Southwest Fisheries Science Center
PRBO Conservation Science (PRBO)
Scripps Institution of Oceanography
U.S. Fish and Wildlife Service (USFWS)

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LETTER FROM PRBO'S EXECUTIVE DIRECTOR

April, 2005

Dear Colleagues,

Protection and conservation of marine birds is synonymous with protection and conservation of ocean ecosystems. Though long revered as symbols of freedom and strength, seabirds are actually highly sensitive to changes and disturbances in their environment. From the wind-swept islands where seabirds roost and breed, to the estuarine, bay and pelagic zones where they feed, seabirds reflect the health and condition of the ecosystems upon which they survive.

As conspicuous top predators, seabirds alert us to changing ocean conditions and threats affecting other marine wildlife, including whales, sea turtles, seals, sea lions and commercial fish. From climate variability and food web composition to destructive fishing practices and toxic pollution —such as the DDT contamination that decimated populations of the majestic Brown Pelican in the late 1960s—seabirds can help us understand the state of our oceans and provide insights into sustainable management for the long-term.

Both the U.S. Commission on Ocean Policy and the Pew Oceans Commissions recently concluded that our oceans are in peril, with potentially grave socio-economic repercussions. As a nation, we must work together to ensure the health and restoration of these precious, and increasingly threatened, natural resources. We must develop policy and management efforts that are better coordinated, inclusive, and based on sound science.

With this urgent need in mind, PRBO developed this first-of-its-kind **California Current Marine Bird Conservation Plan (CCS Plan)**. The California Current System (CCS) is a vast and diverse oceanic domain spanning over 25 degrees of latitude, from southern British Columbia, Canada to Baja California, Mexico. One of only 5 highly productive eastern boundary current ocean systems on earth that together support over 50% of the world's commercial fisheries, the CCS supports a great diversity of seabirds, marine mammals and fish species.

The **CCS Plan** addresses seabird conservation from an ecosystem perspective, synthesizing information on multiple species, multiple habitats, ecological interactions, and the issues and threats that affect the health of seabirds, their prey and their environments.

This Plan has been created to provide ocean resource managers, policy makers, researchers and the public with science-based tools and recommendations to improve seabird and ocean conservation, to the benefit of marine wildlife and our communities that depend on the ocean for their livelihoods.

Herein you will find **The California Current Marine Bird Conservation Plan Executive Summary Report**. This summary report includes:

- The CCS Plan Executive Summary;
- Chapter 1: Introduction;
- Summaries of the CCS Plan's chapters and conservation recommendations.

Please use this report as a guide to the full chapters of the CCS Plan, which are available to download from our website at www.prbo.org/conservationplanning. The CCS Plan is a living document which will be modified as new information and scientific findings become available. Your input is most valuable to us and we welcome any questions or feedback.

Thank you for your interest in conserving our oceans. Together we can work towards a healthy CCS ecosystem that will benefit marine birds and other marine wildlife, our economies and our communities.

Sincerely,

Ellie M. Cohen
Executive Director
PRBO Conservation Science

EXECUTIVE SUMMARY

The California Current System (CCS) Marine Bird Conservation Plan (CCS Plan) is a collaborative effort of various agencies and organizations that are committed to the conservation of seabirds that breed or feed in the California Current. Extending from southern British Columbia, Canada to Baja California, Mexico, the CCS is a biologically rich large marine ecosystem, supporting a great diversity and abundance of seabirds, marine mammals, sea turtles, fishes and their prey.

The overarching mission of the CCS Plan is long-term conservation of marine birds and their prey. We define this as the maintenance of stable populations, capable of sustaining themselves into the future, as well as the protection and, restoration of all species of marine birds that migrate and breed throughout the CCS.

PRBO Conservation Science obtained funds for the development of the CCS Plan, initiated the project, and brought together the various individuals from agencies and organizations within the region that helped to prepare the CCS Plan.

The conservation agenda for seabirds and initial implementation design have been developed in partnership with a wide array of state and federal agencies, non-governmental research and conservation organizations, academic institutions, and individual researchers.

It is our hope that Version 1.0 of the CCS Plan reflects the start of a long-term process to update scientific information and modify conservation and management recommendations based on the latest information. Thus, we see the CCS Plan as a living document that should be reviewed, evaluated, and updated at regular intervals. In our view, revisions should take place every 3-5 years.

Goals

The main goals of this conservation planning effort are to:

- Compile information on California Current marine bird species and ecosystem features.
- Analyze and synthesize information on marine birds of the California Current and their relationships with their prey, natural enemies, and humans.
- Evaluate and identify gaps in information to be filled by future research and monitoring.
- Determine conservation needs from an ecosystem perspective and propose a conservation agenda.
- Initiate steps to implement the CCS Plan by developing strategies for partnerships and identifying “interest bridges” with user groups, agencies, and other organizations.

Overall Findings

In compiling data, identifying gaps, and writing the CCS Plan, a few general themes became apparent:

- (1) information on marine birds of the CCS is scattered, sometimes disorganized and is often difficult to obtain;
- (2) the current threats faced by marine birds in the CCS are numerous and in many cases are increasing in number and intensity; and (3) there are still many knowledge gaps that need to be filled in order to understand seabird conservation biology in a more complete manner.

Overall Recommendations

The CCS Plan provides specific recommendations for researchers, managers, educators, conservationists, and policy-makers to guide seabird conservation in the CCS. Recommendations are listed at the end of Chapters 2-12 and could be used to structure management programs.

CHAPTER 1. INTRODUCTION

The California Current System (CCS) is a large marine ecosystem, stretching from British Columbia to Baja California. This system hosts an abundance and diversity of marine life including over 150 species of breeding and migrating seabirds, at least 29 species of whales and dolphins, and a variety of sea turtles, seals, sea lions, and fish. As one of the world's five eastern boundary current systems, the waters in the CCS are extremely productive, yet variable, and serve as a "feeding trough" of the North Pacific. As such, the region supports many far-ranging species from the Southern Hemisphere, as well as major resident populations of seabirds and other organisms of the Northern Hemisphere. The CCS is home to fishery and eco-tourism industries essential to the coastal economies of North America.

An Ecosystem Approach to Seabird Conservation

Upper trophic-level predators such as seabirds depend on marine invertebrates and fishes for their survival. Owing to exceptional ocean climate variability, the food webs of seabirds in the CCS change considerably over multiple time scales—from seasonal to centurial. Therefore, in order to develop an understanding of seabird population change, and its causes, it is crucial to include an understanding of temporal environmental variability and ecosystem and seabird response.

An ecosystem-level approach to seabird conservation considers the relationships of all species in the environment, including both breeding and migratory species, as well as all positive and negative interactions that affect seabird demography. At the core of this approach is the study and understanding of food web and predator-prey dynamics. By striving to understand these relationships, steps can be taken to manage and sustain key prey that support CCS seabirds. In general, the food webs of marine birds in the CCS consists of small coastal pelagic fish, young-of-the-year-predatory fish (e.g., salmonids and groundfish), macro-zooplankton (large copepods and euphausiid crustaceans), and squids. These prey species vary in distribution and abundance in relation to environmental variability, such as the El Niño/La Niña cycle and lower frequency ocean climate changes of the Pacific Decadal Oscillation.

An ecosystem-level approach also includes understanding of the habitats of seabirds including both the island rocks and bays where they roost and breed as well as the open ocean where they feed. Spatial variability in habitat characteristics and qualities must be quantified and key habitats protected where necessary.

Finally, an ecosystem-level approach includes humans in the seabird conservation equation. Coastal development, pollution, overexploitation of marine resources, and climate change are the principle negative influences that humans impose on the CCS ecosystem. However, humans must also be part of the solution. Therefore, an ecosystem-level approach to seabird conservation must include a strategy for involving coastal communities in identifying issues and developing solutions.



Photo: David Gardner

*Western Gull adult on nest with three eggs.
Año Nuevo Island, CA*

1.1 NEED FOR AN ECOSYSTEM-LEVEL MARINE BIRD CONSERVATION PLAN

As environmental threats and stressors continue to grow, an ecosystem approach is both timely and needed for the conservation of seabirds and the ocean environment. Many recent studies have demonstrated the decline of marine biodiversity, the decline of marine top predators (fish, birds, mammals), and the collapse of commercial fisheries around the world (8, 9). In the CCS we have witnessed this decline in sardine, salmon, and groundfish fisheries as well as a decline of many seabird and marine mammal populations. Many species have been listed under the Endangered Species Act, and while some species have recovered (e.g., gray whale), others continue to exist in a diminished state.

The myriad of species and conservation problems in the CCS are interrelated and often tend to exacerbate one another. Fishing impacts have received scrutiny and fishers have, somewhat unfairly, received the brunt of criticism with respect to many issues in ocean ecosystem management. The situation is actually quite complex, with the future of northeastern Pacific fisheries intimately linked with the future of the ecosystem's integrity, which varies in relation to *both* natural and anthropogenic factors.

One solution is to adjust marine management towards an integrated multi-species, multi-disciplinary approach that considers the entire ocean ecosystem—including humans. Understanding the significance of natural and human influences on marine systems from climate variability to exploitation, is essential for making appropriate long-term policy and management decisions in support of healthier oceans and seabird populations.

1.2 WHAT IS AN ECOSYSTEM CONSERVATION PLAN? A CONCEPTUAL MODEL

Both “bottom-up” and “top-down” forces influence seabirds in the California Current. “Bottom-up” factors affect the prey consumed by seabirds. Bottom-up factors include climatic forces that alter winds, currents, sea temperature, salinity, and nutrient input. Top-down factors include human-induced interactions, such as pollution and fisheries and natural sources of mortality from predators, diseases, and parasites.

Bottom-up and top-down factors interact. For example, fishery effects on seabird food webs can be either positive or negative. In the southern CCS, a large fishery for market squid (*Loligo opalescens*) may reduce the availability of this critical winter food resource for seabirds. However, in the northern CCS, an extensive fishery for hake (*Merluccius productus*) may improve the feeding opportunities for seabirds by removing large fish which compete with seabirds for a similar prey base (euphausiid crustaceans and small fishes). The sum of all these factors has direct and indirect effects on marine birds by altering foraging success, demographic parameters, and ultimately population dynamics. Therefore, this conservation plan focuses on the role of variable or simultaneous and interacting bottom-up and top-down forces in managing marine bird communities and populations.

1.3 GEOGRAPHIC AND TAXONOMIC CONSIDERATIONS

Geography

The California Current forms the eastern leg of the North Pacific Gyre, which rotates in a clockwise fashion around the Pacific basin. The geographic coverage of the CCS Plan encompasses coastal and pelagic regions that are under the direct influence of the California Current (CC), a large, slow-moving, southward-flowing pelagic current along the west coast of North America. For this plan, we assume the northern extent of the California Current reaches the coast of North America at the northern tip of Vancouver Island, British Columbia, Canada. We assume the southern extent of the California Current flows westward away from the North American coast at Punta Eugenia, Baja California Peninsula, Mexico (Fig. 1.1). These boundaries vary in relation to major east-west currents of the North Pacific Gyre (the North Pacific Current [West Wind Drift] and North Equatorial Current, respectively). Northern and southern delineations of this ecosystem are also supported by upwelling centers which infuse coastal waters with cold, nutrient enriched waters.

Together, the California Current and upwelling centers make the CCS essentially a temperate, sub-arctic ecosystem, though periodic intrusions of sub-tropical waters during El Niño events can dramatically alter the occurrence of sub-arctic vs. sub-tropical species in the region. Moreover, to the south of Punta Eugenia, mangroves become the dominant coastal vegetation, whereas north of this point, mangrove swamps are not found. The western boundary for the CCS Plan is the 200-mile Exclusive Economic Zones (EEZs) of Mexico, the U.S., and Canada. This boundary is political, rather than oceanographic or biological. In summary, we have chosen these delineations because they reflect core areas of the CCS from an oceanographic-biological perspective from north to south, and core management areas from east to west.

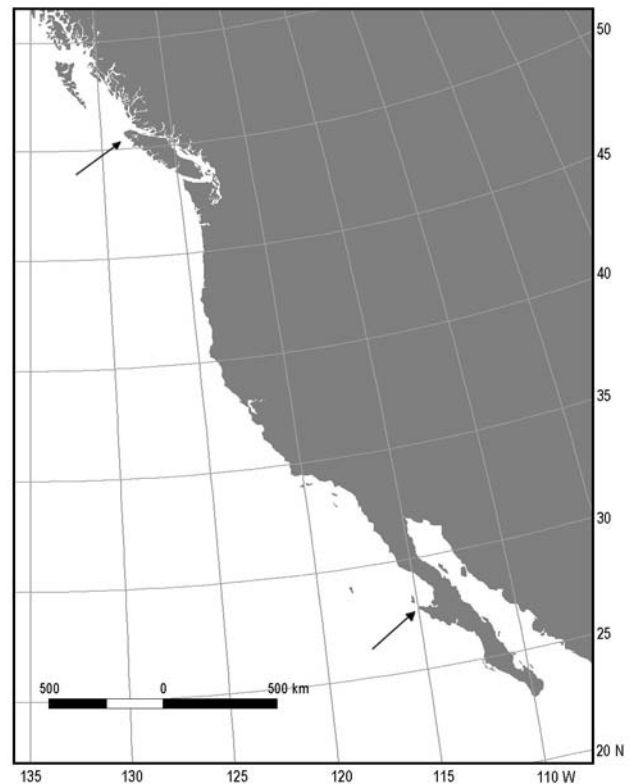


Figure 1.1 – Map of the geographic regions included in the CCS Plan. Arrows indicate the northern and southern limits (see text for details).

Taxonomy

The CCS Plan includes all seabirds that breed or feed within the CCS. Some of these species, such as loons, phalaropes, and grebes, breed or feed inland for part of the year, but feed within the CCS during the non-breeding season. Other species, like shearwaters, breed in the Southern Hemisphere, but migrate each austral winter to forage in the CCS. There are a total of 38 breeders within the CCS, and a minimum of 53 species of common migrants, although this diversity varies considerably from year to year (**Appendix A**).

The focal species encompassed in the CCS Plan are those that feed primarily in the open ocean, ‘beyond the surf zone’. These species belong to the families Gaviidae (loons), Podicipedidae (grebes), Diomedidae (albatrosses), Procellariidae (shearwaters and petrels), Hydrobatidae (storm-petrels), Fregatidae (frigatebirds), Phaethontidae (tropicbirds), Pelecanidae (pelicans), Phalacrocoracidae (cormorants), Scolopacidae (phalaropes), Laridae (skuas, jaegers, gulls, and terns), and Alcidae (auks and puffins).

1.4 GENERAL CHARACTERISTICS OF CCS MARINE BIRDS

Seabirds are marine organisms. Many species come ashore only to breed, while the remainder of the year is spent on the ocean. The amount of time spent on the water varies between species. Albatross, for example, spend the majority of their life at sea, often not touching land for years at a time, whereas gulls spend as much or more time on land than at sea during the non-breeding season.

Regardless of the time spent at sea, a common characteristic of all seabirds is that they rely on marine habitats for nutrition. Whether surface gleaners, plunge divers, or pursuit divers, seabird diet consists of small fish, squid and zooplankton year-round. This may be supplemented with the eggs and chicks of other seabirds, carrion, and human refuse (e.g., fishing offal), however in all cases, the majority of food is obtained from the ocean.

The abundance of food in the CCS, resulting from great ocean productivity, attracts millions of seabirds that breed and migrate throughout the CCS each year. As a result of feeding opportunities and breeding habitat, the avifauna of the California Current is diverse and abundant, and includes species with sub-arctic to sub-tropical biogeographic affinities. Migrant species which travel to these waters to forage typically outnumber the breeding species on an annual basis (10, 11).

Seabirds have several characteristics that make them uniquely adapted to marine life. Generally speaking these include extremely dense waterproof feathers, layers of fat to insulate against cold waters, and a desalinization system to remove and excrete the excess salt. Many seabirds are long-lived (some > 50 years), have low reproductive rates, and delay sexual maturity until they are 5-10 years of age. These life history characteristics make most CCS seabirds vulnerable to morbidity and very slow to recover from population declines due to anthropogenic and/or natural changes in the environment.



Photo: David Gardner

Common Murre adults in the colony. Southeast Farallon Island, CA.

1.5 CONSERVATION AND MANAGEMENT CHALLENGES AND OPPORTUNITIES

The same factors that make the CCS so attractive to seabirds also pose conservation and management challenges and opportunities. Perhaps the greatest conservation challenge is that seabird foraging habitats are in the ocean, and the ocean is commonly viewed and regulated as a public resource held in trust for the common good. Therefore, seabirds are affected by the ‘tragedy of the commons’ as are fisheries.

Contrary to the situation in terrestrial ecosystems where land use can be defined and exchanged on the free market, ocean protection strategies are mostly limited to stewardship. Even for the terrestrial habitats where seabirds court, breed, and roost, the situation is markedly different than that of most other bird species. This is because seabirds tend to congregate on offshore rocks, pinnacles, and islands, and along the coast of North America these lands are primarily owned and controlled by the government. The degree of stewardship of seabird habitats varies, ranging from near-total protection from human use (e.g., Farallon Island National Wildlife Refuge) to biodiversity stewardship as merely one of several goals, as is the case on islands used for strategic defense purposes (e.g., San Clemente Island in the Channel Islands, operated by the U.S. Navy).

Opportunities for the conservation of aquatic habitats have been increasing in recent years. In response to a considerable body of research on the utility of ‘no-take marine reserves’ for biodiversity conservation, the U.S., Mexican, and Canadian governments are making strides towards creating a “network” of marine protected areas (MPA) along the west coast. In addition, there have been major ocean policy reviews such as the Pew Oceans Commission and the U.S. Commission on Ocean Policy reports, new ocean conservation legislation at both the state and federal levels, and increasing public awareness of ocean (and seabird) conservation issues. Many ongoing marine conservation and fishery management initiatives along the Pacific coast of North America now include ‘ecosystem considerations’, with seabirds being part of this novel approach (e.g., see the Pacific Coast Ocean Observing System Science Plan, www.pacocs.org).

One of the primary goals of the CCS Plan is to broaden the appreciation of seabirds as marine organisms and to ensure that the ecological needs and conservation issues facing seabirds are considered as various new marine conservation and policy initiatives develop. The overall implementation recommendation for the CCS Plan is to facilitate region-wide, coordinated monitoring, research, and conservation planning through formation of a ‘Joint Venture’. Chapter 12 details the value of joint ventures as effective venues for bringing together disparate stakeholders for ocean and seabird conservation in the CCS.



Photo: Eric Preston

*Black-footed Albatross adult on water.
West of San Francisco, CA.*

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The California Current Marine Bird Conservation Plan Appendix 1

Breeding and Migrating Seabirds in the California Current System



Photos: Eric Preston, David Gardner and Ben Saenz

APPENDIX 1: BREEDING AND MIGRATING SEABIRDS IN THE CALIFORNIA CURRENT SYSTEM

Breeding seabirds in the California Current System and their basic breeding distribution

(CA = California, OR = Oregon, WA = Washington, CN = Canada, MX = Mexico).

Common Name	Scientific Name	Breeding Range
Ancient Murrelet	<i>Synthliboramphus antiquus</i>	WA, CN
Arctic Tern	<i>Sterna paradisaea</i>	WA
Ashy Storm-Petrel	<i>Oceanodroma homochroa</i>	CA, MX
Black Skimmer	<i>Rynchops niger</i>	CA
Black Storm-Petrel	<i>Oceanodroma melania</i>	CA, MX
Black-vented Shearwater	<i>Puffinus opisthomelas</i>	MX
Brandt's Cormorant	<i>Phalacrocorax penicillatus</i>	CA, OR, WA, CN, MX
Brown Pelican	<i>Pelecanus occidentalis</i>	CA, MX
California Gull	<i>Larus californicus</i>	CA, OR, WA
Caspian Tern	<i>Sterna caspia</i>	CA, OR, WA, CN
Cassin's Auklet	<i>Ptychoramphus aleuticus</i>	CA, OR, WA, CN, MX
Common Murre	<i>Uria aalge</i>	CA, OR, WA, CN
Craveri's Murrelet	<i>Synthliboramphus craveri</i>	MX
Double-crested Cormorant	<i>Phalacrocorax auritus</i>	CA, OR, WA, CN, MX
Elegant Tern	<i>Sterna elegans</i>	CA, MX
Fork-tailed Storm-Petrel	<i>Oceanodroma furcata</i>	CA, OR, WA, CN
Forster's Tern	<i>Sterna forsteri</i>	CA
Glaucous-winged Gull	<i>Larus glaucescens</i>	OR, WA, CN
Gull-billed Tern	<i>Sterna nilotica</i>	CA, MX
Heermann's Gull	<i>Larus heermanni</i>	MX
Horned Puffin	<i>Fratercula corniculata</i>	CN
Laysan Albatross	<i>Phoebastria immutabilis</i>	MX
Leach's Storm-Petrel	<i>Oceanodroma leucorhoa</i>	CA, OR, WA, CN, MX
Least Storm-Petrel	<i>Oceanodroma microsoma</i>	MX
Least Tern	<i>Sterna antillarum</i>	CA, MX
Magnificent Frigatebird	<i>Fregata magnificens</i>	MX
Marbled Murrelet	<i>Brachyramphus marmoratus</i>	CA, OR, WA, CN
Mew Gull	<i>Larus canus</i>	CN
Northern Fulmar	<i>Fulmarus glacialis</i>	CN
Pelagic Cormorant	<i>Phalacrocorax pelagicus</i>	CA, OR, WA, CN, MX
Pigeon Guillemot	<i>Cephus columba</i>	CA, OR, WA, CN
Rhinoceros Auklet	<i>Cerorhinca monocerata</i>	CA, OR, WA, CN
Ring-billed Gull	<i>Larus delawarensis</i>	CA, OR, WA
Royal Tern	<i>Sterna maxima</i>	CA, MX
Thick-billed Murre	<i>Uria lomvia</i>	CN
Tufted Puffin	<i>Fratercula cirrhata</i>	CA, OR, WA, CN
Western Gull	<i>Larus occidentalis</i>	CA, OR, WA, CN, MX
Xantus's Murrelet	<i>Synthliboramphus hypoleucus</i>	CA, MX

Common migrant seabirds in the CCS

Based on observations from the California Cooperative Oceanic Fisheries Investigation (CalCOFI) (1987-2003) and Department of Fisheries and Oceans Canada-Line P (DFO-Line P) programs (1996-2003). CalCOFI and Line P capture the northern and southern extremes of the CCS.

Red-throated Loon <i>Gavia stellata</i>	Manx Shearwater <i>Puffinus puffinus</i>	Parasitic Jaeger <i>Stercorarius parasiticus</i>
Pacific Loon <i>Gavia pacifica</i>	Short-tailed Shearwater <i>Puffinus tenuirostris</i>	Pomarine Jaeger <i>Stercorarius pomarinus</i>
Arctic Loon <i>Gavia arctica</i>	Sooty Shearwater <i>Puffinus griseus</i>	South Polar Skua <i>Stercorarius maccormicki</i>
Common Loon <i>Gavia immer</i>	Wilson's Storm-Petrel <i>Oceanites oceanicus</i>	Little Gull <i>Larus minutus</i>
Yellow-billed Loon <i>Gavia adamsii</i>	Red-billed Tropicbird <i>Phaethon aethereus</i>	Bonaparte's Gull <i>Larus philadelphia</i>
Red-necked Grebe <i>Podiceps grisegena</i>	Red-tailed Tropicbird <i>Phaethon rubricauda</i>	Black-headed Gull <i>Larus ridibundus</i>
Horned Grebe <i>Podiceps auritus</i>	Red-faced Cormorant <i>Phalacrocorax urile</i>	Franklin's Gull <i>Larus pipixcan</i>
Eared Grebe <i>Podiceps nigricollis</i>	Masked Booby <i>Sula dactylatra</i>	Thayer's Gull <i>Larus thayeri</i>
Western Grebe <i>Aechmophorus occidentalis</i>	Brown Booby <i>Sula leucogaster</i>	Glaucous Gull <i>Larus hyperboreus</i>
Clark's Grebe <i>Aechmophorus clarkii</i>	Blue-footed Booby <i>Sula nebouxii</i>	Slaty-backed Gull <i>Larus schistisagus</i>
Short-tailed Albatross <i>Phoebastria albatrus</i>	Red-footed Booby <i>Sula sula</i>	Sabine's Gull <i>Xema sabini</i>
Black-footed Albatross <i>Phoebastria nigripes</i>	Surf Scoter <i>Melanitta perspicillata</i>	Black-legged Kittiwake <i>Rissa tridactyla</i>
Mottled Petrel <i>Pterodroma inexpectata</i>	Black Scoter <i>Melanitta nigra</i>	Common Tern <i>Sterna hirundo</i>
Cook's Petrel <i>Pterodroma cookii</i>	White-winged Scoter <i>Melanitta fusca</i>	Black Tern <i>Chlidonias niger</i>
Murphy's Petrel <i>Pterodroma ultima</i>	Red-breasted Merganser <i>Mergus serrator</i>	Kittlitz's Murrelet <i>Brachyramphus brevirostris</i>
Buller's Shearwater <i>Puffinus bulleri</i>	Red Phalarope <i>Phalaropus fulicaria</i>	Parakeet Auklet <i>Aethia psittacula</i>
Pink-footed Shearwater <i>Puffinus creatopus</i>	Red-necked Phalarope <i>Phalaropus lobatus</i>	Crested Auklet <i>Aethia cristatella</i>
Flesh-footed Shearwater <i>Puffinus carneipes</i>	Long-tailed Jaeger <i>Stercorarius longicaudus</i>	

The California Current
Marine Bird Conservation Plan
Summary of Research and
Conservation Recommendations:
Chapters 2–12



Photos: David Gardner and Eric Preston

Chapter 2 Summary

SEABIRD STATUS, CONSERVATION, AND MANAGEMENT IN THE CALIFORNIA CURRENT

For seabird conservation in the California Current to be successful several factors need to be determined. These include:

- the status of breeding and migratory marine birds in the CCS, including population estimates, distribution, and main threats at colonies and at sea;
- current conservation status in the U.S., Canada, Mexico, and globally;
- current habitat protection, both on land and at sea; and
- management jurisdiction for seabirds and their habitats.

Chapter 2 of the CCS Plan provides individual species accounts, highlights current habitat protection efforts and discusses current seabird conservation status at the state, federal, and global levels (**appendices B.1, B.2 and C.1, C.2**).

In addition, chapter 2 provides a broad overview of the most important agencies, legislation, executive orders and initiatives established at the federal and state level that can be used to influence seabird conservation in the CCS.

For the full version of Chapter 2, and appendices listed above, please visit www.prbo.org/conservationplanning.



Photo: David Gardner

Double-crested Cormorant adult. Alcatraz Island, CA.

Chapter 3 Summary

SEABIRD HABITATS OF THE CALIFORNIA CURRENT AND ADJACENT ECOSYSTEMS

The coastal and offshore areas of the California Current region provide a variety of feeding, roosting and nesting habitats for seabirds. Chapter 3 of the CCS Plan presents a summary of both terrestrial and marine habitat use.

For the full version of Chapter 3 please visit www.prbo.org/conservationplanning. Provided below is a summary of recommendations from Chapter 3 on conserving and managing seabird habitats in the CCS.

Chapter 3 Research and Monitoring Recommendations

1. Identify important roosting and breeding habitats within the CCS, and their protection status.
2. Identify important historic breeding and roosting sites, the causes for change in use of these areas, and whether restoration is warranted.
3. Identify locations where introduced plants and animals limit seabird breeding opportunities.
4. Identify cases where seabird breeding is limited by interactions with overabundant species (e.g., gulls).
5. Identify areas of high boat or air traffic that cause potential or actual disturbance to seabird colonies.
6. Identify the principle predators at colonies, and those colonies that are most threatened by predators.
7. Identify major threats to seabirds during their migration through the CCS and/or at their wintering grounds.
8. Investigate the effects of native animal disturbance at seabird colonies (e.g., pelicans, geese, eagles, pinnipeds).
9. Evaluate the effects of reintroduction of eagles and falcons on seabird populations.

Chapter 3 Conservation and Management Recommendations

1. Work in cooperation with agencies to protect important seabird habitats from human disturbance and introduction of non-native species.
2. Develop and implement programs to eradicate introduced predators and prevent further predatory mammal introductions on islands.
3. Restore colonies that have been damaged by human disturbance and mammalian introductions. Develop a plan to restore and expand breeding populations on islands from which seabirds have been extirpated or reduced.
4. Regulate areas with high boat traffic, such as ferries, recreational boaters and kayakers, that affect seabird colonies.
5. Increase enforcement of airplane and helicopter ceiling regulations.
6. Monitor and evaluate effectiveness of artificial habitat (e.g., nest boxes) on populations of select species.
7. Continue to use social attraction methods as needed for restoration and management. Identify and monitor locations and species for which this technique may increase population size.
8. Facilitate projects that involve vegetation restoration for burrow-nesting seabirds.
9. Work to decrease attraction of egg and chick predators to seabird nesting habitats (e.g., the interaction of campgrounds with corvids and Marbled Murrelets in coastal forests).

Chapter 4 Summary

DEMOGRAPHY AND POPULATION DYNAMIC MODELS AS A CORNERSTONE OF SEABIRD CONSERVATION AND MANAGEMENT

Seabirds of the CCS face many conservation challenges. The primary challenge is to maintain or restore populations in the face of habitat destruction, predation, prey depletion, and bycatch mortality.

Population dynamics for all species reflect, ultimately, four processes: reproduction, survival, recruitment and movement. Seabird life histories are characterized by long adult life spans, low reproductive rates and deferred maturity. Once breeding begins it can be intermittent (in some species not all breeding-age adults attempt to reproduce every year). These life history characteristics make seabirds of the CCS vulnerable, particularly to events that kill breeding age birds.

Recent developments in quantitative population biology are providing new tools for seabird conservation. First, in the past few decades there have been major advances in seabird population ecology. This has been fueled by sophisticated methods to estimate demographic parameters, such as adult survival, which has been difficult to estimate in the past. Second, there has been extensive elaboration of theoretical models and frameworks which can be applied to seabird populations. These include metapopulation models, source/sink models, and stochastic population models, including population viability analyses.

Chapter 4 of the CCS Plan reviews aspects of demography relevant to seabird conservation, and provides a framework for developing and evaluating conservation and management efforts from a population biology context.

For a full version of Chapter 4 please visit www.prbo.org/conservationplanning. Provided below is a summary of recommendations from Chapter 4 of the CCS Plan.

Chapter 4 Research and Monitoring Recommendations

1. Include assessments of adult survival as an essential component of all seabird monitoring programs in the CCS.
2. Study sources of adult, nestling and egg mortality for all seabird species.
3. Conduct research to determine which demographic parameters are most sensitive to temporal environmental variability. This will facilitate the development of predictive population models.
4. As possible, add measurements of demographic parameters to long-term seabird monitoring programs.
5. Conduct research into how demographic parameters co-vary through time to aid in the development of predictive models.
6. Investigate spatial variation of species demographic parameters for metapopulation modeling efforts.

Chapter 4 Conservation and Management Recommendations

1. Identify and quantify sources of mortality for seabird species of concern.
2. Increase the use of modeling in decision making and as a practical conservation tool in general.
3. Train new experts (i.e. graduate students) in quantitative population biology and the use of population dynamics modeling for seabird conservation.

Chapter 5 Summary

CLIMATE AND FOOD: “BOTTOM UP” CONTROL OF SEABIRD POPULATIONS

“Bottom-up” control of seabird populations includes factors that influence the prey that are consumed by seabirds, namely zooplankton, squid, and fish. Spatial and temporal ocean climate variability and change is the principal mechanism for bottom-up control of seabird population parameters and dynamics.

Chapter 5 explores how seabirds respond to temporal environmental variability and change in the CCS. This chapter includes descriptions of large scale oceanographic and atmospheric processes and the effects of climate variability on seabird food webs.

Following a discussion of climate variability, Chapter 5 turns to the role of dietary analyses and prey consumption models in seabird conservation. The results of prey consumption models are highly valuable for conservation and management of *both* seabirds and fisheries. For example, including estimates of prey consumption in fisheries management plans can be used to establish ecologically sensitive fishery quotas. Prey consumption models can also be used to establish the role of seabirds in the natural mortality of fish. In seabird conservation efforts prey consumption models are especially useful tools to examine the impacts of fisheries on seabird populations as well as characterizing the effects of interannual and interdecadal variability in ocean climate on fish and fisheries in the CCS.

For the full version of Chapter 5 please visit www.prbo.org/conservationplanning. Provided below is a summary of recommendations from Chapter 5 of the CCS Plan.

Chapter 5 Research and Monitoring Recommendations

1. Investigate prey consumption by seabirds (at short and long time scales) in the CCS to assess seabird prey requirements, seabird-based prey mortality, potential conflicts with current or future fisheries, and the consequences of removal of predatory fish to ecosystem structure and functioning.
2. Enhance monitoring of the effects of climate change on seabird diet and population dynamics of prey (fish, squid, zooplankton); use and develop novel techniques of dietary analysis (e.g., Stable Isotope Analysis, Fatty Acid Analysis).
3. Develop programs and databases that enable spatial and temporal comparisons of seabird diets and prey characteristics.
4. Establish standardized methodologies for use in studying diet and prey consumption for a variety of seabird colonies in the CCS.

Chapter 5 Conservation and Management Recommendations

1. Integrate seabird prey requirements into state and federal fishery management plans.
2. Investigate seabird prey requirements prior to opening new fisheries in the CCS.

Chapter 6 Summary

PREDATORS, COMPETITORS, DISEASE, AND HUMAN INTERACTIONS: “TOP DOWN” CONTROL OF SEABIRD POPULATIONS

Marine birds in the Pacific are faced with many threats, on land and at sea, natural as well as anthropogenic. Natural threats include predators, disease, parasites and marine biotoxins.

Anthropogenic threats include loss or degradation of habitat, human disturbance, introduced species, mortality from oil and other marine pollution, and fisheries interactions that cause direct seabird mortality (i.e., bycatch).

Chapter 6 discusses several top-down effects on seabird populations. The most serious direct effect is seabird bycatch. Indirect effects which threaten seabird population health include disturbance to seabirds at colonies, oil contamination from vessels, and disease.

For a full version of Chapter 6 please visit www.prbo.org/conservationplanning. Provided below is a summary of recommendations from Chapter 6 of the CCS Plan.



Photo: Suzi Eszterhas

Brandt's Cormorant parent and chick. Alcatraz Island, CA.

Chapter 6 Research and Monitoring Recommendations

Bycatch and other Fisheries Interactions:

1. Foster communication with agencies involved in fisheries management to keep informed of potential or emerging fisheries that may affect seabird bycatch in the CCS.
2. Use population dynamics models to estimate and evaluate the potential impacts of fisheries bycatch on seabird populations.
3. Identify current or potential impacts of aquaculture (e.g., salmon farming) on seabirds, including change in predator-prey interactions and competition.
4. Identify the spatial and temporal overlap between seabird foraging “hotspots” and fisheries in the CCS.
5. Collate and distribute information regarding seabird species that are affected by fisheries bycatch.
6. Investigate how international fisheries affect seabirds of the CCS.
7. Model population decline of seabird species (e.g., Sooty Shearwaters, Black footed Albatross) in relation to both bycatch and climate/ecosystem change.
8. Identify areas of high boat traffic that have potential or actual conflicts with seabirds at-sea.
9. Continue, or begin, population monitoring programs of seabird species that are impacted or have the potential for being impacted by fisheries.
10. Conduct studies on foraging ranges and diet of seabirds (e.g., Short-tailed, Black-footed, and Laysan albatross) which are often victims of bycatch.
11. Assess each fishery in U.S. Pacific waters for seabird bycatch. Design mitigation measures that are fisheries- and species-specific to minimize or eliminate bycatch.

Disease, Parasites, and Biotoxins:

1. Identify the main seabird diseases, parasites, and biotoxins responsible for seabird mortality events and model their effects on seabird population dynamics.
2. Conduct surveys for diseases present in adult seabirds, fledglings and juveniles to evaluate how diseases are affecting different age classes of seabirds.
3. Develop a standardized collection protocol for unusual mortality events for both live and dead birds.
4. Develop a seabird stranding network (similar to the Marine Mammal Stranding Network) to facilitate pathological and toxicological sampling.
5. Develop collaborations with the USGS—Wildlife Health Laboratory and local agency and university partners to facilitate necropsies and pathological examinations during seabird mortality events.
6. Coordinate dispersal of dead seabirds for research and specimen archival.
7. Establish an archival freezer for future use studies of seabird genetics, pathology, parasitology, etc.
8. Determine whether parasite loads, disease prevalence, or pathogen prevalence is greater in habitats that are more fragmented, more disturbed, and/or more polluted.
9. Evaluate breeding success in relation to contaminants and potential pathogens.
10. Evaluate environmental conditions associated with harmful algal blooms (HABs) and determine whether agricultural run-off and coastal development is contributing to this problem.
11. Conduct research on HABs and the physiological and pathological effects on seabirds.
12. Determine prevalence of West Nile Virus in seabirds and evaluate potential mortality from spread of this disease.
13. Test for prevalence of the following diseases in seabirds in the CCS: New Castle's, St. Louis, Western Encephalitis viruses.

**Chapter 6 Conservation and Management
Recommendations**

Fishing Interactions and Marine Ecosystem Protection:

1. Managers need to be aware of emerging fisheries that could potentially impact seabird bycatch and take action before they become a problem.
2. Examine krill fishing moratoriums in California National Marine Sanctuaries (NMS) and work to establish a CCS-wide ban on krill fishing.
3. Ban fishing for forage species around important seabird breeding colonies and foraging areas.
4. Despite the obvious value of Observer Programs and the necessity of these programs for documenting impacts of fisheries on seabirds and other marine animals, there are few Observer Programs for Pacific fisheries. Fisheries that have a high potential for seabird bycatch need to be identified, and funding secured for observer coverage for these fisheries.
5. Resolution is needed for conflict between tribal gillnet fishing in Washington State and seabird bycatch.
6. Work with appropriate agencies to develop solutions for studying and lessening, as needed, interactions between seabirds and aquaculture.
7. Establish a network of Marine Protected Areas for seabird foraging “hotspots” in the CCS.

Disease, Parasites, Marine biotoxins:

1. Establish a national and international database of seabird morbidity and mortality events of both natural and anthropogenic causes.

Chapter 7 Summary

OTHER HUMAN-SEABIRD INTERACTIONS

Fisheries are just one human-seabird interaction that can have significant effects on seabird populations. Additional interactions that can have population-level consequences for seabirds in the CCS include habitat change, pollution, and disturbance.

Chapter 7 of the CCS Plan discusses and highlights various human-seabird interactions, including loss of nesting or roosting habitats, modification of marine habitats, the impact of introduced and “overabundant” species, effects of pollution (oil, organochlorine, metal and plastic), and direct human disturbance at colonies.

For a full version of Chapter 7 please visit www.prbo.org/conservationplanning. Provided below is a summary of recommendations from Chapter 7 of the CCS Plan.

Chapter 7 Research and Monitoring Recommendations

1. Investigate and model short-term and long-term effects of oil spills (chronic and catastrophic) on seabird prey, habitats, and population dynamics.
3. When an oil spill occurs, model the mortality of all species affected to determine appropriate mitigation and restoration efforts.
4. Assess oil pollution threats along the coast and identify areas most at risk (based on frequency of vessel traffic, time of year, and seabird numbers and diversity, etc.).
5. Implement regular monitoring of contaminant levels in seabird eggs, feathers, and tissues and of the effects of contaminants on seabird demography (survival and fecundity). Use bycaught seabirds to monitor contaminant levels.
6. Evaluate sublethal effects of contaminants.
7. Determine whether environmental contaminants are affecting breeding hormone concentrations and reproductive success.
8. Identify sources of contaminants and garbage in marine systems.
9. Examine levels of ingestion of plastics and other garbage in live and dead seabirds; determine the magnitude of this problem at the population level.
10. Map all sunken vessels in the CCS, with information on oil quantity and type aboard each vessel, date of sinking, depth, etc.
11. Identify which seabird species and colonies are most at risk from freshwater runoff (non point contaminant sources), especially from urban and agricultural centers.
12. Create a database that contains the results of seabird contaminant analyses and distribute this information to agencies with mandates to maintain water quality.
13. Investigate more thoroughly the interactions between terrestrial and marine environments regarding contaminant introductions to the ocean.
14. Consider removing fuel/oil from large-volume sunken vessels near colonies or near important seabird foraging habitats.
15. Conduct float/sink dispersal studies on small seabirds (nearshore and near island) to evaluate beach deposition rates.
16. Further investigate and document the effects of human disturbance on seabirds.

Chapter 7 Conservation and Management Recommendations

1. Ensure that all oil transportation vessels have a double hull.
2. Change routes of major oil transportation vessels and barges based on studies of main current and wind patterns (by season) and potential impacts on important seabird colonies. Conduct studies to identify the level of “threat” in case of major oil spill at important colonies and where changes need to be recommended.
3. Enforce current bilge pumping regulations and work with appropriate agencies to increase strictness of regulations.
4. Use California oil spill response and documentation protocols as a model and make them available to other states in the CCS that lack comparable response protocols.
5. Create a database that includes a list of sensitive seabird areas, sensitive times of year, and a list of contact people for each of these areas. This database should be made available in the case of oil spills or other contaminant emergencies.
6. Require bilge tank cleaning to occur further offshore than current regulations mandate.
7. Work with waste removal and sanitation departments to decrease exposure of seabirds to garbage.
8. Evaluate and monitor the effects of light-intensive fishing activities on offshore, nearshore, and island colonies.
9. Include fisheries effects in management plans. Priority topics to include are: bycatch; light effects on seabirds; and disturbance of seabird colonies or roost sites by fishing vessels.



Photo: David Gardner

Heerman's Gull adult foraging. Ocean Beach, San Francisco, CA.

Chapter 8 Summary

USE OF SEABIRDS AS ECOLOGICAL INDICATORS AND BIOLOGICAL SAMPLERS OF THE CALIFORNIA CURRENT

Higher trophic level predators, such as predatory fish, seabirds and marine mammals depend on the ocean for survival and reproduction. As such, they may be good integrators and indicators of ecosystem 'health', including spatial and temporal variability in food web dynamics, prey stocks, and the effects of human activities.

Seabirds may be useful indicators because they are conspicuous and can be relatively easy to study. A number of commonly measured seabird parameters may be useful as ecosystem indicators. These include: diet, reproductive success, adult survival, and fledging mass.

Chapter 8 of the CCS Plan discusses the various ways that seabirds can be used as ecological indicators and biological samplers. Seabird indicators and samplers may aid in understanding and forecasting fish and zooplankton stocks, variation in habitat qualities, fishery statistics, and levels of marine pollutants.

For a full version of Chapter 8 please visit www.prbo.org/conservationplanning. Provided below is a summary of recommendations from Chapter 8 of the CCS Plan.

Chapter 8 Research and Monitoring Recommendations

1. Assess seabird parameters for their utility as ecosystem indicators.
2. Identify and prioritize the most effective parameters and seabird species for use as samplers.
3. Investigate associations between seabird productivity (or other parameters) and forage fish condition and biomass. Attempt to develop predictive models based on this information.
4. Investigate relationships between seabird species and commercial fish species that forage on the same prey species (e.g., chinook salmon) and attempt to develop predictive models based on this information.
5. Investigate the use of seabird diet for developing fisheries recruitment indices (e.g., the Multivariate Rockfish Index); integrate seabird data with traditional methods to study these organisms.
6. Examine quantitative data on the local distribution, timing and magnitude of prey abundance in relation to variability in seabird reproductive and other life history parameters.

Chapter 8 Conservation and Management Recommendations

1. Encourage the use of seabird-derived information (i.e. diet and reproductive parameters) in fishery management plans and fishery stock assessments.
2. Educate fisheries managers about the utility of seabird-based predictive models of fisheries and fish body condition.

Chapter 9 Summary

CURRENT AND HISTORIC SEABIRD RESEARCH

The Pacific Ocean hosts a wide variety and great abundance of marine birds which collectively require a complex range of habitats throughout the year. Long-term studies at colonies and at sea are highly valuable for determining changes in seabird populations and communities in these habitats. Seabird studies may also be useful for monitoring ecosystem variability.

Chapter 9 of the CCS Plan reviews some of the important seabird research and monitoring programs conducted at colonies and at sea in the CCS since 1970. This chapter considers the general goals and objectives of various programs and provides recommendations for future directions.

For a full version of Chapter 9 please visit www.prbo.org/conservationplanning. Provided below is a summary of recommendations from Chapter 9 of the CCS Plan.



Photo: David Gardner

*Brandt's Cormorant adults & juveniles.
Año Nuevo Island, CA.*

Chapter 9 Research and Monitoring Recommendations

Marine Ecosystem:

1. Identify areas of special significance for seabird foraging in the CCS (e.g., downstream for upwelling centers).
2. Determine how seabirds can be used as indicators of environmental variability on multiple time scales.
3. Initiate more detailed and broader dietary studies to determine differences in prey selection and consumption within the CCS.
4. Utilize telemetry on a wide variety of species to more accurately evaluate foraging habitats throughout the year, and age and sex differences in foraging.

Population Monitoring:

1. Develop standardized survey methods to determine population size, distribution, and trends. Due to environmental variation, multiple annual censuses may be needed to detect population changes.
2. Quantify population estimate discrepancies between aerial photographic and ground-based surveys; examine and calibrate surveys of seabirds developed by radar and other new techniques.
3. Establish a database of professionally reviewed and accepted techniques for seabird research. For example, telemetry attachment methods, blood collection, morphometric measurements, capture methods, etc.
4. Establish a regional database of banding and marking data and make this available to the public.
5. Establish coordinated, long-term demographic studies of seabird populations to determine status, dynamics and trends of populations; use genetic studies to investigate movements between populations and describe population structure.
6. Establish stronger collaborative relationships between Canadian, U.S., and Mexican researchers and others monitoring seabird populations in the CCS.
7. Lobby the National Science Foundation and other agencies (e.g., NOAA) to allocate more resources to seabird research and monitoring.
8. Increase resources to U.S. Fish and Wildlife Service for seabird research and monitoring.

Chapter 10 Summary

EDUCATION AND OUTREACH

Scientific efforts for conservation have little impact without support of the general public. To build understanding and support, research, management, and conservation programs must share their findings and involve community groups, individuals, and partners through education and outreach.

Education and outreach activities focusing on the CCS should take an ecosystem approach—from zooplankton to humans - and teach key concepts about the CCS ecosystem, threats, and conservation approaches.

The goals of chapter 10 of the CCS plan are to outline key concepts for seabird conservation in the CCS for education and outreach, to identify stakeholder groups, and to highlight examples of educational opportunities and resources for educators in the CCS.

A summary of the key concepts for seabird conservation outreach and education in the CCS are listed below. For a more detailed discussion of these concepts please view the full version of Chapter 10, available at www.prbo.org/conservationplanning.

Key Concepts for Seabird Education and Outreach in the CCS.

1. To adequately support seabirds and other marine life, we must not overexploit the marine resources that seabirds depend upon.
2. To sustain healthy populations, seabirds must be able to evade predators, find food, and mate in disturbance free environments.
3. Seabirds possess special adaptations that allow them to thrive in the variable CCS marine environment—often in harsh conditions, and during periods of food scarcity.
4. Seabirds depend on habitats that are diverse in structure, flora, and fauna, and are worth protecting.
5. Non-native plants and wildlife and an overabundance of native predators can upset the dynamic balance of seabird habitats.
6. Seabirds are most vulnerable to disturbance from humans during the nesting cycle, or when they occur in large aggregations at sea.



Photo: David Gardner

Brandt's Cormorant adult. Alcatraz Island, CA.

Chapter 11 Summary

SEABIRD CONSERVATION STRATEGIES AND NEEDS

Chapter 11 of the CCS Plan discusses five major conservation strategies for seabirds of the CCS. A summary of these strategies is provided below. For a full version, download CCS Plan Chapter 11 at www.prbo.org/conservationplanning.

Mitigation and elimination of bycatch:

It is essential that injury and mortality from fisheries bycatch is reduced or eliminated. As long as fisheries using gill nets or long-lines exist, bycatch will be of concern. However, there are certain measures that wildlife managers and fishers can take to reduce the risk of seabird entanglement in fishing gear. These measures include (1) observer programs to identify problems, where problems exist and which species are affected, and (2) mitigation measures and cooperation with fishing communities to reduce bycatch (e.g., bird scaring lines). Destructive fishing gear should be eliminated.

Protecting food webs—marine reserves and minimizing fisheries prey depletion:

Estimates show that more than 40% of the world's fish are fully exploited, with an additional 25% over-exploited, exhausted or recovering. Fully protected marine reserves are an emerging tool in marine conservation. By protecting geographical areas, the food webs upon which seabirds depend may be protected. Areas downstream from upwelling cells in the CCS may be particularly important foraging sites for seabirds. Localized protected areas around colonies may also be useful to protecting seabird food resources.

Restoration:

Seabird communities and populations in the CCS have been subjected to numerous anthropogenic impacts. Restoration is becoming an effective management tool to counteract these effects and aid in the recovery of seabird populations. Successful restoration plans aim to return populations and communities to the level and function that would have occurred had the disturbance not taken place.

Coastal Development:

Effective conservation of seabirds must aim to protect not only the terrestrial habitats important for breeding and roosting, but also the marine habitats of seabirds. Coastal development places pressures on nearshore marine environments that may affect seabirds. Future development should be evaluated based, in part, on potential effects on local seabird populations.

Climate Change:

The affects of humans on seabirds in the CCS should be evaluated in relation climate variability and change. Climate change is the ecological backdrop of seabird conservation, and must be included in assessing mitigation and restoration measures for seabird of the CCS.



Photo: David Gardner

Common Murre two adults. Southeast Farallon Island, CA

Chapter 12 Summary

A “CALIFORNIA CURRENT JOINT VENTURE”: AN IMPLEMENTATION STRATEGY FOR THE CCS PLAN

Effective management of the CCS ecosystem requires comprehensive cross-jurisdictional coordination, innovative tools, and novel partnerships. Implementation and success of the CCS Plan will require involvement and collaboration of regulatory authorities at local, state, national and international levels, as well as the participation of academic institutions, coastal communities and interested individuals.

In terrestrial ecosystems, joint ventures have been successful in bringing together diverse constituents to implement conservation goals and objectives. Joint ventures are voluntary public-private partnerships among those seeking to achieve conservation objectives in a specific geographic region. Comprised of individuals, corporations, conservation organizations, and local, state, provincial, and federal agencies, joint venture partners accomplish together what is often difficult or impossible to do individually.

A California Current Joint Venture (CCJV) is proposed as a venue for implementing the CCS Plan. The overarching function of the CCJV will be to coordinate capabilities of many partners to effect conservation of the California Current System and its seabirds.

For a full discussion of a potential CCJV, please download Chapter 12 of the CCS Plan, available at www.prbo.org/conservationplanning.

Potential goals of a CCJV will be to:

- recognize and protect the food webs and habitats that support marine predators, including seabirds, whales, dolphins, turtles, swordfish, tuna, sharks, and many valuable fish;
- ensure that biodiversity conservation and fisheries health is promoted;
- recognize that fish are an integral part of the food web, and hence must be managed as such;
- implement science-based, multi-species adaptive conservation plans;
- seek to protect and support our marine economy.

Potential benefits of a joint venture partnership include:

- long-term, programmatic conservation approach vs. individual, disconnected projects;
- creation of beneficial partnerships with business, particularly the fishing industry;
- leveraging funds to execute research and conservation projects;
- increased accountability on conservation dollars spent.
- elevating ecosystem based management and top predator issues within management agencies;
- meeting jurisdictional realities while enhancing cross-border and cross-jurisdictional cooperation;

The California Current Marine Bird Conservation Plan

Chapter 2

Current Seabird Status, Conservation, and Management in the California Current



Photo: Dave Gardner, PRBO Conservation Science

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The California Current Marine Bird Conservation Plan Chapter 2

*Current Seabird Status, Conservation,
and Management in the California Current*

Version 1.0

**Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum**

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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CHAPTER 2. CURRENT SEABIRD STATUS, CONSERVATION, AND MANAGEMENT IN THE CALIFORNIA CURRENT

For a seabird conservation plan to be successful, several factors first need to be identified, including (1) the status of breeding and migratory marine birds in the CCS (population estimates, distribution, and main threats at the colony and at sea); (2) current conservation status of seabirds in the U.S., Canada, Mexico, and globally; (3) current habitat protection, both on land and at sea; and (4) management jurisdiction for seabirds and their habitats. This type of information is required before recommendations can be made regarding conservation of marine birds.

In this chapter we highlight the status of seabirds in the CCS (appendices 2 and 3) and their current conservation status at the state, federal, and global levels. In addition, we describe current habitat protection. Protecting the habitats where marine birds breed, roost, and feed, limiting disturbance therein, and protecting seabird prey bases from fishing pressures are essential measures for conservation of these animals.

There are currently many protected terrestrial and marine habitats throughout the California Current region; however, enforcement is often difficult because of lack of personnel or remoteness of habitat. There are also key feeding sites that currently have no protection. At the end of this chapter we provide a broad overview of the most important agencies, legislation, executive orders, programs, and initiatives established at the federal and state level that can and do influence the welfare of seabird species in the CCS. The agencies and programs listed here affect marine birds directly through impacts to their populations, their breeding success, and their habitat and/or indirectly through impacts to their prey base and predators.

2.1 CONSERVATION STATUS OF SEABIRDS

Many species that breed and/or feed in the California Current have special conservation status because of specific threats to the population or decreasing trends. Each species may be listed under several different lists, briefly explained below (see Appendices 4 and 5 for listings).

Each U.S. state has its own process for listing, independent of the federal listing. Mexico lists species through the “Norma Oficial Mexicana,” and the entity that is responsible for listing within Canada is the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Since 1977, COSEWIC has been responsible for determining the national status of species on an annual basis. IUCN–The World Conservation Union (formerly the International Union for the Conservation of Nature and Natural Resources) generates the annually updated Red List, which identifies globally threatened flora and fauna, www.redlist.org.

Of the 38 species that breed within the California Current, three are listed as endangered in California (Brown Pelican, Least Tern, and Marbled Murrelet), two in Oregon (Brown Pelican and the Least Tern), and one in Washington (Brown Pelican) (Appendix 4). The Brown Pelican and the California Least Tern are also federally listed as endangered (207).

The Brown Pelican was severely impacted by the use of pesticides in the late 1960s and early 1970s (52, 54) and was listed in 1970. The California Least Tern was federally listed in 1970, mainly because of habitat loss, predation, shooting, and egg collection (132, 133).

Many of the species that historically nested in coastal estuaries and marshes now nest on artificial habitats such as dredge-spoil islands and salt pond dikes. Several of these species are listed under the federal Endangered Species Act (California Least Tern), as Birds of Conservation Concern (Gull-billed, Caspian, and Elegant terns), or on state threatened/endangered species lists. The Ancient Murrelet is listed as a Species of Special Concern by COSEWIC in British Columbia, www.speciesatrisk.gc.ca.

Coastal development and logging of old growth forests has impacted seabirds along the west coast of North America; in particular, Marbled Murrelet habitat was reduced by 90% as a result of logging in the 1800s (208). Loss of habitat to timber harvest resulted in the listing of this segment of the population as threatened under the Endangered Species Act in 1992, and as threatened in British Columbia in 2000. This species is also state listed as threatened in Oregon and Washington.

In Mexico, the Guadalupe Storm-Petrel was endemic to Guadalupe Island, Baja California. This species was reported as abundant on Guadalupe Island as late as 1906 (122), but by 1922 it was declared extinct (121).

Amongst the migrant species, one is globally listed as endangered, Cook's Petrel, four are listed as vulnerable (Short-tailed Albatross, Black-footed Albatross, Buller's Shearwater, and Pink-footed Shearwater), and two are listed as low risk/near threatened (Mottled Petrel and Murphy's Petrel) (Appendix 5).

2.2 CURRENT HABITAT PROTECTION

Many key seabird sites (especially breeding colonies) have been designated and protected as national wildlife refuges (NWR), national parks, national monuments, state parks, private ecological reserves, and natural preserves. In the marine realm, national marine sanctuaries (NMS) and marine protected areas (MPA; including marine reserves, marine conservation areas, and marine parks) near important seabird roosting and breeding sites offer important benefits for seabird conservation.

The largest seabird colonies in California, the Farallon Islands and Castle Rock, are both national wildlife refuges and, thus, under the protection of the U.S. Fish and Wildlife Service. Five of the seven Channel Islands (San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara) are protected as part of the Channel Islands National Park, and the waters around these islands (1,252 square nautical miles) are designated as a national marine sanctuary. The eastern region of Santa Cruz Island (encompassing 24% of its area) is included in the national park, and the western section is owned and managed by The Nature Conservancy (76% of the area).

The California Coastal National Monument includes 883 acres of rocks, islands, and pinnacles in California (R. Hanks, pers. comm.) and are protected and managed by the U.S. Bureau of Land Management, in partnership with the California Department of Fish and Game and California State Parks. The Channel Islands Marine Reserve was established in 2002 by a vote of the California Fish and Game Commission. Their action created the largest system of marine reserves off the U.S. West Coast. Effective January 1, 2003, the decision set aside 132 square nautical miles within the Channel Islands National Marine Sanctuary in 13 separate areas closed to most or all fishing.

In Oregon, all of the ocean rocks and islands are included within the Oregon Islands National Wildlife Refuge and the Oregon Islands Wilderness Area. The wildlife refuge provides breeding grounds for 13 seabird species numbering approximately 1.2 million individuals (more than Washington and California combined).

In Washington, there are five national wildlife refuges, all within the Olympic Coast National Marine Sanctuary on the outer coast. This NMS encompasses 217 km of coastline, from the Canadian border to the Copalis River. According to the U.S. National Fish and Wildlife Service, four of these national wildlife refuges (Flattery Rocks, Quillayute Needles, Protection Island, and Copalis) contain 80-90% of the state's seabirds, corresponding to 12 species. The Protection Island NWR includes one of the largest Rhinoceros Auklet breeding colonies in the world and the largest Glaucous-winged Gull colony in Washington. The majority of the nesting seabirds are found in the northern half of the state on the islands of the Maritime National Wildlife Refuge and the San Juan Islands.

The San Juan Islands NWR, originally established to protect colonies of seabirds, encompasses 84 rocks, reefs, grassy islands, and forested islands in the San Juan Islands and northern Puget Sound. This northern coast is more rugged and rocky, with numerous offshore rocks. Washington has 600-800 offshore rocks and islands, approximately 550 of which are in the national wildlife refuge system (Kevin Ryan, pers. comm.).

Along the Pacific coast in the Baja California region all of the islands are federal property, although only three are explicitly protected as a natural reserve (Natividad, Asunción, and San Roque islands in the Vizcaino Biosphere Reserve). Even these "protected" islands receive virtually no management to protect the breeding seabirds. Actions to remove introduced species, stop future introductions, and limit human disturbance by non-governmental organizations are the only conservation actions currently undertaken on these islands.

The Pacific Islands Biosphere Reserve plan is a proposal to protect all of the Pacific Baja islands; however, progress has been made for only one island thus far, Guadalupe Island, which is only awaiting the signature of the president to be officially designated as a reserve. The remaining islands (Cedros north to Los Coronados) are included in a proposal that was submitted to the Mexican government and is currently under consideration. The Mexican Federal Congress has shown support for the reserve, and it is likely to be decreed in 2004. If successful, reserve status will provide legal protection for all of the islands, but it is unknown whether there will be funds available to actually monitor and patrol them.

In Canada, habitat protection is also of great concern, although many colonies that are important seabird breeding areas are currently protected within national parks, national park reserves, ecological reserves, and wildlife management areas. However, several areas currently have no protection status, although protection planning processes for marine and terrestrial habitat are ongoing (1).

The Canadian Wildlife Service, in consultation with partners including First Nations, other levels of government, and various NGOs, is in the process of trying to establish Canada's first marine wildlife area (MWA). This MWA would help protect seabirds that breed on the Scott Islands as well as the thousands of migrants that use the waters in this region. Delineation of the boundaries has yet to be completed, but will be based largely on at-sea seabird studies (telemetry and surveys). There is currently a moratorium on offshore oil and gas exploration in the region; however, the moratorium may be lifted in the near future. It is therefore a crucial time to establish protection of the marine habitat used by seabirds in British Columbia, CA.

2.3 MANAGEMENT JURISDICTION FOR SEABIRDS AND THEIR HABITATS

Within all three nations that can lay claim to waters of the CCS (Canada, the United States, and Mexico), there exists an overall schism between agencies and laws regulating the use and management of terrestrial versus marine resources. Seabirds, which nest on land but spend the majority of their lives in the waters that provide their food, are often caught in the middle in terms of management of their habitat (nesting and feeding). Furthermore, the wildlife agencies with a mandate to protect seabirds are never the same as the agencies mandated to manage fisheries, because fish are managed as exploitable resources rather than as wildlife.

Protection and management of seabirds' terrestrial habitats (breeding and roosting sites) is relatively centralized in Canada, Washington, Oregon, and Mexico. Along the coast of California, however, terrestrial jurisdiction is more fragmented and includes the U.S. Fish and Wildlife Service (FWS), U.S. National Parks Service (NPS), state parks, U.S. Bureau of Land Management (BLM), and The Nature Conservancy (TNC).

A. Summary of Agencies, Laws, and Programs Related to Canadian Management of Seabirds

The management of wildlife in Canada is shared by the federal, provincial, and territorial governments. Different agencies have jurisdiction through different legislation for (1) the management and protection of seabirds, (2) their land-based habitats, and (3) seabirds' foraging habitats (i.e. the ocean and fisheries).

The land where seabird colonies are located is primarily under provincial management or occasionally under Parks Canada management (as either national parks or national park reserves). The food that seabirds eat and the oceans in which they spend much of their lives are managed by the Department of Fisheries and Oceans (DFO).

Description of Jurisdiction and Legislation by Agency in Canada

The Canadian Wildlife Service (CWS) is an agency within Environment Canada (EC), a federal department that also includes related water and environmental protection, climate science, and climate change, among others. CWS handles wildlife matters that are the responsibility of the federal government. These include the protection and management of migratory birds as well as nationally significant wildlife habitat. Other responsibilities are endangered species, control of international trade in endangered species, research on wildlife issues of national importance, and international wildlife treaties and issues.

Some bird species, both migratory and non-migratory, are specifically reserved for management by provincial governments. CWS authority for protecting seabirds only extends to the birds themselves and the contents of their nests, not to their habitat (whether land or sea). For example, CWS can limit activities that would involve the taking of eggs and birds or the disturbance of, or damage to, nests, but not activities that threaten breeding, nesting, or foraging habitats. The only exception would be where lands are federally held, but not as national parks.

Under the authority of the Canada Wildlife Act, CWS does manage two types of wildlife areas for the benefit of migratory birds. These are migratory bird sanctuaries (MBS) and national wildlife areas (NWAs are roughly equivalent to U.S. national wildlife refuges).

Migratory bird sanctuaries were originally established to prevent hunting of migratory birds – to afford protection of birds, eggs, and young, under the authority of the Migratory Bird Convention of 1917. CWS can limit hunting and disturbance in an MBS, but not the use of the land. National wildlife areas protect all habitats within their boundaries. The process of defining NWAs starts by prohibiting all activities and uses and then developing a plan that will allow limited permitted activities as appropriate, depending upon the ecological needs of the area. The Canada Wildlife Act also gives the CWS authority to establish protected marine areas.

Parks Canada, another federal agency, has authority to manage the land and nearshore marine habitats of seabirds through park reserves, such as in the Queen Charlotte Islands. Parks Canada also has authority to designate a representative system of marine protected areas under the National Marine Conservation Areas Act.

The Department of Fisheries and Oceans (DFO or Fisheries and Oceans Canada) has jurisdiction over protection and management of marine mammals and fish, including regulating fisheries. DFO has the authority and jurisdiction to manage fisheries under the Oceans Act, which requires sustainable development, integrated management, and a precautionary approach. The Oceans Act also gives the DFO the mandate to establish a network of marine protected areas.

The provincial government of British Columbia has jurisdiction over certain species of birds, including crows, blackbirds, cormorants, and upland game birds. Provincial governments also have authority to protect and manage land habitats through the designation of ecological reserves. Many reserves in B.C. protect islands that are important seabird colonies (reserves are also established to protect other components of biodiversity).

Most such reserves have been designated in the past few decades. The provincial government also has authority to protect and manage non-bird species, with the exception of the recently passed Species At Risk Act (SARA), Canada's newly passed endangered species law. EC is accountable for recovery actions on all listed species except marine mammals and fish, for which DFO takes the lead.

The B.C. government also governs activities in provincial waters, which are defined in a more complex way than are state waters in the U.S. Provincial waters are generally defined as "from headland to headland." For example, inside bays and estuaries would be 100% provincial waters as well as waters internal to the province such as the Strait of Georgia. There is, however, some disagreement between the federal and provincial governments about the extent of B.C. provincial waters, including areas such as Hecate Strait, between the B.C. mainland and the Queen Charlotte Islands, and Queen Charlotte Sound, on the central coast of B.C.

First Nations (i.e. native peoples) constitute another layer of government, as they are semi-autonomous. First Nations in Canada have land claims that extend into the ocean (potentially as far as the entire EEZ). There are approximately 10-12 First Nations groups in B.C. with marine interests. First Nations are working towards agreements with the federal government to obtain coverage of claims on waters within the EEZ. It will therefore be essential to work with First Nations in any process to establish an MPA or reserve.

Description of Key Canadian Seabird Conservation Programs

Marine Protected Areas

DFO, EC, and Parks Canada all have different pieces of legislation that establishes their authority to create marine protected areas. The Oceans Act governs DFO, and it states that DFO is to be the federal "lead" on establishing MPAs. However, the other two departments have their own legislation for establishing MPAs, but that legislation does not include explicit authority over fisheries.

For this reason, any fishing limitations or marine reserves designated by EC or Parks Canada would have to be undertaken in cooperation with DFO, which tends to have less of an ecosystem management perspective than the other two agencies, although this is changing.

Currently there is a precedent-setting effort by the CWS to use their authority under the Canada Wildlife Act to establish a marine wildlife area, the Scott Islands. These islands, located off the northern tip of Vancouver Island, include B.C.'s most important seabird colony on Triangle Island. The Scott Islands are already protected as an Ecological Reserve. The idea is to establish a "sanctuary" for seabirds, where both their land and marine habitats are protected and under conservation management. This process would involve overlapping jurisdictions and, at a minimum, require the cooperation of the CWS, DFO, First Nations, and the British Columbia provincial government.

A provincial/federal strategy was drafted in B.C. to agree on a process for designating MPAs. While it has not yet been formally ratified, its intent is being upheld by the agencies involved. For this reason, it is assumed that the B.C. provincial government will not be a stumbling block in any CWS-led marine wildlife area designation processes. DFO would undoubtedly retain jurisdiction over all fisheries within the proposed marine wildlife area.

Generally, there is a small area of water surrounding coastal terrestrial ecological reserves. In addition, some reserves, such as Chucklesit Bay on the west coast of Vancouver Island, are totally marine. None are currently protected from fishing, although a slow process for designating them as no-take reserves is underway. For most, the marine area is usually small (from low tide line up to several hundred yards from shore); nevertheless, there is a question over who has final say on fishing within this reserve buffer zone.

Bycatch Reduction/Mitigation

Nationally, and locally in B.C., the CWS works with DFO to assess the level of seabird bycatch from fisheries. DFO has been helpful in the past by collaborating with CWS in training fisheries observers on how to collect seabird data (especially in longline fisheries). The program raised enough awareness among fishermen that representatives of the halibut fishery came to DFO to request that all halibut boats exceeding a certain length use seabird avoidance devices as a condition of licensing. Ken Morgan, CWS, is lead for these bycatch programs.

Another project, developed by the National Audubon Society, seeks to further educate fishers on how to remove longline hooks from live seabirds. A poster explaining this process has been produced in multiple languages (Spanish, Korean, Japanese, Chinese, and English). CWS and DFO are collaborating on finding the funds to have the poster translated into French and distributed among fishing associations operating off the west and east coasts of Canada.

Oil Pollution Assessment

CWS is conducting studies to determine the level and seasonality of chronic oiling to predict mortality and population effects of such oiling on seabirds. One study considers trajectory models for spills, ship traffic, and at-sea distribution of birds. The goal is to establish a baseline of the “background” level of oiling off the B.C. coast. Baseline is needed because of the prospect of lifting the current moratorium on oil and gas exploration and development off the B.C. coast.

The moratorium was a joint provincial and federal agreement covering the entire EEZ. If the moratorium were lifted, protections would extend only to 20 km from shore. Ken Morgan is the lead contact for this program.

B. Summary of Agencies, Laws, and Programs Related to U.S. Management of Seabirds

In the U.S., findings of the Pew Oceans Commission include recognition that a plethora of overlapping and sometimes conflicting laws, agencies, and regulations inhibits the efficient and effective management of marine ecosystems. These many overlapping mandates may inhibit ecosystem management.

Whereas the U.S. Fish and Wildlife Service has primary responsibility for the management of migratory birds, including seabirds, National Oceanic and Atmospheric Administration (NOAA) Fisheries, formerly the National Marine Fisheries Service or NMFS, has primary responsibility for the management of the marine environment and fisheries (i.e. a significant portion of the seabird prey base).

Description of Jurisdiction and Legislation by Agency in the U.S.

The U.S. Fish and Wildlife Service (USFWS) is the primary federal agency responsible for the conservation and management of migratory birds, including seabirds.

Several international treaties, domestic laws, and executive orders have been enacted that provide protection for migratory birds. The most important pieces of legislation are: Migratory Bird Treaty Act, Fish and Wildlife Conservation Act, Endangered Species Act, National Wildlife Refuge System Administration Act, and National Wildlife Refuge System Improvement Act.

Other more narrowly focused laws, with respect to seabirds, include those governing oil spill response and damage assessment (e.g., Oil Pollution Act) and other maritime contaminant issues (e.g., Federal Water Pollution Control Act); regulation of commercial and sport fisheries (e.g., Magnuson-Stevens Fishery Conservation and Management Act, High Seas Driftnet Fishing Moratorium Protection Act, and the High Seas Fishing Compliance Act); management of coastal habitats (e.g., Coastal Zone Management Act and Fish and Wildlife Coordination Act); and the management of introduced plants (e.g., Federal Noxious Weed Act).

Within USFWS, the different divisions have defined, and often overlapping, responsibilities concerning the conservation and management of seabirds. Migratory Bird and Habitat Programs has the lead in implementing the Service's responsibilities with regards to migratory birds. Ecological Services includes several key components: Endangered Species, Environmental Contaminants, and Habitat Conservation.

Endangered Species has primary responsibility for seabirds listed under the Endangered Species Act (ESA). Environmental Contaminants encompasses the Service's Damage Assessment and Spill Response Division – the primary FWS contact in the event of an oil, or other contaminant spill. The Habitat and Conservation Branch includes the Coastal Program, Habitat Conservation, and Partnerships programs. The Office of Law Enforcement enforces federal wildlife and habitat laws that affect migratory birds.

In addition to these broad responsibilities, the USFWS also has site-specific management responsibilities associated with the National Wildlife Refuge (NWR) System. The largest U.S. seabird colonies in the Pacific are located on refuges and the majority of the region's seabirds nest on refuge lands.

Other federal and state agencies, tribes, non-governmental organizations, and private individuals that own seabird colony sites in the CCS include: Bureau of Land Management, National Park Service, Department of Defense, state parks, and The Nature Conservancy.

U.S. Fish and Wildlife Service-related Legislation and Executive Orders:

a) The Fish and Wildlife Conservation Act of 1980 created a program to help states emphasize non-game species, thereby avoiding the need to list them under the ESA. This legislation resulted in the development of the Birds of Conservation Concern (B.C.C.) list, which the Migratory Bird office uses to prioritize actions. In 1989, the act was amended to require the USFWS to identify lands and waters in the United States and other nations in the Western Hemisphere whose protection, management, or acquisition will foster the conservation of migratory non-game birds.

b) The North American Wetlands Conservation Act of 1989 provides funding and direction for the North American Waterfowl Management Plan and the Tripartite Agreement on wetlands between Canada, U.S., and Mexico. A North American Wetlands Conservation Council was created to recommend projects to be funded under the act to the Migratory Bird Conservation Commission. Currently \$30 million per year is available under the act for wetland and waterbird conservation.

c) The Neotropical Migratory Bird Conservation Act of 2002 provides grants to countries in Latin America, the Caribbean, and the United States for the conservation of neotropical migratory birds that winter south of the border and summer in North America. Currently \$5 million per year is available. At least 75% of the funds must be spent outside of the United States and the non-federal match is 3 to 1. The law encourages habitat protection, education, researching, monitoring, and capacity building to provide for the long-term protection of neotropical migratory birds.

d) Executive Order 13186 of 2001 mandates greater federal coordination to meet the requirements of the Migratory Bird Treaty Act and specifically calls for heeding recommendations of the continental bird conservation plans. The USFWS is developing memorandums of understanding (MOUs) with other federal agencies to strengthen migratory bird conservation by identifying and implementing strategies that promote conservation and minimize the take of migratory birds.

NOAA Fisheries (formerly the National Marine Fisheries Service or NMFS) is an agency within the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce. NOAA Fisheries and respective state agencies manage the prey of seabirds and marine habitats

where they forage. In 2001, NOAA Fisheries staffed a position for a national seabird coordinator as well as identified staff in each of its regions, science centers, and headquarter offices to address issues associated with seabird/fishery issues. The NOAA staff work in collaboration with regional representatives from the USFWS and the Department of State as part of an Interagency Seabird Working Group.

NOAA Fisheries has jurisdiction over fisheries management and regulation in U.S. federal waters (from 3 to 200 miles offshore), in coordination with the eight regional fisheries management councils. The management councils help to develop fishery management plans, but NOAA Fisheries approves the plans and then develops and enforces fishing regulations. In the Pacific, the Pacific Fisheries Management Council (PFMC) has jurisdiction over CCS waters, the Western Pacific Management Council has jurisdiction over Hawaiian and western Pacific waters, and the Northern Pacific Management Council has jurisdiction over Alaskan EEZ waters.

NOAA also has important responsibilities in conjunction with oil spill response. NOAA established the Damage Assessment and Restoration Program (DARP) in 1990 to fulfill natural resource trustee responsibilities assigned in the Clean Water Act (CWA), the Superfund Act, the Oil Pollution Act of 1990 (OPA), and the National Marine Sanctuaries Act (NMSA).

DARP provides a single focus for natural resource damage assessment and restoration. Protracted and costly litigation to recover damages often is avoided because NOAA, other co-trustees, and the responsible parties are provided an opportunity to agree to a settlement that restores injured resources.

In addition, NOAA's National Ocean Service addresses important responsibilities associated with oil spill response through its Office of Response and Restoration (OR and R). OR and R is the focal point in NOAA for preventing, planning for, and responding to oil spills, releases of hazardous substances, and hazardous waste sites in coastal environments and restoring affected resources. OR and R protects and restores coastal resources through the application of science and technology. On behalf of the public, OR and R addresses environmental threats from catastrophic emergencies, to chronic releases, to vessel groundings in sanctuaries.

NOAA-related Legislation and Executive Orders:

a) Executive Order 13158: Marine Protected Areas 2000, calls for an expanded and strengthened comprehensive system of MPAs throughout the U.S. marine environment and institutes a number of mechanisms to achieve this (NOAA Fisheries and USFWS are lead agencies).

b) The 1994 Magnuson-Stevens Fishery Conservation and Management Act (Magnuson Act first passed 1976), asserts U.S. jurisdiction over fisheries in the EEZ, over all anadromous species (fish, like salmon, that spawn in freshwater and then migrate to the sea) throughout their migratory range (except when in waters of a foreign nation), and over continental shelf fishery resources that extend beyond the EEZ. The act established eight regional fishery management councils to implement provisions of the act, including development of fishery management plans (FMP), reviews of foreign fishing applications, and public hearings.

Under the Magnuson-Stevens Act, the fisheries management councils have authority over all species from 3 to 200 nautical miles offshore, but each council can move directly to recommend regulations only for those species that have a federal FMP approved by NOAA Fisheries. For the West Coast (Washington, Oregon, and California), federal FMPs have been approved for groundfish, salmon, coastal pelagic species, and highly migratory species. To restrict harvest of other species, the appropriate council or NOAA Fisheries would have to develop FMPs for those other species before proceeding with restrictions, although it may be possible for the council to impose restrictions on the take of FMP species in non-FMP fisheries.

While a council can recommend the creation of marine reserves under its Magnuson-Stevens Act authority, it has limited ability to protect fish and habitat in the marine reserve from anything other than fishing impacts. Thus, councils do not control dredging, dumping, or other potentially damaging activities. However, councils can comment to other state and federal agencies about actions that may harm marine reserve areas. For example, a council could comment if an agency wanted to issue a permit for dumping dredge materials in fish habitat.

c) The 1996 Sustainable Fisheries Act (amendments to Magnuson), includes new requirements for reversing decline in marine fish populations. These include FMPs that designate essential fish habitats and steps to protect habitat from non-fishing as well as fishing impacts. FMPs must specify objective and measurable criteria to determine whether a fishery is overfished. If overfished and rebuilding, the act requires reduced harvests, the impacts of which must be fairly allocated among harvesters. The act requires that both bycatch and the mortality of unavoidable bycatch be minimized.

d) The 2000 reauthorization of the National Marine Sanctuaries Act identifies and designates national marine sanctuaries (NMS) (of special national significance); for designated NMS, the act provides for comprehensive and coordinated resource protection, management, monitoring, conservation, and public education while facilitating all public and private uses of sanctuary resources that are not prohibited by other authorities. Sanctuaries, frequently described as national parks of the sea, are managed according to site-specific management plans prepared by NOAA's National Marine Sanctuary Program (NMSP), within NOAA's Ocean Service. The primary activities currently prohibited within NMS are oil and gas exploration and development. At present, the five west coast NMSs are updating their management plans.

Native American tribes in the U.S. constitute another layer of government. The U.S. government deals with Native American tribes as sovereign nations. They have claims and ownership to certain islands that have seabird colonies, as well as some shoreline areas with colonies. Tribes also have subsistence hunting and traditional rights, which extend to fishing prey species and possibly even hunting of seabirds. For example, Washington State regulatory changes instituted to reduce seabird bycatch from salmon gillnets do not apply to tribes.

Description of Initiatives by State in the U.S.

Washington

The Northwest Straits Marine Conservation Initiative was established by Congress in 1999. The goal of the initiative is to restore and protect the marine resources and environment of the Northwest Straits of Washington. The initiative was established in 1999 and must report to Congress in 2004 on progress towards specific benchmarks for environmental restoration and public process.

The Northwest Straits Commission (NWSC) and seven Marine Resource Committees (MRCs) were established under the NWS Initiative. Taken together, they represent a “bottom-up” local approach to protecting, restoring, and managing resources that cross many jurisdictions.

The MRCs are citizen-based committees appointed by locally-elected officials in each of the seven northwestern counties of Washington. The NWSC is a 13-member body that represents the MRCs as well as the Indian tribes and the state of Washington. The role of the MRCs is to determine local needs and to carry out habitat restoration, rehabilitation of marine populations, and outreach to citizens on marine environmental concerns and solutions. The NWSC provides technical assistance, planning, and coordination for the Initiative.

The Initiative is funded by Congress through NOAA and through various local sources and competitive grants. Source: <http://www.pacificmpa.org/>

Accountability is key to the Northwest Straits Initiative. A series of *performance benchmarks* have been crafted to measure progress in protecting and restoring degraded resources and habitats of the Northwest Straits. In addition, the program is authorized for a limited period. After the initiative's six-year term, Congress must approve any further support of program activities. Source: <http://www.nwstraits.org/aboutnsi.html>

Oregon

The Oregon Coast National Wildlife Refuge Complex is comprised of six national wildlife refuges that protect a variety of coastal habitats spanning 320 miles of the state's rugged coastline. Stretching from Tillamook Head south to the California border, three of the six are marine refuges (Oregon Islands, Cape Meares, and Three Arch Rocks) that protect coastal rocks, reefs, islands, and several headland areas. These habitats support some of the most important seabird nesting colonies in the United States. More than a million seabirds, including Common Murres, Tufted Puffins, cormorants, and storm-petrels, nest there.

Oregon Ocean Policy Advisory Council (OPAC) (2002) was established by the governor of Oregon. After nearly two years of study of marine reserves and protected areas in the U.S. and worldwide, the Oregon Ocean Policy Advisory Council (OPAC) found that sufficient evidence existed to recommend that: a) Oregon establish a limited system of marine reserves in order to test and evaluate their effectiveness in meeting marine resource conservation objectives; and b) before designating any specific marine reserves, Oregon must obtain additional information and conduct further study, analysis, and deliberation through an open, public process with extensive stakeholder involvement.

The OPAC made no recommendation about either a specific system of reserves or area locations or the use of marine reserves for fishery management. (Roy Lowe is involved in an effort to establish an MPA buffer around seabird colonies in Oregon.)

California

California's Marine Life Management Act (MLMA)

became law on January 1, 1999, marking the beginning of science-based fisheries management within an ecosystem context for California state waters.

The Act includes the following requirements:

- The MLMA applies not only to fish and shellfish taken by commercial and recreational fishermen, but to all marine wildlife.
- Rather than assuming that exploitation should continue until damage has become clear, the MLMA shifts the burden of proof toward demonstrating that fisheries and other activities are sustainable (precautionary principle).
- Through the MLMA, the legislature delegates greater management authority to the Fish and Game Commission and the Department of Fish and Game.
- Rather than focusing on single fisheries management, the MLMA requires an ecosystem perspective including the whole environment.
- The MLMA strongly emphasizes science-based management developed with the help of all those interested in California's marine resources.

At the time of this writing, the Nearshore Fishery Management Plan had been completed for the nearshore finfish fishery, with plans on squid and abalone (among others) in preparation.

The MLMA includes several underlying goals and premises:

- **Conserves Entire Systems:** It is not simply exploited populations of marine life that are to be conserved, but the species and habitats that make up the ecosystem of which they are a part.
- **Non-Consumptive Values:** Marine life need not be consumed to provide important benefits to people, including aesthetic and recreational enjoyment as well as scientific study and education.
- **Sustainability:** Fisheries and other uses of marine living resources are to be sustainable so that long-term health is not sacrificed for short-term benefits.
- **Habitat Conservation:** The habitat of marine wildlife is to be maintained, restored, or enhanced, and any damage from fishing practices is to be minimized.

- **Restoration:** Depressed fisheries are to be rebuilt within a specified time.
- **Bycatch:** The bycatch of marine living resources in fisheries is to be limited to acceptable types and amounts.
- **Fishing Communities:** Fisheries management should recognize the long-term interests of people dependent on fishing, and adverse impacts of management measures on fishing communities are to be minimized.

To meet these standards, the MLMA calls for using scientific information and constituent involvement in the development of fishery management plans. A master plan will prioritize fishery management needs and an annual "Status of the Fisheries Report" will be produced to assess the status of California's fisheries and management effectiveness. Source:

<http://www.dfg.ca.gov/mrd/mlma/index.html>.

California's Marine Life Protection Act (MLPA) is a pioneering piece of legislation passed in 1999, which requires that the California Department of Fish and Game develop a plan for establishing networks of marine protected areas in California waters to protect habitats and preserve ecosystem integrity, among other things. The following information describes the process and work accomplished to date.

The MLPA states that "marine life reserves" (defined as no-take areas) are essential elements of an MPA system because they "protect habitat and ecosystems, conserve biological diversity, provide a sanctuary for fish and other sea life, enhance recreational and educational opportunities, provide a reference point against which scientists can measure changes elsewhere in the marine environment, and may help rebuild depleted fisheries."

The act requires that a comprehensive Master Plan of proposed MPAs be developed to both establish a conservation-based network as well as improve the conservation design and value of the small reserves already in existence.

The MLPA establishes six overarching goals:

1. To protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems.
2. To help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted.
3. To improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and to manage these uses in a manner consistent with protecting biodiversity.
4. To protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value.
5. To ensure that California's MPAs have clearly defined objectives, effective management measures, and adequate enforcement, and are based on sound scientific guidelines.
6. To ensure that the state's MPAs are designed and managed, to the extent possible, as a network. Source: <http://www.dfg.ca.gov/mrd/mlpa/index.html>

The vote by the commission to establish no-fishing zones is aimed at helping to reverse the alarming drop over the past decade in the population of several marine species that were once plentiful off the California coast, including red snapper, angel sharks, and abalone. Source: <http://www.flmnh.ufl.edu/fish/InNews/CIreserve2002.htm>

I. Description of Key Federal Seabird Conservation Programs

Conservation Planning

The U.S. Fish and Wildlife Service Pacific Region Seabird Conservation Plan is a major initiative on behalf of seabirds within the CCS (and U.S. Pacific islands). The intent of the plan is to define FWS priorities for action and the long-term expenditures required to implement them. In particular, increases in the federal budget needed to implement the plan will be sought.

For example, a high priority that the plan has identified is the need for a program of standardized monitoring for seabirds, including standardized protocols and a comprehensive design. FWS will contract with USGS and collaborate with Oregon State University, Patuxent, and others to develop a detailed waterbird monitoring protocol. The plan is currently undergoing internal review within the agency and will subsequently be sent out for peer review.

The FWS is the lead in an interagency working group (also including NOAA Fisheries and the Department of State) to develop a “National Plan of Action for the Reduction of Seabird Bycatch in Longline Fisheries,” required under the International Plan of Action (IPOA) for the Reduction of Seabird Bycatch (see Chapter 11 for a more detailed explanation of this). The plan of action will apply to all U.S. vessels regardless of where they fish.

Fisheries Management Interface

NOAA Fisheries hires or subcontracts observers on fishing vessels. FWS liaises with NOAA Fisheries concerning the observer program. There is a delicate relationship between FWS and NOAA Fisheries with respect to sharing and analysis of data on seabird bycatch and ensuring sufficient coverage of the observer program. FWS provides technical assistance to NOAA Fisheries concerning training observers to monitor seabirds and seabird bycatch. (M. Naughton, pers. comm.).

FWS has also been regularly consulting with NOAA Fisheries and the PFMC concerning the Highly Migratory Species Fishery Management Plan, providing technical assistance with respect to bycatch of seabirds and other listed species.

Seabird colony monitoring

FWS has recently completed a catalogue of seabird colonies in Oregon, and has contracted services to develop a similar catalogue for California. They are also working closely with the Bureau of Land Management (BLM) in Oregon and California to ensure that their global information system (GIS) is compatible with BLM’s system. The plan is to keep the catalogue updated and accessible via the web, rather than compiling and publishing a catalogue each year.

Oil Pollution

FWS interfaces with NOAA on oil spills through their Ecological Services, Environmental Contaminants branch. NOAA’s Damage Assessment and Restoration Program (DARP) was shaped by over a decade of assessing injuries to coastal and marine resources that reached a peak following the Exxon Valdez oil spill in March 1989.

NOAA’s program provides a single focus for natural resource damage assessment and restoration. Protracted and costly litigation to recover damages often is avoided because NOAA, other co-trustees, and the responsible parties are provided an opportunity to agree to a settlement that restores injured resources.

This approach of working cooperatively with responsible parties to collect data and conduct assessments minimizes costly duplication of effort.

NOAA’s trust resources include:

- commercial and recreational fishery resources;
- anadromous species;
- endangered and threatened marine species and their habitats (sea turtles, for example);
- marine mammals (such as whales, dolphins, and seals);
- marshes, mangroves, seagrass beds, coral reefs, and other coastal habitats; and
- all resources associated with national marine sanctuaries and national estuarine research reserves (e.g., coral reefs).

C. Summary of Agencies, Laws, and Programs Related to Mexican Management of Seabirds

Description of Jurisdiction and Legislation by Agency

In the northern Pacific off the coast of Mexico, there are three primary agencies with responsibility for managing and regulating use of seabird habitat: the Secretaría de Gobernación (Secretary of Governance); the Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca, y Alimentación, also known as SAGARPA (Secretary of Agriculture, Grazing, Rural Development, Fisheries, and Food); and the Secretaría de Medio Ambiente y Recursos Naturales or SEMARNAT (Secretary of Environment and Natural Resources).

The Secretaría de Gobernación governs activities on the islands located off the Pacific coast of Baja California (the southern limit of the CCS), primarily through the issuance of island use permits to fishery cooperatives and others. In addition, all the waters off the coast of Mexico (from the high tide line +20 meters out to the 200-mile Exclusive Economic Zone boundary) are considered federal waters under their jurisdiction. For example, infrastructure in support of oil and gas prospecting or processing would require approval from Gobernación.

SAGARPA governs fisheries management, primarily through the issuance of permits to all fishermen for their fishing rights, and also through the development of Fishery Management Plans. These plans are supported by information from fisheries research centers located in each state (Ensenada, Baja California and La Paz, Baja California Sur).

SEMARNAT houses three agencies with the responsibility to protect and manage marine bird terrestrial habitats (i.e. islands and coastal areas). These agencies are the Comisión Nacional de Áreas Naturales Protegidas or CONANP (Natural Protected Areas Commission), the Dirección General de Vida Silvestre (Wildlife Agency), and the Instituto Nacional de Ecología or INE (National Institute of Ecology).

Most impacts to marine birds of Mexico occur as a result of the terrestrial developments and activities of fisheries cooperatives, particularly the lucrative abalone and lobster fisheries. Such cooperatives, along with other visitors and users of the islands, have over the years been responsible for the introduction of exotic mammalian herbivores and predators to islands with important marine bird colonies.

Such introductions have significantly reduced the seabird populations of these islands.

For example:

- Cats on Asunción and cats and rats on San Roque were mostly responsible for the extirpation of one of the two known colonies of Cassin's Auklet in the Baja Pacific, as well as other seabird species.
- Cats and dogs on Natividad, together with lights and roads built by residents, significantly reduced the Black-vented Shearwater colony, which harbors 95% of the world's nesting population of this species.
- Rabbits brought by co-op members to San Benito Islands devastated the flora and competed for burrows with seabirds.
- Fishing co-ops also disturb birds, especially pelicans and cormorants, as a result of having people on the islands walking around.
- Direct habitat loss from the development of fisheries co-ops also occurs, although this impact is comparatively minimal.
- Guano mining has displaced birds on San Roque and San Jerónimo.

Within SEMARNAT, CONANP is the primary land management agency with jurisdiction over the designation, conservation planning, and management of four different types of protected areas: biosphere reserves (e.g., the Vizcaíno Biosphere Reserve located in Baja California Sur), national parks (such as Loreto Bay National Park), wildlife protected areas (such as the Gulf of California Islands), and natural resource protected areas.

Vida Silvestre has responsibility for managing protected species and their habitats designated under the Norma Oficial Mexicana (roughly the Mexican equivalent of the Endangered Species Act). This includes the generation of protected species plans and designation of critical habitat. Vida Silvestre also has jurisdiction over all wildlife hunting on federal, state, and private lands under the Ley General de Vida Silvestre. INE is responsible for conducting applied research to aid in the management and protection of natural systems in Mexico.

Description of Key Seabird Conservation Programs in Mexico

At this writing, Mexican Pacific islands in the southern CCS do not have any official protected status; however, a proposal to create a Pacific Coast Baja California Island Biosphere Reserve has been sponsored by the Grupo de Ecología y Conservación de Islas (GECI).

If successful, such a proposal would permanently protect the islands from future development; require the creation of comprehensive management plans for the resources; and result in greater oversight of fishing activities on the islands. Guadalupe Island, which was originally a part of the GECI proposal, has since been officially proposed by the Mexican government as a Biosphere Reserve, with the proposal undergoing review in fall 2003.

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The California Current Marine Bird Conservation Plan Appendix 2

Species Accounts – Breeding Seabirds of the California Current

Version 1.0

Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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APPENDIX 2: SPECIES ACCOUNTS – BREEDING SEABIRDS OF THE CALIFORNIA CURRENT (References located in Chapter 2)

Ancient Murrelet *Synthliboramphus antiquus*

The world population of Ancient Murrelets (ANMU) is likely between 1-2 million birds, with the core of this population in British Columbia (with 540,000 breeding individuals, (1)), and Alaska (2). South of British Columbia (B.C.), the only documented breeding was in 1924 at Carroll Island, Washington (3). It is not known if ANMU currently nest in Washington, but it is considered probable based on observations of staging adults between Carroll Island and Jagged Island in early April (U. Wilson, pers. comm.). Based on frequent observations of ANMU in protected waters of Washington and adjacent Canadian waters, it appears that these areas are important wintering habitat for this species (4, 5). ANMU are also recorded in low numbers in Oregon and California waters during winter and early spring (6).

Data indicate declines throughout the range, primarily due to introduced mammalian predators on colony islands (2, 7). Given the post-breeding southern dispersal, at-sea threats are the highest concern for this region. Introduced mammals are currently considered the greatest threat to populations in the eastern Pacific, and programs to remove them from nesting islands have been initiated in B.C. and Alaska (8-10). At sea, ANMU may be negatively impacted by oil pollution and interactions with fisheries (8, 9). The magnitude of the interaction between ANMU and fisheries is currently unknown, although it may be especially important in the foraging habitat in the inshore waters of Washington.

Arctic Tern *Sterna paradisaea*

Arctic Tern (ARTE) population size estimates from 1980 suggest that more than 30,000 ARTE pairs breed in south to south-central Alaska and in the Russian Far East (11). The breeding population in the CCS region is limited to a small colony (10-20 pairs) discovered on Jetty Island in Puget Sound, Washington in 1977 and 1978 (12, 13), although it is unknown if they currently breed there (13). ARTE have an extensive non-breeding migration, often covering 11,000 miles, moving along the west coast of the Americas and wintering in Antarctic and sub-Antarctic waters (14, 15).

Globally, most breeding populations and sites are currently not at risk, although population trends for this species are poorly known (14). The pelagic nature of this species makes it particularly vulnerable to oil spills and fisheries bycatch. The small breeding population in this region, which has been completely absent at times (13), is extremely susceptible to impacts from human disturbance. ARTE may be vulnerable to changes in their food supply since they appear not to shift to other foods when their principal prey is not available (13, 16).

Ashy Storm-Petrel *Oceanodroma homochroa*

The Ashy Storm-Petrel (ASSP) is endemic to the CCS, breeding on at least 16 islands or offshore rocks from northern California south to Los Coronados in Baja California, Mexico. The largest breeding colonies are on the Farallon Islands and the Channel Islands, which together support approximately 98% of the breeding population (15, 17). The world population is estimated at approximately 10,000 breeding birds (18). On the Farallon Islands, the breeding population declined 42% between 1972 and 1992 (19). This significant decline is mainly attributed to predation of adults by Western Gulls (*Larus occidentalis*), owls, and possibly mice (20, 21). Population trends at other colonies are not known, although there is no apparent trend in the at-sea numbers in Monterey Bay (22).

Small population, restricted distribution, concentration at a few colonies, extended chick-rearing period, slow growth rates, and low reproductive rates make the ASSP especially vulnerable to threats. A more recent conservation issue is the potential negative impact of bright lights used by squid boats in the vicinity of the Channel Islands and the Farallon Islands, which may disorient storm-petrels, affect their behavior, or enhance avian predation (23). Plastic ingestion can potentially be of concern to ASSP, although this is not documented (22). Eggshell thinning was of concern in the late 1960s and early 1970s (24), and, recently, relatively high levels of DDT and PCB were found in ASSP nesting on Santa Cruz Island, California (25). Oil spills can have devastating effects on seabird populations (26), although documentation of ASSP mortality in oil spills is poor (27), most likely because affected birds die at sea and their bodies sink or are scavenged.

Black Skimmer *Rynchops niger*

The estimated North American breeding population of Black Skimmers (BLSK) is between 65,000 and 70,000 individuals (28). The first California breeding record was in 1972, at the Salton Sea (29). Since then, there has been an expansion of their range, although many of these colonies have poor reproductive success. Currently, there are small, isolated colonies along the California coast from San Francisco to San Diego. In 1995 the state's total was estimated at 1,200 pairs (21). In addition, BLSK sightings have been reported in Baja California, in Estero Punta Banda, Bahia San Quintin, Laguna Ojo de Liebre, and Bahia San Ignacio, though there is no indication they breed in any of these locations (30).

Current threats are those common to all of the coastal terns nesting in southern CA: flooding of nest sites, bird and mammal predation, human disturbance, and potential loss of habitat due to development. The proximity of colonies to urban areas makes them especially vulnerable to disturbance by humans, pets, and feral animals that can disrupt breeding of these southern California colonies and may have contributed to low reproductive success in the past.

Black Storm-Petrel *Oceanodroma melania*

The Black Storm-Petrel (BLSP) is endemic to the California and Gulf of California islands. As is the case for most nocturnal, burrow or crevice nesting species, population estimates are extremely limited and there are few colony-based data to provide a population trend. The current population is estimated at approximately 600,000 breeders, most of which breed on Islas San Benito, Mexico (approx. 95% of the world's population) (S. Wolf and B. Keitt, pers. comm.). Approximately 300 individuals breed at Santa Barbara Island and associated Sutil Island, California (17). Breeding is also possible at Prince (San Miguel), Anacapa, and San Clemente islands (31). Little information is available on historical numbers or trends, but introduced predators on many breeding islands suggest populations have declined from historic levels (32). Although most breeding islands are now free of introduced mammals, it is unlikely that populations have recovered to historic numbers.

Eradication of feral animals has occurred on several islands and is under way at other islands within the range (B. Tershy, pers. comm.). Predation of eggs by the native deer mouse on Santa Barbara Island is likely to occur, given that they prey on Xantus's Murrelet eggs (S. Wolf, pers. comm.). Owls and Peregrine Falcons are also likely predators at most breeding sites (33). Storm-petrels are inherently vulnerable to ingestion of plastics and other marine debris (34), although it is unknown to what degree this occurs in BLSP. There is evidence of eggshell thinning in Ashy Storm-Petrel eggs at Santa Cruz Island, Channel Islands, California, caused by recent high levels of DDT and PCBs (25); thus, this issue is likely to be a threat for this species as well.

Black-vented Shearwater *Puffinus opisthomelas*

The Black-vented Shearwater (BVSH) is the only shearwater that breeds in the CCS. Historical population estimates are not available for this species; however, it is likely current populations are considerably reduced (35). On Natividad Island, where 95% of the world's population currently nests, habitat destruction has reduced the colony area by at least 15% (36). Presently this species nests on Natividad, the three San Benito Islands, and islets Afuera and Negro off Guadalupe Island and has likely been extirpated by introduced cats or rats from Guadalupe, Asunción, and San Roque islands (37). Reliable population estimates are available only for Natividad Island (75,000 pairs, (38)). For the San Benito Islands (150-500 pairs) and islets Afuera and Negro (150-250 pairs), population estimates are based on cursory site visits or numbers of birds observed at sea around the colonies.

Brandt's Cormorant *Phalacrocorax penicillatus*

The Brandt's Cormorant (BRCO) is endemic to the west coast of North America and reaches the southernmost extent of its range on Santa Margarita Island, Baja California Sur. The most recent surveys indicate a global population of approximately 121,500 breeding birds (bb), 87% of which breed along the Oregon and California coasts. Small numbers of BRCO breed in B.C. (190 individuals, (1)), and small populations of BRCO breed on most of the Mexican islands (39). Overall, the BRCO population appears to be relatively stable or increasing; however, individual colony size (40, 41) and productivity (42-44) vary interannually in response to changing oceanographic conditions (e.g., ENSO) (42, 44, 45).

Breeding populations in Mexico have most likely declined in the past century due to severe reductions of historically large colonies on Los Coronados, San Martín, San Jerónimo, San Roque, and Asunción islands, principally from the impacts of human disturbance and introduced species (46). The most serious conservation concern for BRCO is human disturbance at breeding colonies, resulting in nest abandonment and increased predation by gulls and ravens (42, 47, 48). Exploitation of the prey base by human fisheries (49) is also an important concern. Relatively small numbers of BRCO are killed as a result of oil contamination and gillnet fisheries, though the impacts of these events on populations are not well-studied (50). It is unknown if contaminants currently pose a serious problem for BRCO.

Brown Pelican *Pelecanus occidentalis*

The North American Brown Pelican (BRPE) population size is estimated at approximately 194,000 breeders (51), most of which are found along the coasts of southern California and Baja California, Mexico. Only two colonies are in California, on Anacapa and Santa Barbara islands (Channel Islands) (52-56). North American populations underwent dramatic declines during the 1960s and early 1970s due primarily to eggshell thinning induced by pesticide use (57, 58). Although populations have recovered somewhat from these declines (54, 58, 59), they continue to show substantial interannual variation in productivity as related to prey availability (60), disturbance at colonies, and disease outbreaks (F. Gress, pers. comm.). Current populations are mostly stable (39). Only the Los Coronados and San Martin Islands are thought to now support fewer breeders than historic maximums (55, 61).

Although DDE and other eggshell thinning contaminants were banned in the U.S. in the early 1970s, their continued use in Mexico may still be causing problems for colonies in the Gulf of California (54, 57). Adult mortality occurs through introduced mammal predation, oil pollution, entanglement in fishing gear (62), and light disturbance from the squid fishery in the Channel Islands, causing nest abandonment and low reproductive success (F. Gress, pers. comm.). Populations may also be affected by disturbances to breeding and roosting sites and declines in prey stocks due to overfishing or general environmental degradation (54). Substantial die-offs of BRPE due to domoic acid intoxication from phytoplankton blooms (63), bacteriological outbreaks at sewage outflows (64), and botulism (e.g., at the Salton Sea) contribute to local population declines.

California Gull *Larus californicus*

The North American breeding population of California Gull (CAGU) was estimated at 276,000 birds in 1980, of which about 75,000 bred in Washington, Oregon, and California (75). As with other gull species, populations of CAGU likely increased throughout the mid-1900s in response to increased human-related food availability and decreased harvest of eggs and feathers (75-77).

Populations may be leveling off at the turn of the 21st century due to changes in dumping practices, especially on the wintering grounds along the coast (77, 78).

Human impacts on CAGU tend not to be serious due to remote localities of many breeding colonies, abundance of breeding individuals within colonies, and the resilience of gull individuals and populations. Minor impacts include shooting and trapping, ingestion of plastics and other toxins from garbage dumps, and the effects of contaminants and oil spills at the wintering grounds (76, 79). The most serious potential impacts involve disturbance to breeding colonies, resulting in increased intra-specific predation of chicks, and water-use practices that reduce water levels, allowing formation of land bridges that create access to breeding colonies by mammalian predators (77, 80, 81).

Caspian Tern *Sterna caspia*

In North America there are an estimated 32,000-34,000 breeding pairs (BP) of Caspian Terns (CATE) (51, 82). The largest CATE colony in the world (9,933 BP in 2002) is in the Columbia River estuary on East Sand Island (ESI), Oregon (82). CATE are a common resident along both coasts of Mexico (83), however this species does not breed on any of the Mexican Pacific islands. It is reported to breed in small numbers in Laguna Ojo de Liebre (160 pairs) (30), Estero San Quintin (10 pairs) (30), and Laguna San Ignacio (150 pairs) (30). There has been a general increase in the Pacific population of CATE since the 1960s, which is probably due, in part, to the terns' colonization of human-enhanced nesting sites on the coast in close proximity to abundant fish resources (82, 84). Concomitant with this general increase and shift to ESI has been a decline in the number of colonies over the past 20 years (82).

CATE colonies are highly susceptible to habitat loss or degradation from vegetative succession, erosion, or inundation and from human-caused management actions (82). Colony loss from tidal action and high water levels has occurred at several colonies in Washington and California (82). The greatest conservation concern for CATE is the large population concentration at one colony. This concentration results in increased risk from stochastic events such as disease, contaminant and fuel spills, natural disasters, introduced predators, and human disturbance. Additionally, there have been conflicts with other species' management, namely endangered salmon near the Columbia River estuary colonies. Human activity (including researcher disturbance) at or near nesting sites can greatly reduce reproductive success (85). There is evidence that organochlorine pollutants, such as PCB and DDE, continue to impact some CATE colonies (86, 87).

Cassin's Auklet *Ptychoramphus aleuticus*

Current population size of the Cassin's Auklet (CAAU) is estimated at 3.6 million breeding birds (51, 65) with the core of the population in British Columbia (2.7 million, (1)). The largest colony in the world is at Triangle Island, Canada with 548,000 breeding pairs, although this population is declining at an alarming rate (66). The U.S. Pacific region encompasses <5% of the global population: 63% of the U.S. breeding population in Washington (87,600), 37% in California (50,600), and <1% in Oregon (500) (17, 65, 67). In the Channel Islands, large colonies of Cassin's Auklets breed on Prince Island and Castle Rock, which lie offshore of San Miguel Island, and on Santa Cruz Island. CAAU were extirpated from Santa Barbara Island by introduced cats, but a small population continues to breed on an offshore islet, Sutil (17, 68). CAAU currently breed on six Mexican islands and were extirpated by introduced cats on four other islands during this century (39). The San Benito Islands are the only active colony of the CAAU subspecies *P. a. australe*, which formerly bred on San Roque and Asunción Islands (65). Recent population estimates of 75,000 breeding birds on the San Benito Islands (39) and 68,000 breeding birds on San Jerónimo (unpublished estimate, B. Keitt, S. Wolf, 2002) indicate that the CAAU population is much larger than the 20,000–40,000 breeding individuals previously reported for Mexico (65).

Populations of CAAU appear to be declining throughout most of the species' range, and several historic colonies have disappeared, mainly due to introduced predators (65). Reasons for the declines may be a result of predation by Peregrine Falcons and gulls (69) as well as changes in planktivorous food resources between 1978–1999 (44, 70–72). In conjunction with low adult survival at some of the main breeding colonies (66, 73), CAAU face several threats, including the introduction of mammalian predators to breeding grounds (65), entanglement in gillnets and other fishing gear (74), and effects of oil spills (62, 65). An indirect human effect involves increased chick predation by gull populations that have been artificially inflated due to human practices (69). A possible human-related effect relates to global warming and warming of the oceans, which appears to be correlated with declines in the prey resources of CAAU (70–72).

Common Murre *Uria aalge*

The total Pacific breeding population of Common Murres (COMU) is estimated at 4.3 million birds (51), although these numbers are confounded due to overlap with the similar Thick-billed Murre (*Uria lomvia*) at many colonies in the subarctic (88, 89). The core of the COMU breeding population in the CCS region is in Oregon (712,000 breeders, 66% of total). California has approximately 352,000 breeders (34%), and Washington, 7,000 (<1%) (90). There is a comparatively small population of breeders in B.C. (8,400) (1). In recent decades, the central California population has been drastically reduced (by at least 50%) due to gillnet fisheries and oil spill mortality (90, 91), but has started to recover since the adoption of tighter restrictions on these fisheries and active restoration work at some colonies (92–94). In Oregon, population trends appear relatively stable since 1988, when surveys became more standardized, and in Washington, a combination of anthropogenic and natural factors has resulted in overall declines in the population (90).

While the widespread global distribution of COMU makes them less susceptible as a species, local populations can be significantly impacted by oil contamination, gillnet mortality, and human disturbance. Fisheries can cause direct mortality and reduce prey availability, and new or developing fisheries may pose a serious threat. COMU are highly susceptible to oiling, given their tendency to form large rafts on the water, and are especially vulnerable during the period from July to October, when chicks fledge and adults may be flightless during portions of this time. COMU are the most numerous species affected in many spills (62, 95).

Craveri's Murrelet *Synthliboramphus*

The majority of the world's population of Craveri's Murrelet (CRMU) breeds on islands in the Gulf of California. Observations of Craveri's Murrelets during the breeding season suggest they do nest on the Baja California Pacific islands. Jehl and Bond (96) report 31 murrelet observations off southern Baja California (between Punta Eugenia and Cabo San Lucas) of which all identified individuals were ascribed to Craveri's. At the San Benito Islands, Delong and Crossin (97) collected 19 murrelets of which 5 were Craveri's; all had enlarged gonads. No data on population size at the San Benito Islands or for the Gulf of California exist. Very little is known of the breeding biology or natural history of this species besides data from egg collections and a few observations of nests (98, 99). Presumably, threats to this species are the same as those described for other alcid species.

Double-crested Cormorant *Phalacrocorax auritus albociliatus*

The current estimated breeding population of Double-crested Cormorant (DCCO) in the CCS region is approximately 62,000 individuals (1, 51, 100). In Washington, 3,300 breeding birds were estimated in 1989, concentrated mostly in Grays Harbor, the San Juan Islands, and the outer coast, with numbers apparently increasing (13). A total of 10,037 breeding birds were estimated in California in both marine and estuarine habitats (1989-1991), and 12,500 were estimated in Oregon (1988-1992), both states showing increasing trends (17, 100). Approximately 4,000 individuals breed in B.C. (1). In Mexico, small populations of DCCO currently breed on the majority of islands (39). However, historically large colonies on Mexican islands have most certainly declined during this century due to severe population reductions. During the early to mid-1900s, populations on Santa Cruz and Santa Catalina were extirpated due to human disturbance (41) and populations on Prince, West Anacapa, and Santa Barbara/Sutil islands declined to 350 individuals by the 1970s as a result of human disturbance and eggshell thinning produced by DDE contamination in the Southern California Bight (41). However, populations in the Channel Islands have since increased, largely as a result of reduced pesticide use, a reduced level of disturbance (17), and the creation of artificial breeding and foraging habitat (33, 100, 101). In 1999, DCCO re-occupied San Martín Island, which is the largest historic colony in North America (102), after suffering disturbance from feral cats, domestic dogs, and humans (103).

Human disturbance of nesting and roosting birds, pollution, habitat conversion, and introduced predators currently pose the largest threats to DCCO populations (101). Commercial and sports fisheries view the DCCO as a pest species and a competitor (104). Aquaculture practices are currently expanding and will become of increasing importance in the near future.

Elegant Tern *Sterna elegans*

The Elegant Tern (ELTE) has the most restricted breeding distribution of any tern in North America with 90-97% of the global breeding population (<30,000 pairs) concentrated at Rasa Island, Mexico (105). Historically, their distribution included small colonies on San Roque Island (106) and Asunción Island (107), in addition to colonies in the Gulf of California. Egg collecting and introduced species are most likely responsible for historic ELTE extirpations from the Gulf Islands (108). Only five colonies are currently active, two in Mexico and three in southern California (105). There has been a general range expansion into southern California, although attendance at these breeding sites fluctuates among years in response to ENSO conditions, habitat changes, and disturbance events. Population size at Rasa Island increased following the establishment of the island as a reserve in 1964, but recent trends are unclear (109). ELTE breeding range and population size have not recovered to known historical levels, when colonies were more widespread than at present (14, 105).

The world population is vulnerable due to its restricted range, concentration of >90% of the population at one colony, sensitivity to disturbance, and major loss of breeding habitat. Continued northern expansion is potentially limited due to dense human development along most of the coast. Current threats to ELTE populations include habitat conversion via development, introduced species, disturbance at breeding colonies, egg harvesting, entanglement in fishing gear, and military activity (105). Contaminant concerns include oil spills and other chemical pollutants at breeding and wintering sites.

Fork-tailed Storm-Petrel *Oceanodroma furcata*

Population estimates for the Fork-tailed Storm-Petrel (FTSP), as for other storm-petrels, are difficult to obtain due to their nocturnal attendance at colonies and their burrow/crevice-nesting habits (17). There are an estimated 305,000 individuals in the CCS, with the bulk of the population in B.C. (1, 51). Five confirmed colonies have been identified in Washington, all along the outer coast, with an estimated 3,900 breeding birds (209). In Oregon, 1,000 birds were estimated to breed on several offshore rocks and islands (209), with 410 birds estimated at six colonies in central and northern California (17). Little information exists concerning population trends of FTSP (13, 17), although populations in California may have shown a decrease since historical times as a result of changes in vegetation and soil at some of the main FTSP colonies, thereby reducing nesting habitat (17). Numbers of FTSP at sea in California waters also appear to have diminished since the 1960s (209).

Threats to FTSP include loss of nesting habitat, predation, interactions with fisheries, oil spills, and contaminants. Plastic ingestion is common for storm-petrels and can potentially be of concern to FTSP, although this is not known. Shell thinning of seabird eggs was of concern in the late 1960s-early 1970s (24), and is likely of major concern at present times, as shown by relatively high levels of DDE found in the eggs of FTSP breeding on the Queen Charlotte Islands, Canada (111). Oil spills, both chronic and catastrophic, can have devastating effects on seabird populations (26), although documentation of FTSP mortality in oil spills is low, most likely because affected birds die at sea and their bodies sink or are scavenged.

Forster's Tern *Sterna forsteri*

The population estimate for Forster's Tern (FOTE) for the coastal portion of the CCS region is 3,550 breeding birds (in 1989-1990) at 21 colonies in California (17), representing approximately 7% of the North American breeding population (51). Since 1980, FOTE populations appear to have declined in the San Francisco Bay and Monterey Bay areas due to human disturbance and predation (17). Inland colonies have also declined due to increases in agricultural and water developments which have decreased FOTE nesting and feeding habitats (17).

Documented and potential threats to the FOTE populations include exposure to pesticides and contaminants, habitat degradation, and predation (23, 110). Levels of organochlorine pollutants (DDE) have been correlated with eggshell thinning in FOTE breeding in California (87). In addition, development in wetland areas can degrade breeding habitat through draining, filling, or flooding riparian areas (17, 110). Nests are vulnerable to wave action and a suite of mammalian, avian, and reptilian wetland predators (110). FOTE have been known to nest on salt pond levees in San Francisco Bay; however, many colonies have been displaced or reduced in numbers because of human disturbance and predation from the introduced red fox (*Vulpes vulpes*) (17).

Glaucous-winged Gull *Larus glaucescens*

Because of the extensive hybridization between the Glaucous-winged Gull (GWGU) and the Western Gull (WEGU) in Washington and Oregon, estimating population size is difficult. In Washington, 39,923 GWGU and WEGU birds (combining both species) were estimated (13). There are an estimated 4,000 breeders in Oregon (41), and 58,000 in B.C. (1). As with other gull species, populations of GWGU have increased throughout the mid-1900s in response to increased human-related food availability and decreased harvest of eggs and feathers, but may be leveling off at the turn of the 21st century due to changes in dump management, especially on the wintering grounds (78, 114, 115).

Minor impacts on the population include ingestion of plastics and other toxins from garbage dumps (116) and the effects of contaminants and oil spills on the wintering grounds. The most serious potential impact involves disturbance to breeding colonies, resulting in increased intra-specific predation of chicks (117), although effects on the overall population appear to be minimal (118-120).

Guadalupe Storm-Petrel *Oceanodroma macrodactyla*

The Guadalupe Storm-Petrel (GUSP) was endemic to Guadalupe Island. This species was reported to be a winter breeder that nested in the cypress forest on top of the island (121). As late as 1906, GUSP was reported as abundant on Guadalupe Island; however, at that time feral cat predation was described as heavy (122). August 1912 was the last observation of the GUSP on the breeding grounds, and it was declared extinct in 1922 (121).

Gull-billed Tern *Sterna nilotica*

The total number of Gull-billed Terns (GBTE) is not well documented, and systematic surveys are needed to determine if more colonies exist in Mexico. The estimate from all known *S. n. vanrossemi* colonies is less than 600 pairs, with the small U.S. colonies (at the Salton Sea and South San Diego Bay) accounting for approximately 30%. Currently, the U.S. population is small but relatively stable. A recently described colony of 150 to 200 pairs exists on Montague Island at the mouth of the Colorado River (112) and 200 pairs reportedly breed in the Ensenada de La Paz (30) area. Population size and trends in Mexico are unknown.

A primary conservation concern is the small population size and limited breeding distribution, with most birds concentrated at a few sites. As with many species of terns along the Pacific coast, GBTE suffer from loss of nesting habitat, predation, human disturbance, and organochlorine contamination (113). GBTE appear to be more vulnerable to disturbance than other terns, and during the breeding season disturbance can cause chick and adult mortality from predation and early dispersal of young (113).

Heermann's Gull *Larus heermanni*

The majority (95%) of the world population of Heermann's Gulls (HEEG), estimated at fewer than 450,000 breeding birds, nests on a single island, Rasa Island, in the Gulf of California (123). Small colonies of HEEG currently breed on 11 additional islands in Mexico, two of which are located on the Pacific coast of Baja California. The colony on Middle San Benito Island was first reported in 1971 with 9 pairs, and increased to 100 pairs in 1993, 2000, 2001 (46, 123). A small breeding population of 35 pairs was reported on San Roque Island in 1927 (124) and subsequently 33 in 1993 and 42 pairs in 1994 (B. Tershy, pers. comm.). HEEG currently nest at 12 of the 19 colony sites in which they have been historically reported, suggesting that the population may be experiencing a downward trend (123).

Commercial eggging in Mexico, which frequently caused complete breeding failure on Rasa Island until the island was protected in 1964, has been banned (123). However, prey depletion by fisheries, mortality from fisheries bycatch, pollutants, disturbance, habitat conversion, introduced predators, exploitation, and oceanographic changes pose significant threats to current populations (123).

Horned Puffin *Fratercula corniculata*

The total world population of Horned Puffins (HOPU) is estimated at 1.2 million birds (88), but this estimate is considered unreliable due to difficulties associated with censusing crevice-nesting seabirds (125). In the CCS region, HOPU are considered a rare and local summer visitor and occasional breeder, with only one confirmed breeding location on a tiny, unnamed islet off Anthony Island in the Queen Charlotte Islands, Canada (126). Breeding is suspected at up to 11 additional locations in British Columbia, including Triangle and Kerouad Islands (126), though their current breeding status in B.C. is unknown. The total estimated breeding population in British Columbia is 25 pairs (126). HOPU are not thought to breed south of B.C., but their non-breeding range extends to the offshore waters of central California (126).

HOPU suffered widespread population declines between the '70s and '90s due to changes in forage fish stocks, bycatch mortality, and the introduction of mammalian predators to breeding colonies (127). Oil pollution and ingestion of plastics are also considered a concern for this species (128). HOPU are not routinely monitored at any sites in the north Pacific so current trends and threats to this species are not well understood.

Laysan Albatross *Phoebastria immutabilis*

Laysan Albatross (LAAL) breed primarily in the northwest Hawaiian Islands. Colonization of Mexican islands was first reported in 1983 (129) at Guadalupe Island and this species has now been reported to breed at San Benedicto (20 pairs) and Clarion Islands (130). At Rocas Alijos, birds have been reported alighting on the water near the rocks and touching down on top of the rocks. Observed breeding displays by birds near the rocks suggest they may start breeding there in the future (131). On Guadalupe Island the population is growing rapidly, from only 4 birds in 1976, to 138 birds in 1993, to 198 birds in 2001 (Pitman unpublished data). LAAL are doing surprisingly well on Guadalupe despite the proximity of their colony to the Navy base and the presence of feral cats and dogs on the island. On Clarion Island the breeding colony was reported extirpated by feral pigs; however, pigs were removed in 2001 and a small, but unknown, number of LAAL were reported breeding in 2001.

Leach's Storm-Petrel *Oceanodroma leucorhoa*

Leach's Storm-Petrel (LHSP) is the most widespread procellariiform in the Northern Hemisphere, breeding and migrating in both the Atlantic and Pacific Oceans (138, 139). Four subspecies are generally recognized: *O. l. leucorhoa* breeds in the North Atlantic Ocean and eastern North Pacific Ocean, from the Aleutian Islands, Alaska south to the Farallon Islands, California (138, 139); *O. l. beali* on San Miguel and Santa Barbara islands in the Channel Islands; *O. l. chapmani* on Los Coronados and San Benito Islands; *O. l. socorroensis* and *O. l. cheimomnestes* on Guadalupe Island (140). Overall population trends are unknown, (138) and no historical population numbers are available for *O. l. chapmani*. Current population estimates are 200 birds on Los Coronados (141) and 1,200,000 on San Benito (39), both of which are based on little more than educated guesses.

Many individual colonies have been extirpated by introduced animals or habitat alteration, including changes in vegetation and soil (138). The main cause of mortality at breeding colonies is predation by introduced foxes, cats, dogs, rats, pigs, and mice (on newly hatched chicks and eggs) (19, 138, 142). Native predators such as river otters, gulls, raptors, and corvids also cause adult mortality (138). On Coronado Norte and Sur predation by feral cats has likely caused a population decline. The Guadalupe subspecies has never been adequately surveyed and their nomenclature remains a matter of discussion. It has been suggested that all colonies on the main island were extirpated by cat predation and habitat loss (122). Other threats include eggshell thinning due to organochlorine contamination from pesticides (143). While at sea, oil pollution or oil-dispersant emulsions may affect LHSP, as well as ingestion of plastics and other man-made products (138).

Least Storm-Petrel *Oceanodroma microsoma*

The only documented breeding location of Least Storm-Petrels (LTSP) in the CCS region is on the San Benito Islands, where it is abundant on all three islands. The LTSP is considered the most abundant marine bird in the Gulf of California (144). Recent estimates suggest the population to be approximately 270,000 birds (39). However, this is not considered an accurate population estimate as it is based on short stays on the islands rather than on reproducible surveys. Population estimates range from 100,000 (145) to 500,000 (146) individuals. There are no data on population trends.

Least Tern *Sterna antillarum*

The Least Tern (LETE) subspecies *Sterna antillarum browni* is distributed along the Pacific coast of California and Baja California. In California, LETE breed coastally and have increased from 600 pairs in 1973 to 2,750 pairs in 1994 (132), and 3,511 pairs in 2002 (CDFG unpublished data). In Baja California, small populations totaling 400 breeding pairs nest coastally in the Gulf of California (112). On the Pacific coast of Baja California Sur, an additional 35 pairs have been documented breeding on Magdalena, Margarita, and Creciente Islands since the early 1990s (30) (E. Palacios, pers. comm.). The population has contracted remarkably from historical distribution due to loss of habitat, predation, and some losses due to shooting and egg collecting (132, 133). There are no reliable historical estimates, but qualitative reports from the late 1800s and early 1900s indicated that LETE were abundant in southern California (133). California LETE was federally listed in 1970 (133) and the population has increased almost 8-fold in California since 1973.

Predation, human disturbance, off-road vehicle and recreational disturbance, coastal development impacting nesting habitat, and pesticides pose the largest threats to LETE populations (112, 132). Other potential concerns to the recovery of this species include reduced prey availability due to environmental conditions that reduce prey, such as El Niño events (134), potential (yet unknown) issues at wintering grounds (132, 133), and contaminants such as heavy metals and PCBs (135-137). The potential of domoic acid poisoning from contaminated prey (D. Robinette, pers. comm.) is also of concern.

Magnificent Frigatebird *Fregata magnificens*

The Magnificent Frigatebird (MAFB) breeds on only one island in the Mexican islands, Santa Margarita, which is the northernmost breeding location for this species. Current breeding population is estimated at 40,000 birds (39). No accurate historical information is available to indicate whether this population is stable or otherwise. Cats have been observed to depredate frigatebird chicks on the island (39).

Marbled Murrelet *Brachyramphus marmoratus*

Population estimates for the Marbled Murrelet (MAMU) indicate 60,000 individuals in B.C. (1), 5,500 in Washington, 5-15,000 in Oregon, and 6,450 in California (51, 88, 147). Most population estimates of MAMU have involved ground-based detection surveys (148), though the power of these surveys to detect trends is low (149). Numbers of MAMU encountered on the ocean have declined across the CCS in the last two decades (147), and the Alaskan population decreased by 50% between 1972 and 1992 (150). Quantitative demographic estimates of population status in Desolation Sound, British Columbia, suggest a stable or slightly decreasing sample population (151).

The key conservation concern is loss of breeding habitat through removal of old-growth forests (88, 148, 152); this is most evident in the southern part of the species' range (147, 148). Management action to preserve habitat is underway. Nest site predation is another conservation concern for nesting success (148), and direct human activity and artificial sources of food appear to increase numbers and diversity of nest predators (153). Threats in the marine environment include oil pollution (154) and bycatch in gillnets (33).

Mew Gull *Larus canus*

The Mew Gull (MEGU) is nearly circumpolar in its distribution, breeding in the Pacific from central Alaska and northwestern Canada, south to interior northern and coastal western B.C. (126, 155, 156). The only breeding area within the CCS is on Vancouver Island and coastal B.C., where they generally form small colonies (2-400 pair) (157) often mixed with Herring and Bonaparte's Gulls (126). The global population is not well known, but is estimated to exceed one million pairs (M and B). MEGU generally form small colonies (2-400 pair) (157), often mixed with Herring and Bonaparte's Gulls (126). The non-breeding range extends south along the west coast of North America to southern California. MEGU are generalist predators and scavengers (158) and are not considered threatened in any part of their range.

Northern Fulmar *Fulmarus glacialis*

The total estimated worldwide population of the Northern Fulmar (NOFU) is 10-12 million, with only approximately 2.8 million breeding in North America (159). Although not known to breed anywhere within the CCS, it is suspected that a few pair breed on Triangle Island in B.C. Adults have been observed on cliffs there since 1974, and have regularly attended nest sites throughout the breeding season, though no eggs or chicks have ever been recorded (126).

NOFU have relatively low vulnerability to bycatch, oil pollution, pesticides, and other identifiable threats compared to other seabirds, although longlining (160) and the ingestion of plastics (128) could become a concern if conservation measures are not taken. NOFU are not considered threatened in North America or elsewhere but the concentration of the Pacific population at few colonies presents some risks in the case of catastrophic events.

Pelagic Cormorant *Phalacrocorax pelagicus*

The Pelagic Cormorant (PECO) reaches its southernmost range limit on Todos Santos Island, Baja California (161). Breeding sites are generally dispersed along the coast, making accurate surveys difficult. The global population of this species is estimated at approximately 400,000 birds (161). Of the 69,000 breeders found in North America (51), 45% breed within the CCS. Overall numbers have remained stable or increased (17, 41, 161), although PECO colony size and reproductive success appear to be sensitive to El Niño conditions, and year-to-year variability is high (17, 43, 67, 142, 162). Individual colonies can experience significant declines (i.e., at the Farallon Islands) as a result of human disturbance and other unknown factors, potentially related to climate change (44).

PECO are highly sensitive to human disturbance at breeding colonies, although human disturbance is not of high conservation concern for this species because of their tendency to nest on steep cliffs. There is a history of mortality from pesticide use and oiling events (161, 163), but the species' vulnerability to oiling is considered moderate (95). Contamination may have a significant impact on local colonies of PECO (161), but their broad range and patchiness of breeding sites makes them less susceptible on a population-wide scale (17). Shooting and trapping by fishermen, who view them as competitors, and gillnet mortality are also concerns (161), although they currently do not appear to be major factors.

Pigeon Guillemot *Cepphus columba*

The global population of Pigeon Guillemots (PIGU) is estimated at 235,000 (164), with 69,000 breeders in North America (51). The population size in the CCS has been estimated at 35,000 birds (1, 17, 41, 164). The majority of the population in the CCS breeds in California (16,000 birds, (17)). Population trends are unknown, hampered by differences in census methodology and access to colonies (13); however, there has been significant growth and the establishment of new colonies in the southern part of the range (17). PIGU are extremely sensitive to changes in oceanographic conditions, with population size and reproductive success fluctuating in response to warm and cold water events (41, 43, 44, 142).

PIGU's widespread distribution along the Pacific coast makes them less vulnerable as a species to threats from human disturbance, conflicts with fisheries, and mortality from oil spills. Local and regional populations, however, can be significantly impacted by these threats (26, 89), especially since PIGU tend to form large rafts on the water. Vulnerability to oil contamination is considered high (95) and gillnet fisheries can cause significant local mortalities (17), but is not considered a threat to the species as a whole (164). Another important concern for this species is human disturbance and the introduction of mammalian predators to breeding colonies (142).

Rhinoceros Auklet *Cerorhinca monocerata*

World population estimates of Rhinoceros Auklets (RHAU) are extremely rough at 1.5 million breeding birds, with approximately 1 million in the North American region (172). Most (>95%) of the North American breeding population is concentrated at eight colonies on islands in southeast Alaska (12%), British Columbia (73%) and Washington (13%) (172). RHAU were extirpated from California circa 1860, but population numbers have increased and birds have re-colonized the historic range over the past 50 years (172, 173). RHAU is the only non-larid seabird with an increasing population that breeds in the California Current System (49).

Documented and potential threats to the RHAU populations include predation, oil contamination, fisheries interactions, and habitat degradation. Historically, extirpations were caused, at least in part, by introduced mammals such as rabbits, that may have outcompeted RHAU for nesting space in California and Washington (142). Mortality due to Peregrine Falcons, Bald Eagles, and other avian predators has been documented at breeding colonies (174-176). Such natural predation pressure, when combined with other threats, may affect a colony's long-term sustainability. Disturbance and trampling of burrows by humans, pinnipeds, surface nesting or roosting birds, or introduced animals can cause nest loss and lowered reproductive success. Additionally, mortalities have been documented in the California and Washington gillnet fisheries (177, 178), and declines observed since the 1980s at some Washington colonies may be due to this fishery (172).

Ring-billed Gull *Larus delawarensis*

The overall North American population of Ring-billed Gulls (RBGU) is estimated at 1,700,000 breeders, with <1% breeding in the California Current region (51). RBGU have been recorded nesting in Willapa Bay, Washington since 1976 (13, 165) and in the Columbia River estuary, Oregon. There is no current information on breeding activity in Washington (U. Wilson, pers. comm.), although in 1976 it was estimated at 106 individuals (13). As with other gull species, overall populations of RBGU have increased throughout the mid-1900s in response to increased human-related food availability and decreased harvest of eggs and feathers (75, 76, 166-168). However, western populations of RBGU may be leveling off at the turn of the 21st century due to changes in dumping practices (169), especially on the wintering grounds along the coast (78, 168).

Human impacts on RBGU tend not to be serious due to remote localities of many breeding colonies, abundance of breeding individuals within colonies, and the resilience of gull individuals and populations. Minor impacts on the coastal breeding populations and wintering birds in this area include ingestion of plastics and other toxins from garbage dumps, and the effects of contaminants and oil spills. The most serious potential impacts involve disturbance to breeding colonies, resulting in increased intra-specific predation of chicks (170, 171), although given the large continental populations, disturbance to these colonies on the western extent of the range would have little effect on the overall population.

Royal Tern *Sterna maxima*

Approximately 125,000 Royal Terns (ROTE) breed in North America, Central America, and the West Indies (179). Breeding of ROTE in the CCS region is restricted to small and recent colonies in southern California and a few scattered colonies along the Pacific coast of Baja California (Laguna Ojo de Liebre, Laguna San Ignacio, Punta Banda, San Quintin, Bahia Magdalena, Ensenada de La Paz, and Delta del Rio Colorado) (30). In southern California, ROTE were first reported breeding in San Diego Bay in 1959 (180), where a small group of 35 pairs bred in 1999 (181). Nesting has also been attempted on the salt ponds at the south end of San Diego Bay (182). Breeding has also been reported at Bolsa Chica Ecological Reserve (Orange County, California) in 1988-1990 (4-20 birds) (183). ROTE were once more common in California, (184); however, numbers have declined during the past 30 years, which may be a result of a range expansion of the Elegant Tern (185).

ROTE populations appear to fluctuate in response to changes in abundance and distribution of their main prey, sardines and anchovies, which in turn respond to changes in oceanographic conditions (186). These small breeding populations are extremely vulnerable to the effects of disturbance from humans and animals. Colonies are often destroyed by natural disturbance, high tides, and storms (181). It is unknown if fisheries interactions are a threat to ROTE.

Thick-billed Murre *Uria lomvia*

The total worldwide breeding population of Thick-billed Murres (TBMU) is estimated at 15-20 million birds, of which only 4.7 million are estimated to occur in the Pacific (187). In the CCS, they breed in only one location, on Triangle Island, where an estimated 35 pair are intermixed with several thousand pairs of Common Murres (*Uria aalge*) (126).

While their widespread global distribution makes this species less vulnerable, various anthropogenic factors can have a significant impact on local populations. Murres are particularly vulnerable to oil spills because of their tendency to form large rafts on the water (95). Fisheries interactions and prey depletion due to overharvesting or climate variability may also pose a threat. Hunting, fisheries bycatch (especially gillnet mortality), and oiling are known causes of decline in the Atlantic population, as well as for populations in the Pribilof Islands and western Aleutians (163).

Tufted Puffin *Fratercula cirrhata*

The North American Tufted Puffin (TUPU) breeding population has been estimated at approximately 3 million breeders (51), though accurate estimates are difficult to obtain, as in most crevice-nesting seabirds (17). Approximately 78,000 birds breed in B.C. (1), 23,000 in Washington (13), 5,000 birds in Oregon (6), and 276 in California (17). Overall, the population appears to be relatively stable, despite population declines from historical numbers at several locations and potential colonization of new areas (17, 142, 188).

TUPU are vulnerable to oil pollution (95), entanglement in fishing gear (189), and predation from introduced mammals (88). Introduced species, such as rabbits, may also compete for burrow space (142, 190). Populations may decline at some locations as a result of the re-establishment and recovery of Rhinoceros Auklets because of competition for available breeding habitat (142). Competition with commercial fisheries (191) and high losses in gillnet fisheries (189) have also contributed to their decline in some areas. There is a general lack of information available for TUPU because of the inaccessibility of nests, their small populations at some locations, and variability in colony attendance between days and years (17, 142).

Western Gull *Larus occidentalis*

The Western Gull (WEGU) is a CCS endemic with a restricted breeding distribution extending from southern Washington to Santa Margarita Island, Baja California Sur, and a small world population size of fewer than 40,000 pairs nesting at fewer than 200 colony sites (192). The majority of the population is concentrated in California (50-77%) (17, 51), and the largest single colony is found on Southeast Farallon Island, with approximately 20,000 to 22,000 birds (17, 67). WEGU nest on most of the Mexican Pacific islands; however, population sizes are not known on Los Coronados, Cedros, San Roque, or Asunción (39). Historically, WEGU populations were reduced as a result of human efforts to reduce gull numbers in the 1800s (142). However, the population appears to be increasing due to the restriction of human activity at many of the important breeding sites (41) and increased food availability at dumps (192) but may be leveling off at the turn of the 21st century due to changes in dumping practices (193). Population sizes and trends in Oregon and Washington are not well known and are further complicated by the high degree of hybridization with GWGU (13).

The relatively small population size and limited range make the WEGU highly susceptible to threats such as introduced predators, human disturbance, oil and pesticide contamination, other toxins, and the spread of avian diseases. Disturbance to breeding colonies may result in lowered reproductive success and increased intra-specific predation of chicks (194). Organochlorine concentrations in eggs in central California have decreased since the 1970s, most likely as a response to DDT restrictions (195). Other concerns are the spread of avian botulism within colonies. Egg collecting and human disturbance continues to impact populations on the Mexican islands (39).

Xantus's Murrelet *Synthliboramphus hypoleucus*

Current global population estimates for Xantus's Murrelet (XAMU) are less than 10,000 pairs (196). The majority nest on Santa Barbara Island, California (approximately 60% of the California population), with smaller numbers breeding on San Miguel, Santa Cruz, Anacapa, Santa Catalina, and San Clemente islands (all in the Channel Islands) (196, 197). The size of the population on Santa Barbara declined by 30-50% between 1977 and 1991 (198, 199). There are some indications that populations in California have increased from the 1900s due to the removal of introduced mammals from breeding islands, including cats and rabbits from Santa Barbara and Anacapa islands (196). However, introduced cats and rats on islands in Mexico have significantly reduced breeding populations on Los Coronados North, Todos Santos, San Martin, and San Jeronimo and may have extirpated breeding colonies of the southern subspecies, *Synthliboramphus hypoleucus hypoleucus*, from Natividad, Asunción, and San Roque islands (32, 200).

The limited breeding distribution and small population make XAMU vulnerable to threats such as oil pollution, organochlorine contaminants, incidental bycatch from fisheries, and mortality caused by attraction to bright lights on ships and platforms (197, 198). In the colonies, native predators, such as owls and falcons, can have a substantial impact on the population (39, 201), and native deer mice (*Peromyscus maniculatus*) prey on XAMU eggs (20). Non-native predators on eggs, chicks, and adults include feral cats and black rats (196). XAMU are also threatened by human activities in the southern part of their range, where colonies and fishing villages overlap (200). Changes in oceanographic conditions, including El Niño events and large-scale regime shifts, may affect XAMU food supply (20, 202). The Island Conservation and Ecology Group (ICEG) has initiated the removal of introduced predators on the islands west of Baja California.

The California Current Marine Bird Conservation Plan Appendix 3

Species Accounts – Migratory Seabirds of the California Current

Version 1.0

**Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum**

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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APPENDIX 3: SPECIES ACCOUNTS – SPECIES THAT MIGRATE TO THE CALIFORNIA CURRENT

Each summer hundreds of thousands of seabirds migrate to the CCS to feed in its rich waters. Over 100 species of seabirds have been recorded migrating to the CCS (see appendix A). The abundance and species composition of migrants in the CCS is correlated with short and long-term changes in ocean temperature (203-205), discussed in greater detail in Chapters 3 and 5.

The density of migrants at sea is highest during the spring and fall and is also higher in the summer than in the winter. By far the most numerous seabird (and most numerous migrant) during the summer months is the Sooty Shearwater (*Puffinus griseus*) (206), which breeds between September and May in New Zealand and the southern tip of South America (15). The other two shearwater species that can be found in the CCS are the Pink-footed Shearwater (*Puffinus creatopus*) and the Buller's Shearwater (*Puffinus bulleri*). Both species also breed in the Southern Hemisphere, in New Zealand (Buller's) and on islands off Chile (Pink-footed) (15). The Northern Fulmar (*Fulmarus glacialis*) is considered a "breeder" in the CCS, although numbers of breeding individuals are unconfirmed and likely small (see species account).

Mean density (birds/km²) at sea of predominant migrants to the CCS in July, December, and total. (Table modified from Tyler et al. 1990).

SPECIES	JULY	DECEMBER	TOTAL
Sooty Shearwater	33.81	0.01	33.82
Phalarope spp.	5.61	0.9	6.51
Northern Fulmar	3.04	3.39	6.43
Pink-footed Shearwater	2.5	0.02	2.52
Black-legged Kittiwake	0	2.41	2.41
Herring Gull	0.01	2.36	2.37
Pacific Loon	0	1.44	1.44
Black-footed Albatross	0.86	0.1	0.96
Bonaparte's Gull	0.02	0.86	0.88
Buller's Shearwater	0.23	0	0.23
Common/Arctic Tern	0.19	0	0.19
Pomarine Jaeger	0.03	0.11	0.14
TOTAL	46.3	11.6	57.9

The California Current Marine Bird Conservation Plan Appendix 4

Conservation status of species that breed in the California Current

Version 1.0

Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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APPENDIX 4: CONSERVATION STATUS OF SPECIES THAT BREED IN THE CALIFORNIA CURRENT

COMMON NAME	CALI-FORNIA ¹	ORE-GON ²	WASH-INGTON ³	FED-ERAL ⁴	CANADA ⁵	MEXICO ⁶	NAWCP ⁷	IUCN ⁸
Northern Fulmar <i>Fulmarus glacialis</i>								
Laysan Albatross <i>Diomedea immutabilis</i>						T		
Black-vented Shearwater <i>Puffinus opisthomelas</i>						E		VU
Leach's Storm-Petrel <i>Oceandroma leucorhoa chapmani</i>						T	L	
Leach's Storm-Petrel <i>O. l. socorroensis</i>						E		
Leach's Storm-Petrel <i>O. l. cheimomnestes</i>						T		
Black Storm-Petrel <i>Oceanodroma melania</i>	SC					T	H	
Ashy Storm-Petrel <i>Oceanodroma homochroa</i>	SC			BCC		T	HI	LR/nt
Fork-tailed Storm-Petrel <i>Oceanodroma furcata</i>	SC							
Least Storm-Petrel <i>Oceanodroma microsoma</i>						T		
Guadalupe Storm-Petrel <i>Oceanodroma macrodactyla</i>						EXT		CR
Magnificent Frigatebird <i>Fregata magnificens</i>								
Brown Pelican <i>Pelecanus occidentalis</i>	E	E	E	E			M	
Double-crested Cormorant <i>Phalacrocorax auritus</i>								
Brandt's Cormorant <i>Phalacrocorax penicillatus</i>			C				H	
Pelagic Cormorant <i>Phalacrocorax pelagicus</i>							H	
Heermann's Gull <i>Larus heermanni</i>						SP		LR/nt
Ring-billed Gull <i>Larus delawarensis</i>								

APPENDIX 4: Conservation Status of Species That Breed in the California Current

(cont.) - Conservation status of species that breed in the California Current.

COMMON NAME	CALI-FORNIA ¹	ORE-GON ²	WASH-INGTON ³	FED-ERAL ⁴	CANADA ⁵	MEXICO ⁶	NAWCP ⁷	IUCN ⁸
Mew Gull <i>Larus canus</i>								
California Gull <i>Larus californicus</i>	SC						M	
Western Gull <i>Larus occidentalis</i>							L	
Glaucous-winged Gull <i>Larus glaucescens</i>							L	
Gull-billed Tern <i>Sterna nilotica</i>	SC			BCC			H	
Caspian Tern <i>Sterna caspia</i>	SM			BCC			L	
Royal Tern <i>Sterna maxima</i>	SC						M	
Elegant Tern <i>Sterna elegans</i>	SC			BCC		SP	M	LR/nt
Arctic Tern <i>Sterna paradisaea</i>			SM	BCC				
Forster's Tern <i>Sterna forsteri</i>			SM				M	
Least Tern <i>Sterna antillarum</i>	E	E		E		E	H	
Black Skimmer <i>Rynchops niger</i>	SC			BCC			H	
Common Murre <i>Uria aalge</i>			C				M	
Thick-billed Murre <i>Uria lomvia</i>								
Pigeon Guillemot <i>Cepphus columba</i>							M H in BCR 5	
Marbled Murrelet <i>Brachyramphus marmoratus</i>	E	T	T	T, BCC	T		H	VU
Xantus's Murrelet <i>Synthliboramphus hypoleucus</i>	C, SC			BCC		E	H	VU
Craveri's Murrelet <i>Synthliboramphus craveri</i>						T		

APPENDIX 4: Conservation Status of Species That Breed in the California Current

(cont.) - Conservation status of species that breed in the California Current.

COMMON NAME	CALI-FORNIA ¹	ORE-GON ²	WASH-INGTON ³	FED-ERAL ⁴	CANADA ⁵	MEXICO ⁶	NAWCP ⁷	IUCN ⁸
Ancient Murrelet <i>Synthliboramphus antiquus</i>					SC		H HI in BCR 5	
Cassin's Auklet <i>Ptychoramphus aleuticus</i>	SC		C	BCC		T	M H in BCR 5	
Rhinoceros Auklet <i>Cerorhinca monocerata</i>	SC						L	
Tufted Puffin <i>Fratercula cirrhata</i>	SC		C				L	
Horned Puffin <i>Fratercula corniculata</i>								

State, Federal, Canada, and Mexico Rank Codes: BCC = Bird of Conservation Concern; C = State Candidate; SC = Special Concern; SM = State Monitor; T = Threatened; E = Endangered

NAWCP Codes: HI = highly imperiled; H = high; M = moderate; L = low

IUCN Rank Codes: CR = Critically Endangered; VU = Vulnerable; LR/nt = Lower Risk/Near Threatened

¹ State and Federally Listed Endangered and Threatened Animals of California, Dept. of Fish and Game, Habitat Conservation Division, July 2003; and Draft (2003) California Bird Species of Special Concern List, www.prbo.org/BSSC/index.htm

² List of Threatened and Endangered Species, Oregon Dept. of Fish and Wildlife, March 2003, www.dfw.state.or.us

³ Threatened and Endangered Species System (TESS), Oct. 2003, www.ecos.fws.gov/tess_public, and www.pacificbio.org/ESIN/Infopages/Washingtonlist.html

⁴ Birds of Conservation Concern 2002. U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, VA.

⁵ Committee on the Status of Endangered Wildlife in Canada (COSEWIC), www.cosewic.gc.ca

⁶ Norma Oficial Mexicana, NOM-059-ECOL-2000.

⁷ North American Waterbird Conservation Plan, 2002.

⁸ 2002 IUCN Red List of Threatened Species, www.redlist.org.

The California Current Marine Bird Conservation Plan Appendix 5

*Global conservation status of the most common species
that migrate to the California Current*

Version 1.0

Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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APPENDIX 5: GLOBAL CONSERVATION STATUS OF THE MOST COMMON SPECIES THAT MIGRATE TO THE CALIFORNIA CURRENT

IUCN Rank Codes: 1 = Endangered; 2 = Vulnerable; 3 = Lower Risk/Near Threatened
(2002 IUCN Red List of Threatened Species, www.redlist.org).

Red-throated Loon <i>Gavia stellata</i>	Manx Shearwater <i>Puffinus puffinus</i>	Parasitic Jaeger <i>Stercorarius parasiticus</i>
Pacific Loon <i>Gavia pacifica</i>	Short-tailed Shearwater <i>Puffinus tenuirostris</i>	Pomarine Jaeger <i>Stercorarius pomarinus</i>
Arctic Loon <i>Gavia arctica</i>	Sooty Shearwater <i>Puffinus griseus</i>	South Polar Skua <i>Stercorarius maccormicki</i>
Common Loon <i>Gavia immer</i>	Wilson's Storm-Petrel <i>Oceanites oceanicus</i>	Little Gull <i>Larus minutus</i>
Yellow-billed Loon <i>Gavia adamsii</i>	Red-billed Tropicbird <i>Phaethon aethereus</i>	Bonaparte's Gull <i>Larus philadelphia</i>
Red-necked Grebe <i>Podiceps grisegena</i>	Red-tailed Tropicbird <i>Phaethon rubricauda</i>	Black-headed Gull <i>Larus ridibundus</i>
Horned Grebe <i>Podiceps auritus</i>	Red-faced Cormorant <i>Phalacrocorax urile</i>	Franklin's Gull <i>Larus pipixcan</i>
Eared Grebe <i>Podiceps nigricollis</i>	Masked Booby <i>Sula dactylatra</i>	Thayer's Gull <i>Larus thayeri</i>
Western Grebe <i>Aechmophorus occidentalis</i>	Brown Booby <i>Sula leucogaster</i>	Glaucous Gull <i>Larus hyperboreus</i>
Clark's Grebe <i>Aechmophorus clarkii</i>	Blue-footed Booby <i>Sula nebouxii</i>	Slaty-backed Gull <i>Larus schistisagus</i>
Short-tailed Albatross - 2 <i>Phoebastria albatrus</i>	Red-footed Booby <i>Sula sula</i>	Sabine's Gull <i>Xema sabini</i>
Black-footed Albatross - 2 <i>Phoebastria nigripes</i>	Surf Scoter <i>Melanitta perspicillata</i>	Black-legged Kittiwake <i>Rissa tridactyla</i>
Mottled Petrel - 3 <i>Pterodroma inexpectata</i>	Black Scoter <i>Melanitta nigra</i>	Common Tern <i>Sterna hirundo</i>
Cook's Petrel - 1 <i>Pterodroma cookii</i>	White-winged Scoter <i>Melanitta fusca</i>	Black Tern <i>Chlidonias niger</i>
Murphy's Petrel - 3 <i>Pterodroma ultima</i>	Red-breasted Merganser <i>Mergus serrator</i>	Kittlitz's Murrelet <i>Brachyramphus brevirostris</i>
Buller's Shearwater - 2 <i>Puffinus bulleri</i>	Red Phalarope <i>Phalaropus fulicaria</i>	Parakeet Auklet <i>Aethia psittacula</i>
Pink-footed Shearwater - 2 <i>Puffinus creatopus</i>	Red-necked Phalarope <i>Phalaropus lobatus</i>	Crested Auklet <i>Aethia cristatella</i>
Flesh-footed Shearwater <i>Puffinus carneipes</i>	Long-tailed Jaeger <i>Stercorarius longicaudus</i>	

The California Current Marine Bird Conservation Plan

Chapter 3

Seabird Habitats of the California Current and Adjacent Ecosystems



Photo: Dave Gardner, PRBO Conservation Science

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The California Current Marine Bird Conservation Plan Chapter 3

Seabird Habitats of the California Current and Adjacent Ecosystems

Version 1.0

**Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum**

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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CHAPTER 3. SEABIRD HABITATS OF THE CALIFORNIA CURRENT AND ADJACENT ECOSYSTEMS

The coastal and offshore areas of the California Current region provide a variety of feeding, roosting, and nesting habitat for seabirds. The abundant food in the California Current, resulting from high ocean primary productivity, attracts millions of seabirds that breed and/or migrate throughout this region annually, with the non-breeders outnumbering the breeders year-round (1, 2).

Marine habitat characteristics and “quality” vary spatially and temporally, within and between seasons, years, and decades. Naturally occurring climate cycles in the world’s oceans and atmosphere operate at several scales and strongly influence the CCS and, therefore, the ocean habitats that seabirds depend on for their survival, including habitat-specific productivity and predator-prey relationships. While the mechanisms of climate change are not well understood, it seems clear that climate cycles and change in ocean habitats, prey availability, and prey quality are critically linked to changes in seabird demography.

In this section we summarize both terrestrial and marine habitat used by seabirds for breeding, roosting, and feeding in the CCS region. Oceanographic and atmospheric processes leading to marine climate variability on multiple temporal scales, and the response of seabirds to this variability, are discussed in detail in Chapter 5.

3.1 TERRESTRIAL HABITAT

(A1). General Habitat Description

The coastal and offshore areas of the West Coast provide a variety of roosting and nesting habitat, including islands, rocks, cliffs, headlands, beaches, estuaries, and even human-made structures such as bridges, dikes, dredge spoil islands, jetties, and breakwaters. Islands, however, are disproportionately important sites for roosting and nesting.

There are numerous islands off the west coast of North America, several of which contain seabird colonies exceeding 100,000 breeding birds. Numerous bays and estuaries along the mainland coast also provide critical habitat for many seabird species. The largest of these are Puget Sound in northern Washington, the Columbia River estuary on the border between Oregon and Washington, and San Francisco Bay in California.

These protected coastal areas provide important breeding habitat, especially for coastal terns and gulls. East Sand Island in the Columbia River estuary supports the largest Caspian Tern colony in the world and the largest Double-crested Cormorant colony in the Pacific.

a. Islands - - Islands, by their very nature, are isolated and typically provide seabirds with a protected habitat where they can breed and roost with little danger and few disturbances. The largest seabird colonies and the vast majority of breeding seabirds are found on islands, especially on those that are small to medium-sized. Islands are quite variable and have defining features that affect the species and number of seabirds that utilize them, such as size, shape, height, geological composition, micro-habitat characteristics, distance from shore, distance to feeding areas, presence or absence of soil, extent and depth of soil, plant communities, animal communities, and history of bird use.

The smaller islets and rocks often support larger numbers of seabirds. Smaller islands are often uninhabited and free of mammalian predators such as rats, cats, dogs, foxes, and coyotes, although this is not always the case. Included in the island category, but unique, are the low islands found in bays and estuaries. These islands form naturally when sediments fall out of suspension in the slower moving waters of the estuary. They are much more dynamic in shape, size, and composition than the rocky, marine islands and in a natural system islands appear, disappear, and continually change shape. Scoured by

winter floods, these islands often support little or no vegetation and provide important nesting and roosting habitat for coastal species, especially terns, gulls, and Double-crested Cormorants.

b. Cliffs and Headlands - The relatively inaccessible cliffs and headlands along the mainland coast and on larger islands are also an important habitat for seabirds. It is difficult for predators and humans to access these sites, so disturbance and predation are low. This habitat is most important for cormorants, Common Murres, and Pigeon Guillemots.

c. Old Growth Forests - The old growth forests of the Pacific Northwest are the primary breeding habitat for Marbled Murrelets.

d. Wetlands and Estuaries - This type of habitat provides critical nesting and feeding opportunities to numerous resident and migrant plant and animal species.

e. Artificial Structures - Artificial structures can create usable habitat for both nesting and roosting. Caspian Terns are remarkably adaptable and can nest on artificial dredge-spoil islands and other artificial structures (3). The California Least Tern is also very opportunistic; one colony breeds on the former Naval Air Station, Alameda, California on an airplane runway (M. Elliott, pers. comm.). Double-crested Cormorants are another good example of a species that can thrive on human structures. In the San Francisco Bay area, this species breeds on several of the most heavily used bridges (4).

(A2). Habitat Characteristics by Region

a. California

For characterization purposes the state can be divided into three sections: the north coast is typified by rugged headlands, steep cliffs, and exposed beaches; in the central coastal area, rocky shorelines and sandy beaches dominate the landscape; and in the south, the most developed and heavily populated segment, sandy beaches predominate. Large islands are found off southern California (Channel Islands), and thousands of smaller rocks and islands dot the coastline in central and northern California. Major embayments, which provide key nesting, roosting, and feeding habitat, include Humboldt, Tomales, San Francisco, Morro, and San Diego bays.

Carter et al. (5) estimated approximately 643,000 breeding seabirds in the state and identified several important areas, based on high concentrations of breeding birds. The most important breeding areas in the state are Castle Rock (19% of the state breeding population), Farallon Islands (24%), and the northern Channel Islands (13%).

Castle Rock National Wildlife Refuge (NWR) is a 5.7-hectare island situated less than 1 km off the northern California coast. This sparsely vegetated island, ringed with steep cliffs, has a large grassy area with thick soil which is used extensively by five species of burrow nesters (6).

Habitat heterogeneity on the Farallon Islands NWR, a group of offshore granitic islands 42 km west of the Golden Gate Bridge in central California, also allows for a diverse avifauna. The Farallones, at only 85 hectares, are home to the largest and most diverse assemblage of breeding seabirds in the state. Twelve species breed on the islands (5), including the largest colonies of Western Gull and Brandt's Cormorant in the world (7) and one of the largest Ashy Storm-Petrel colonies.

The Channel Islands, located within the highly productive Southern California Bight, are a group of eight large islands, ranging in size from 260-24,910 hectares (91,093 hectares total). The four northern islands (San Miguel, Santa Rosa, Santa Cruz¹, and Anacapa) and Santa Barbara Island are part of the Channel Islands National Park. The islands have a variety of habitats: shrub and grass-covered hills, steep canyons, sandy and rocky beaches, gentle sloping faces, steep cliffs, and some relatively flat areas. All except Anacapa have associated islets and rocks.

These islands support 12 breeding species, including the state's entire population of Brown Pelicans, Xantus's Murrelets, and Black Storm-Petrels, and a large proportion of the global Ashy Storm-Petrel population (5).

¹. Only the eastern 24% of Santa Cruz Island is included in the National Park, the western 76% is owned and managed by The Nature Conservancy

b. Oregon

The Oregon coastline is a fairly direct north/south line extending nearly 1,000 km, and, compared to Washington and California, has few large bays or inland waters, with the exception of the Columbia River estuary.

Coos Bay, in the southern portion, is the largest bay in the state, followed by Tillamook Bay in the north. The coastline consists of rocky and sandy beaches interspersed with rocky headlands and steep cliffs. Two extensive stretches of sand beaches with associated dune systems are found in the central and northern regions of the state: Oregon Dunes National Recreation Area between Coos Bay and Florence and the Clatsop Plains located between Tillamook Bay and the Columbia River. These sandy stretches of coastline with few offshore rocks support very few nesting seabirds but provide important beach roost habitat.

The Columbia River estuary has both natural and human-made dredge-spoil islands that provide ample nesting and roosting habitat for seabirds. The largest Caspian Tern colony in the world and the largest Double-crested Cormorant colony along the Pacific coast are found here. In the Columbia River estuary, East Sand Island is a low, natural island that has been augmented with dredge spoils and is owned by the Army Corps of Engineers.

Oregon has approximately 1,400 offshore islands, rocks, and reefs (R. Lowe, pers. comm.). These rocks and islands are mostly rocky with steep cliffs. The relatively few islands that have well-developed soils are where large numbers of burrow-nesting Leach's Storm-Petrels breed. Major colonies with greater than 100,000 nesting seabirds include: Three Arch Rocks, Goat Island, Whaleshead Island Complex, and Crook Point Complex. Leach's Storm-Petrels and Common Murres are the most abundant species at these colonies.

c. Washington

Washington is home to approximately 300,000 seabirds belonging to 16 species (8). Seabird colonies are mostly found along the outer coast of the Olympic Peninsula, from Copalis Beach to Cape Flattery (9).

Washington has two distinct coastlines: the outer coast, from Cape Flattery to the Oregon border, and the inner coast, which includes the Strait of Juan de Fuca, the San Juan Islands, and the Puget Sound. Habitat along Puget Sound consists of primarily low elevation and relatively flat rocks and islands. The San Juan Islands are large, rocky, and have human inhabitants.

Along the outer coast, the two large bays, Willapa and Grays Harbor, are located in the southern half of the state. Sand beaches with associated dunes dominate this southern coastline.

The majority of the nesting seabirds are found in the northern half of the state on the islands of the Maritime National Wildlife Refuge and the San Juan Islands. This northern coast is more rugged and rocky with numerous offshore rocks. Washington has 600-800 offshore rocks and islands, approximately 550 of which are in the National Wildlife Refuge system (K. Ryan, pers. comm.).

d. Mexico's Baja California

There are 19 main islands off the Pacific coast of Baja California that support breeding seabirds and provide roosting habitat (10) (Figure 3.1). There are an unknown number of islets and rock stacks associated with these islands, some of which provide additional roosting and nesting habitat. All of the Pacific islands of Baja California provide roosting habitat for marine birds.

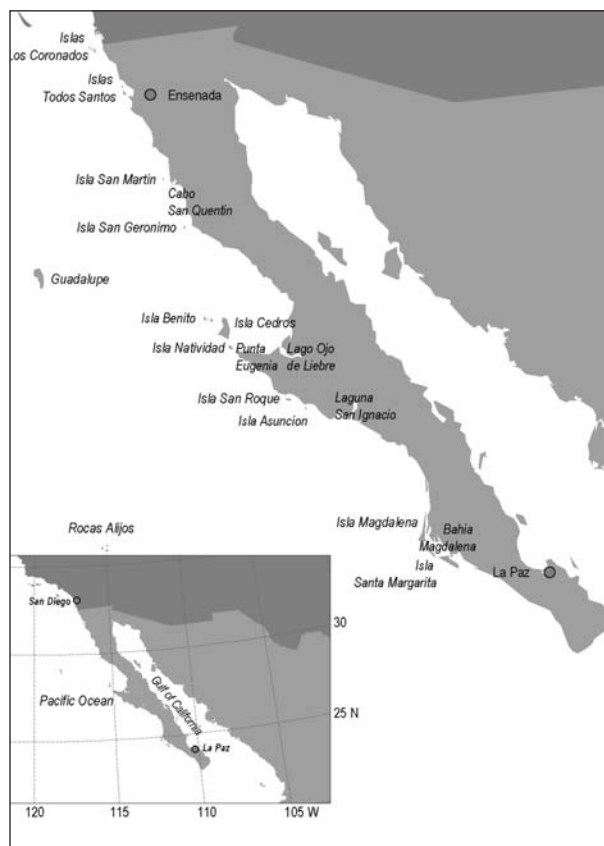


Figure 3.1 – Map of Pacific Baja California islands. Main offshore islands, cities, and geographic features are shown.

In general, numbers and distribution of roosting birds are poorly documented as the focus for researchers has been quantifying numbers of breeding birds. San Martin, San Jeronimo, Asunción, and San Roque islands all support several thousand or more roosting Brown Pelicans, with over 5,000 roosting pelicans recorded on San Martin in September 2002 (B. Keitt, pers. obs.). San Martin, Natividad, Asunción and San Roque islands support large numbers of roosting Double-crested and Brandt's Cormorants.

The main types of seabird nesting habitat on the Baja California Pacific islands are scree and boulder slopes for crevice nesters, sandy flats for burrow nesters and surface nesters, open slopes and ridges for surface nesters, and shrubs and mangrove trees for above ground nesters. Steep cliffs and caves also provide marine bird habitat on some islands, but not to the extent seen on the California Channel Islands. A brief description of each habitat follows:

Scree and boulder slopes – These slopes provide habitat for Least and Black Storm-Petrels, Xantus's and Craveri's Murrelets, Cassin's Auklets, and Black-vented Shearwaters. This is the main habitat type on Los Coronados Islands and is in short supply on Todos Santos Islands. Virtually all of San Martin Island is scree/lava boulder habitat; however, for unknown reasons, few seabirds occupy this habitat. There is no evidence of storm-petrels using the island and Xantus's Murrelet populations are thought to be very small. San Jeronimo has very limited crevice habitat, restricted to the sandstone bluffs at the top of the island. The San Benito Islands provide extensive scree habitat on all three islands. Although Guadalupe Island and its associated islets have extensive scree habitat, its use by seabirds is only documented on Afuera Islet, where Black-vented Shearwaters, Xantus's Murrelets, and Leach's Storm-Petrels breed. Natividad, Asunción, San Roque, Magdalena, and Margarita all have very little scree habitat.

Sand and soil habitat – Natividad, San Jeronimo, San Benito, and parts of Guadalupe Island provide vast expanses of sandy or soil habitat for burrow nesters. Black-vented Shearwaters on Natividad nest almost exclusively in stabilized sand dunes, now covered by the introduced iceplant, *Mesembryanthemum crystallinum*. Cassin's Auklets on San Jeronimo and San Benito, and Leach's Storm-Petrels on San Benito use sandy soil for digging burrows. On Guadalupe, the Guadalupe Storm-Petrel and Leach's Storm-Petrel dug burrows in the soil beneath the once extensive cypress forests. It is unknown whether Leach's still utilize this habitat on the main island.

Shrub habitat – This type of habitat is available primarily on San Martin and Todos Santos Islands. Large numbers of Double-crested Cormorants and Brown Pelicans use the atriplex bushes along the north and east sides of San Martin Island. Double-crested Cormorants also use the atriplex habitat to a lesser extent on Todos Santos South. The only tree habitats in the region are the vast mangrove areas in Magdalena Bay, encompassing parts of Margarita and Magdalena islands. Magnificent Frigatebirds utilize these trees as nesting habitat on Margarita Island. About 1,500 Double-crested Cormorants breed in the mangrove areas around the islands and throughout Magdalena Bay.

Table 3.1 – List of islands in Pacific Baja California, their main habitat, and seabird species that use the island. (BLSP = Black Storm-Petrel, BRPE = Brown Pelican, BVSH = Black-vented Shearwater, CAAU = Cassin's Auklet, CRMU = Craveri's Murrelet, DCCO = Double-crested Cormorant, GUSP = Guadalupe Storm-Petrel, LESP = Leach's Storm-Petrel, XAMU = Xantus's Murrelet, MAFR = Magnificent Frigatebird).

Island or Group of Islands	Main Habitat Types	Species
Los Coronados	scree and boulder slopes	LESP, BLSP, XAMU, CRMU, CAAU, BVSH
Todos Santos	shrub	DCCO
San Martin	scree/lava boulder, shrub	DCCO, BRPE
San Jeronimo	sand and soil	CAAU
San Benito	scree; sand and soil	CAAU, LESP
Guadalupe	scree; sand and soil	GUSP, LESP
Islote Afuera	scree	BVSH, XAMU, LESP
Natividad	sand and soil	BVSH
Asunción*	scree and boulder slopes	LESP, BLSP, XAMU, CRMU, CAAU, BVSH
San Roque*	scree and boulder slopes	LESP, BLSP, XAMU, CRMU, CAAU, BVSH
Magdalena*	mangrove	DCCO
Margarita*	mangrove	MAFR, DCCO

* Indicates south of the CCS boundary as defined in this plan

Table 3.2 - Status and number of breeding individuals on the Channel Islands. The most recent population estimates available are given with the citation in the superscript. Un-italicized font indicates that the estimate is based on a direct nest count or standard sampling method. Italicized font indicates that the estimate is based on an incomplete or preliminary census. Where extirpated populations are listed (E), citations for historic breeding records are given. PE, possibly extirpated, possibly occurred historically; B, breeder, no population estimate available; P, probable breeder, breeding suspected but not confirmed.

	San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	Santa Catalina	San Nicolas	San Clemente	Total Extirpated	populations
Leach's Storm-Petrel (<i>Oceanodroma leucorhoa beali</i>)	114 ^a				204 ^a				318	0
Ashy Storm-Petrel (<i>Oceanodroma homochroa</i>)	1354 ^a		281 ^a		1460 ^a	<50 ⁱ		50 ⁱ	3195	0
Black Storm-Petrel (<i>Oceanodroma melania</i>)	P ^a				274 ^a			P ^a	274	0
Brown Pelican (<i>Pelecanus occidentalis</i>)	E ^{b,c,d}		E ^g	10680 ^a	1236 ^a				11916	2
Double-crested Cormorant (<i>Phalacrocorax auritus</i>)	552 ^a		E ^a	720 ^a	1191 ^a	E ^a			2463	2
Brandt's Cormorant (<i>Phalacrocorax penicillatus</i>)	15700 ^a	4650 ^a	3140 ^a	63 ^a	667 ^a		5089 ^a	56 ^a	29365	0
Pelagic Cormorant (<i>Phalacrocorax pelagicus</i>)	691 ^a	1162 ^a	460 ^a	328 ^a	46 ^a				2687	0
Western Gull (<i>Larus occidentalis</i>)	1892 ^a	170 ^a	1236 ^a	10274 ^a	7678 ^a	156 ^a	6038 ^a	218 ^a	27662	0
Common Murre (<i>Uria aalge</i>)	E ^{a,b,c}								0	1
Pigeon Guillemot (<i>Cepphus columba</i>)	1114 ^a	287 ^a	1459 ^a	74 ^a	284 ^a				3218	0
Rhinoceros Auklet (<i>Cerorhinca moncerata</i>)	19 ^a				PE ^a				19	0-1
Tufted Puffin (<i>Fratercula cirrhata</i>)	10 ^a		E ^{a,g}	E ^{a,b,d,g}	E ^{a,g}				10	3
Xantus's Murrelet (<i>Synthliboramphus hypoleucus scrippsi</i>)	150 ^{a,f}		26 ^a	100-400 ^h	1544 ^a	P ^j		B ^j	1970	0
Cassin's Auklet (<i>Ptychoramphus aleuticus aleuticus</i>)	11584 ^a		736 ^a	2 ^h	156 ^a				12478	0
Total breeding individuals¹	33180	6269	7338	22391	14740	206	11127	324	95575	
Total breeding taxa (species/subspecies)	11-12	4	7	8	11	2-3	2	4-5	14	
Total extirpated taxa (species/subspecies)³	2	0	3	1	1-2	1	0	0	8-9	

1 Total breeding individuals calculated by adding estimates from all islands using the mean of the range where ranges of individuals are given.

2 Does not include historical extirpations where species/subspecies has since recolonized.

3 U.S. Fish and Wildlife Service, Endangered Species Program, <http://endangered.fws.gov/wildlife.html>.

4 California Department of Fish and Game, Natural Diversity Data Base, Species of Special Concern Reports, June 1999.

5 IUCN Red List of Threatened Species, Hilton-Taylor (2000). Sources: a (Carter et al. 1992), b (Willet 1910), c (Hunt et al. 1980), d (Grinnell 1915), e (Wright and Snyder 1913), f (Hunt et al. 1979), g (Howell 1917), h (McChesney et al. 2000), i (Nur et al. 1999), j (Drost and Lewis 1995).

There are five main wetland areas on the Baja peninsula that support breeding and roosting marine birds (11). In addition to being dominated by shorebirds and ducks that over-winter and some of these wetland areas support significant breeding and roosting colonies of seabirds. All information on peninsular sites is summarized from Massey and Palacios (11):

Punta Banda is a wetland located southeast of the town of Ensenada and primarily consists of a shallow estuary lined with pickleweed. It covers 2100 hectares and provides nesting habitat for Least Terns along its sandy beaches and wintering habitat for loons, grebes, gulls, terns, and shorebirds.

San Quintin Bay covers 12,060 hectares and provides breeding habitat for Least Terns. This large wetland is located west of the town of San Quintin and has extensive mud flats with low-lying flood plains extending to the east of the main bay. Laguna Figueroa, located about 15 km north of San Quintin Bay, once supported breeding Caspian and Forster's Terns until human activities in 1992 destroyed the marsh habitat.

Laguna Ojo de Liebre (Scammon's Lagoon) is actually three separate wetlands with an area of 39,300 hectares adjacent to Vizcaino Bay. Double-crested Cormorants, Western Gulls, Least Terns, Caspian Terns, and Royal Terns are known to breed here.

Laguna San Ignacio covers 28,000 hectares and supports breeding colonies of Brown Pelicans, Double-crested Cormorants, Western Gulls, and Least, Royal, and Caspian Terns. The lagoon is the northern range of the red mangrove, which provides habitat for shrub nesters such as Double-crested Cormorants and Brown Pelicans.

Bahía Magdalena is formed by a series of long, narrow sand dune islands, stretching for 250 km along the west coast of the Baja peninsula. Large groves of mangroves thrive in the lagoons on the east sides of the islands. Brown Pelicans, Brandt's Cormorants, Double-crested Cormorants, and Least Terns all breed in the region. The mangroves to the southeast of Margarita Island support 20,000 pairs of Magnificent Frigatebirds.

(A3). Breeding Habitat

Nesting habitat of marine birds can be segregated into three categories: sub-surface, surface, and above-ground shrub or tree nesters. Nesting habitat preference, by species, is shown in Table 3.3.

Table 3.3 – Seabird species that breed in the CCS and typical breeding habitat (listed in alphabetical order).

COMMON NAME	SCIENTIFIC NAME	BREEDING HABITAT
Ancient Murrelet	<i>Synthliboramphus antiquus</i>	crevice, burrow
Arctic Tern	<i>Sterna paradisaea</i>	flat, rocky
Ashy Storm-Petrel	<i>Oceanodroma homochroa</i>	rocky crevices
Black Skimmer	<i>Rynchops niger</i>	flat, sandy
Black Storm-Petrel	<i>Oceanodroma melania</i>	crevice on talus/rock
Black-vented Shearwater	<i>Puffinus opisthomelas</i>	rock crevices, sandy burrows
Brandt's Cormorant	<i>Phalacrocorax penicillatus</i>	cliff tops/slopes
Brown Pelican	<i>Pelecanus occidentalis</i>	mangroves/shrubs
California Gull	<i>Larus californicus</i>	rocky islands
Caspian Tern	<i>Sterna caspia</i>	open, sparse vegetation
Cassin's Auklet	<i>Ptychoramphus aleuticus</i>	soil burrows, rocky crevices
Common Murre	<i>Uria aalge</i>	cliff tops/slopes
Craveri's Murrelet	<i>Synthliboramphus craveri</i>	rocky islands, crevice
Double-crested Cormorant	<i>Phalacrocorax auritus</i>	trees, ground, bridges, etc.
Elegant Tern	<i>Sterna elegans</i>	flat, sandy
Fork-tailed Storm-Petrel	<i>Oceanodroma furcata</i>	crevice on rocky islands
Forster's Tern	<i>Sterna forsteri</i>	ground in marshes
Glaucous-winged Gull	<i>Larus glaucescens</i>	rocky islands
Gull-billed Tern	<i>Sterna nilotica</i>	flat, sandy
Heermann's Gull	<i>Larus heermanni</i>	open ground
Horned Puffin	<i>Fratercula corniculata</i>	burrow/crevice on steep slopes/cliffs
Laysan Albatross	<i>Diomedea immutabilis</i>	open ground
Leach's Storm-Petrel	<i>Oceanodroma leucorhoa</i>	soil burrows, rocky crevices
Least Storm-Petrel	<i>Oceanodroma microsoma</i>	crevice on talus/rock
Least Tern	<i>Sterna antillarum</i>	flat, sandy
Magnificent Frigatebird	<i>Fregata magnificens</i>	mangroves/shrubs
Marbled Murrelet	<i>Brachyramphus marmoratus</i>	old growth forests
Mew Gull	<i>Larus canus</i>	ground, rocky islands
Northern Fulmar	<i>Fulmarus glacialis</i>	cliffs
Pelagic Cormorant	<i>Phalacrocorax pelagicus</i>	steep, rocky cliffs
Pigeon Guillemot	<i>Cepphus columba</i>	rocky crevices on islands or coast
Rhinoceros Auklet	<i>Cerorhinca monocerata</i>	soil burrows, rocky crevices
Ring-billed Gull	<i>Larus delawarensis</i>	ground, rocky islands
Royal Tern	<i>Sterna maxima</i>	flat, sandy
Thick-billed Murre	<i>Uria lomvia</i>	cliff tops/slopes
Tufted Puffin	<i>Fratercula cirrhata</i>	burrow/crevice on steep slopes/cliffs
Western Gull	<i>Larus occidentalis</i>	open ground
Xantus's Murrelet	<i>Synthliboramphus hypoleucus</i>	crevice

All of the procellariiforms (albatrosses, petrels, shearwaters, storm-petrels) and alcids (murres, auklets, puffins) are sub-surface (crevice or burrow) nesters except the Laysan Albatross, a surface breeder; Common Murres, which breed on the relatively flat tops and ledges of offshore rocks and islands; and Marbled Murrelets, which nest in trees in old growth forests, up to 100 km inland from the coast.

Burrowing seabirds have limited nesting habitat given their restriction to coastal or offshore areas that are secure from predators and have an adequate supply of soil, allowing for burrow excavation. Smaller rocks and islands are often devoid of this habitat; therefore, these species are in greatest abundance on slightly larger islands. Of the burrow and cavity-nesting alcids, Tufted Puffins, Horned Puffins, Rhinoceros Auklets, Ancient Murrelets, and Cassin's Auklets typically excavate burrows.

In areas where little soil is available, several of the "burrowing" species (Cassin's Auklets, Rhinoceros Auklets, and Tufted Puffins) will occupy crevices in talus or in rock walls of old foundations; such is the case on the Farallon Islands (7). Pigeon Guillemots and Xantus's Murrelets are cavity nesters. However, guillemots will also utilize artificial cavities such as the underside of abandoned wooden piers and Xantus's Murrelets often nest under vegetation.

Of the burrow/cavity-nesting procellariiforms, Black and Ashy Storm-Petrels rarely excavate their own burrows, nesting instead in rocky cavities and crevices. Leach's and Fork-tailed Storm-Petrels prefer to excavate burrows but will nest in cavities, especially when soil is limited.

Cormorants, frigatebirds, pelicans, gulls, and terns are surface and above-surface nesters. Brown Pelicans and Magnificent Frigatebirds nest on vegetation, often small bushes in ravines or slopes of islands. Frigatebirds also often nest in mangroves. Double-crested Cormorants nest in a wide range of marine, estuarine, and inland habitats including vegetation, the barren surface of offshore islands, ledges of steep cliffs, low-lying estuarine islands and artificial habitats such as the San Francisco Bay bridges (4).

Brandt's Cormorants utilize similar cliff-top and slope habitats to Common Murres and nests of the two species are often interspersed, while Pelagic Cormorants typically nest on small ledges of steep cliff faces. The terns and gulls typically nest on low, flat, open habitats, such as islands in bays and estuaries or isolated beaches and dunes along the mainland coast. With the enormous loss and degradation of west coast beach and estuarine habitats, this group of species has increasingly used artificial

habitats, especially dredge spoil islands, salt pond dikes, levees, airstrips, rooftops, and parking lots.

Western and Glaucous-winged gulls are more marine, nesting primarily on offshore rocks and islands, although small colonies and individual pairs also nest along the mainland coast and on low islands and artificial habitats in bays and estuaries.

(A4). Roosting Habitat

Roosting allows birds to rest, preen and dry their plumage. Communal roosts may also serve social functions such as locations for mate selection and extra pair copulations and facilitate finding prey and increasing foraging efficiency. In addition, the plumage of some seabird species, such as pelicans and cormorants, is not waterproof and roosting on dry land is necessary for drying their feathers (12, 13).

Although most seabirds roost at colony sites, typical roost sites away from the colony differ by species group and include offshore rocks and islands, sand bars in estuaries and river mouths, and human-made structures such as pilings, jetties, and breakwaters (14). Gulls and terns tend to congregate on open sandy beaches, sandy islands, and sand bars. Cormorants also utilize sandy islands and sand bars but they rarely roost in large numbers on mainland beaches subject to frequent disturbance. They are also commonly found on rocky headlands, offshore rocks, coastal trees, and human-made structures such as jetties and transmission towers.

Some seabirds, especially pelicans, cormorants, gulls, and terns return to land regularly to roost, during both the breeding and non-breeding seasons. Pelicans and cormorants roost in similar habitats. Post-breeding pelicans migrate as far north as British Columbia and tend to roost in large numbers, congregating in roosts of up to thousands of individuals (15), with numbers peaking in the late summer and fall (16, 17). Currently, the largest known fall roost site in Oregon is at East Sand Island in the Columbia River estuary. In early September 2002, 10,852 pelicans were counted roosting on this low estuarine island (18).

Other important pelican roost sites include Marina del Rey Harbor, Purisima Colony (near Vandenberg Air Force Base), Año Nuevo Island, Southeast Farallon Island, Point San Pedro, and Elkhorn Slough in California and Grays Harbor in Washington (16-20).

Storm-petrels and alcid generally roost on land during the breeding season, but then remain at sea during the non-breeding season. There are two exceptions to this pattern: Ashy Storm-Petrels return to the Farallon Islands and occupy burrows during all months, although numbers are significantly lower during the non-breeding season (7), and Common Murres return to the breeding colonies in late fall or early winter to roost, but their attendance is intermittent (7).

By monitoring roost sites over a number of years, managers can develop a more complete picture of the health, status, and trends of some seabird populations. For example, when Brown Pelican populations were being affected by chlorinated hydrocarbons (i.e., DDT) in the 1960s and early 1970s, there were declines in roosting numbers throughout their range (21, 22). In addition, juveniles of many seabird species can be distinguished from adults during roost surveys, thereby giving an indication of breeding success (20).

3.2 MARINE HABITAT

The ocean is deceptively heterogeneous. To the layperson, the ocean appears as a featureless seascape, but in reality it is composed of distinct, interacting habitats. The oceanic habitats of seabirds are often associated with physical features, such as currents (e.g., the North and South Equatorial and California currents), fronts, and convergences.

Frontal zones are associated with hydrographic gradients in temperature and salinity (e.g., upwelling plumes, current edges) or bathymetric (e.g., islands and seamounts, canyons and shelf-slope regions) and coastal topographic attributes (e.g., headlands and promontories). These features promote the production and aggregation of prey for upper-trophic level predators such as foraging seabirds (23-27).

Upwelling, the vertical mixing of waters from above and below the thermocline, is an important mechanism supporting the production of seabird prey (macro-zooplankton and fish) in all regions of the Pacific Ocean and especially the CCS (28).

In this section, we provide (1) a general description of the North Pacific Ocean habitats utilized by seabirds and (2) a more detailed account of the California Current System. Naturally occurring climate cycles in the world's oceans and atmosphere strongly influence the California Current System (CCS) and central North Pacific Ocean (NPO) ecosystems and, therefore, the ocean habitats that seabirds depend on for their survival.

A description of large-scale oceanographic and atmospheric processes, operating at short and long timescales, which affect ocean habitats of seabirds and a review of the responses of seabirds to marine climate variability on multiple temporal scales will be discussed in more detail in Chapter 5.

(B1). General Description of Pacific Ocean Habitats

The geographic region broadly considered in this review is the North Pacific Ocean south of the Bering Sea with emphasis placed on the upwelling, coastal domain off the west coast of North America (British Columbia, Washington, Oregon, California, and Baja California).

The clockwise North Pacific subtropical gyre is the principal current gyre in the North Pacific Ocean. Four distinct biogeographic regions, with distinct temperature-salinity records, have been identified: (1) Bering Sea - coastal subarctic, (2) subarctic current - transition zone, (3) North Pacific central water, and (4) the upwelling domain (29).

High temperature and high salinity waters characterize the North Pacific central water; in general, ocean productivity in this region is low. The upwelling domain of the U.S. West Coast is dominated by the California Current System, which is one of five eastern boundary currents worldwide. All of these boundary currents are known for their diverse and abundant marine fish, mammal, and bird communities.

The oceanic habitats used by marine birds vary spatially with latitude, longitude, and distance from land. It is convenient to consider the ocean habitats of seabirds as (1) those associated with static bathymetric and land-based coastal structures, and (2) those associated with hydrography, where waters of varying characteristics converge and diverge. The scale of these habitats varies greatly from tens of kilometers for many static habitats to thousands of kilometers for large-scale hydrographic habitats (26).

a. Ocean Habitats Defined by Static Features

Along the U.S. West Coast, the continental shelf provides relatively shallow (<100 m) habitat for many coastal species such as terns, cormorants, and murre. It is widest (>75 km) in the Southern California Bight and relatively narrow (~15 km) off Washington and Oregon (30).

At the continental shelf break and slope, water depth increases from about 100 m to 2,000 m. Along the outer continental shelf, a frontal convergence zone often appears due to the transition from colder, less saline coastal waters to the warmer and saltier offshore waters; this change also leads to localized upwelling along the shelf break. The shelf break/slope fronts and convergences are important habitats for seabirds due to physical processes that promote productivity and/or concentrate prey. Many species of alcids (e.g., auklets) and shearwaters forage within the shelf break/slope convergences (31). Moreover, the shelf break/slope habitat is a complex region interspersed with submarine canyons, tables, sills, and seamounts.

These structures diversify the underwater topography, and provide additional features upon which the hydrographic environment interacts. Increased numbers of seabirds in the vicinity of seamounts and submarine canyons are likely caused by physical and biological processes that promote the aggregation of macro-zooplankton and fish (32). Beyond the continental shelf break and slope, the California Current flows in a southerly direction; the fastest currents are found 200 km to 500 km offshore (15). Beyond the California Current is the North Pacific central water bioregion.

b. Ocean Habitats Defined by Dynamic Features

Dynamic hydrographic habitats are those created when waters of varying thermohaline (salinity and temperature) characteristics converge and diverge. We refer to these habitats as “dynamic” because they change in size, shape, magnitude, and location through time. Some, such as the edges of major currents (California Current, North and South Equatorial), are persistent, but others are unpredictable and even ephemeral.

In the North Pacific Ocean, major, persistent ocean currents include the Kuroshio and Oyashio currents off Japan and Russia, the North Pacific and Subarctic currents, the California Current, and the North and South Equatorial currents. Along the edges of major currents, fronts form where seabird prey is concentrated by various mechanisms, such as concentrating planktonic prey or nutrients that enhance primary production.

The intensity (strength and flow rate) of major currents leads to the development of smaller-scale (10s - 100s km) meanders, eddies, and rings along the margins of currents. Offshore eddies are important habitats for some pelagic fish (e.g., sardines), but the importance of these habitats for foraging seabirds is unclear. Some eddies, like the Haida eddies off British Columbia, may calve from their parent currents and persist for years in the central North Pacific. Relatively large, persistent eddies in the northeastern Pacific Ocean are known to influence the migration of salmon (33); salmon and seabirds often occupy the same trophic level and feed on similar prey in the eastern North Pacific Ocean.

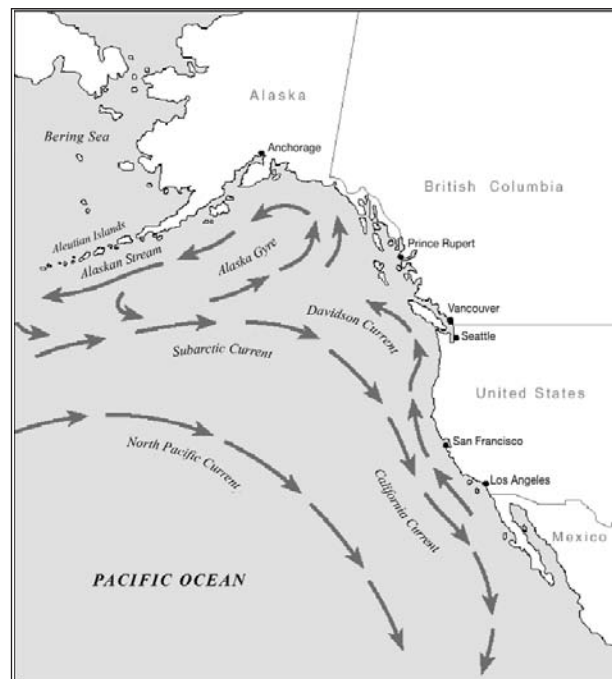
(B2). The Upwelling Domain: the California Current System

The California Current System (CCS) is one of the most biologically productive regions in the world. The main components of the CCS are the southward-flowing California Current, the northward-flowing (in the fall and winter) California Undercurrent (or Davidson Current), the northward-flowing Southern California Undercurrent, and the Southern California Countercurrent/Eddy (Figure 3.3).

Surface flow along the coast (north of Pt. Conception) is generally northward during the fall and winter, but there is a dramatic reversal or “spring transition,” as the current shifts to predominantly southward during the early spring and summer (74). Upwelling of cold, nutrient-rich waters along the coast is greatest in spring and summer, generally reaching a peak in May each year, but this varies substantially between years and with latitude.

Bathymetry, coastal topography, and weather all contribute to spatial and temporal variability in the system (e.g., change in upwelling intensity, formation of eddies and jets, etc.), and the conditions generalized above often reverse for short periods in response to environmental fluctuations (74).

Figure 3.3 – Map of the eastern Pacific, highlighting main ocean currents.



There are a number of upwelling “centers” in the CCS, regions where upwelling is persistent and unusually strong. Point Conception, Point Reyes, and Point Mendocino in California, and Cape Blanco, Oregon, are locales where upwelling is enhanced by coastal promontories and headlands (Figure 3.4).

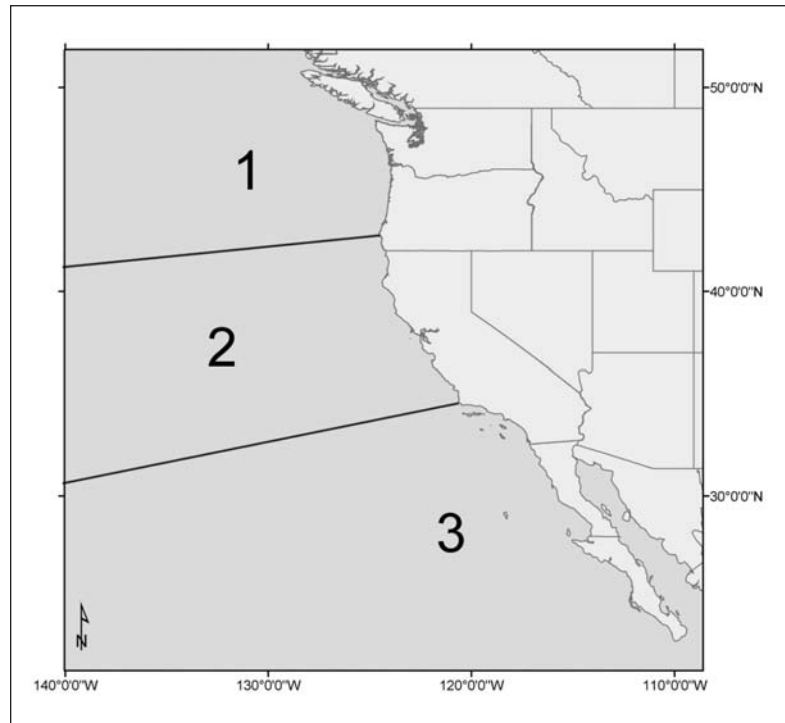
The resulting enrichment of surface waters leads to high levels of productivity in these regions. Moreover, because upwelling occurs in distinct areas, “plumes” of cold, nutrient-enriched waters intersect warmer waters offshore, creating convergence zones and fronts. Where upwelling fronts occur, plankton and fish are trapped, and seabird predators concentrate.

The CCS may be subdivided into three regions, each showing differences in physical and biological attributes (34) (Figure 3.5). In the northern California Current, extensive coastal downwelling in winter is associated with intense winter storms that pass through this region; upwelling occurs, but generally is restricted to the late spring and summer months. In the central CCS, from Pt. Conception, California, to Cape Blanco, Oregon, coastal upwelling occurs year-round (35). Off southern California and northern Baja California, the Southern California Bight represents a physical oceanographic and faunal barrier, separating the cold California Current subarctic waters from warmer subtropical waters to the south. This dynamic ecotone delineates the ranges of many subarctic and subtropical marine bird species (15).

This region is also characterized by substantial seasonal, interannual, and interdecadal variability in oceanographic conditions, which also may lead to changes in the seabird community structure. This variable oceanographic regime produces a convergence of range limits of seabird species with northern and southern affinities. The bight marks the southern range limit of four species with northern boreal affinities (Common Murre, Pigeon Guillemot, Tufted Puffin, and Rhinoceros Auklet) and the northern range limit of the Xantus’s Murrelet and two subtropical species (Black Storm-Petrel and California Brown Pelican). Relatively more subtropical taxa are also found in this region under warm ocean conditions (36).

Figure 3.4 – California Current Subdivisions based on physical and biological attributes.

1. Northern region: extensive coastal downwelling in winter; upwelling in late spring and summer. **2.** Central region: coastal upwelling occurs year-round. **3.** Southern region: Southern California Bight represents a barrier separating the cold subarctic California Current waters from warmer subtropical waters to the south.



The Southern California Bight region, which includes the Channel Islands, Los Coronados, Todos Santos, and San Martín islands, extends from Point Conception to Punta Baja (35° to 30° N) (37). The bight is formed by an eastward bend in the coastline south of Point Conception and is characterized by a wide continental shelf over which the cooler southerly-flowing California Current water merges with warmer northerly-flowing surface water of the California Countercurrent in a large retaining counter-clockwise eddy (38).

The Channel Islands and Pacific Mexican islands are positioned within the southern portion of the CCS, and are characterized by seasonal upwelling of cold, nutrient-rich water, periodic El Niño Southern Oscillation events, and decadal climate shifts (reviewed in Hickey (39)).

Specifically, the Channel and Mexican islands are encompassed within the two southern regions of the CCS characterized by different intensities and durations of upwelling, wind stress, coastal topography, bathymetry, and fresh water flow that influence the seasonal abundance and availability of prey resources (40) and the seabird assemblage in each region (41).

The western Channel Islands and San Nicolas are influenced by the cooler California Current waters and nutrient-rich upwelled waters off Point Conception during spring and summer (38). The southern and eastern Channel Islands are surrounded by warmer, subtropical waters carried north by the California Countercurrent (38). Wind-generated upwelling is most persistent off Point Conception and in the region between San Diego and Punta Baja where the coast is parallel to the along-shore southeast winds (42).

The southernmost region of the CCS, which includes the islands from San Jerónimo southward, is located between Punta Baja and Cabo San Lucas (30° to 23° N). Upwelling-favorable winds persist year-round and peak in spring (43). Upwelling is most intensive at the coastal prominences of Punta Baja, Punta Eugenia, and Punta Abreojos (42) and between Punta Eugenia and Cabo San Lazaro (41), where many seabird colonies are located. Coastal filaments are often formed near coastal promontories where upwelling jets diverge from the shelf, sending narrow streams of colder water seaward often several hundred kilometers across the warmer California Current flow (44).

The region south of Punta Eugenia is characterized by warmer surface waters resulting from thermal heating due to low cloud cover (43). At the southern tip of the Baja California peninsula, subarctic, subtropical, equatorial, and Gulf of California water masses converge to form the temperate/subtropical transition zone (45). Higher sea surface temperatures and the increasing influence of subtropical waters help to define the southern range limits of Brandt's Cormorants and Western Gulls and the beginning of a tropical seabird assemblage marked by nesting Magnificent Frigatebirds.

Differences in coastal topography and in upwelling intensity influenced by wind stress curl further divide the southernmost region into three subregions with different oceanographic characteristics: (a) a zone of maximal upwelling centered at Point Baja, (b) Vizcaino Bay with limited circulation and a seasonal anticyclonic eddy, and (c) the region south of Point Eugenia, marked by advection of warm subtropical and Gulf of California water, cyclonic eddy circulation, and the presence of a more tropical marine prey assemblage (46).

South of 30°N, persistent negative wind stress curl dominates the offshore region year-round (46). While positive wind stress curl can create open ocean upwelling away from the coast that enhances coastal upwelling, negative wind stress curl offshore creates downwelling of surface water (46). Therefore, in this region, nearshore coastal upwelling is dominant and is rarely enhanced by open-ocean upwelling.

In a unique region between Point Baja to Point Eugenia, the lobe of typically offshore negative wind stress curl extends inshore to within 10-20 km of the coast, and Vizcaino Bay effectively separates the water masses along the peninsula into distinct northern and southern components (46). Vizcaino Bay itself forms a semicircle 110 km in diameter and encompasses the broadest portion of the continental shelf, which narrows and breaks steeply west of Cedros Island to Point Abreojos (47). Anticyclonic eddy circulation in the bay is important for the retention and growth of larval fish and plankton, which might otherwise be advected offshore, thereby providing important prey resources for seabirds (46, 48).

(B3). Distribution and Abundance of Seabirds at Sea

Seabirds spend most of their life at sea, and it is from the sea that they derive their food; however, most seabird research has been conducted at colonies. Information on seabird distribution, abundance, and behavior at sea is fundamental to understanding seabird ecology and the formulation of scientifically sound solutions to conservation issues and threats. In addition, this at-sea information is essential for identifying actual or potential conflicts with fisheries activities.

Studies of seabirds at sea have revealed a number of important patterns, including both spatial and temporal changes in species distribution and abundance. Such information should be considered when developing long-term conservation strategies, including the design and establishment of marine protected areas.

In addition, knowledge of seabirds at sea is key to understanding and interpreting the important factors that influence seabird behavior, ecology, and population dynamics. This type of information is valuable to marine bird conservation as it contributes to the determination of species/community vulnerability to oil spills, fisheries interactions, and other anthropogenic factors that may affect seabird populations in the California Current.

In this section, we review information concerning the abundance, distribution, and diversity of seabirds at sea in the Pacific coastal upwelling domain of the West Coast, and how patterns of community organization and individual species dispersion vary seasonally and at longer timescales.

Seabird Patterns, Communities, and Assemblages

The distribution and abundance of seabirds at sea is influenced by oceanographic and biological processes operating at multiple temporal and spatial scales (26). At large spatial scales, greater than 1000s of kilometers, distinct seabird communities are associated with water masses characterized by different temperatures and salinities (29, 32, 49, 50). At smaller spatial scales, 1s to 100s of kilometers, marine birds are influenced by the locations of breeding colonies, distance from land, and physical and biological processes that aggregate prey and make it accessible to foraging seabirds (51-54).

Within the upwelling domain of the west coast of North America, the greatest ocean productivity occurs over the continental shelf, with moderate productivity over the shelf break/slope, and lowest productivity in offshore waters > 2000 m deep. Seabird biomass follows the same general pattern (2).

The high abundance of prey over the continental shelf attracts millions of seabirds that breed in, winter in, or migrate through this region annually (2, 15, 55). Seabird diversity and biomass are greatest during spring and fall migrations. In the winter, when birds found in offshore pelagic waters are mainly local breeders and visitors from northern and inland colonies, overall avifaunal density and diversity are lower (Table 3.4). Such onshore-offshore gradients in seabird assemblages have been documented off California and Washington (Table 3.4) (15, 56, 57).

Seabird communities and assemblages vary considerably within distinct oceanographic domains. In general, highly productive coastal regions sustain greater overall seabird densities than less productive pelagic waters (15, 50, 58). Greater numbers of diving seabirds, which often have high energetic requirements (59), are found in coastal areas along the U.S. West Coast, with the diving alcid and cormorants preferentially inhabiting areas of cool ocean temperatures and high chlorophyll concentrations (53).

In contrast, areas of lower ocean productivity of the equatorial Pacific Ocean sustain less diverse and abundant avifauna, dominated by species that often feed in flocks and procure food by surface-picking and plunge-diving (Table 3.4) (54, 58, 60). Moreover, many of these taxonomic groups (e.g., boobies, shearwaters, and terns) are surface or near-surface feeders (shallow divers) and they rely on underwater predators (tunas, dolphins, etc.) to drive prey to the surface where they become available to near-surface feeding seabirds (Table 3.4) (54, 58, 61, 62).

Individual Species

On the continental shelf, gulls, murres, and shearwaters are the dominant seabird taxa. The coastal avifauna is dominated by locally breeding species, such as Common Murres, Brandt's and Pelagic Cormorants, and Cassin's Auklets, but migratory visitors from the Southern Hemisphere are numerically dominant during much of each year.

The most abundant breeding seabird along the U.S. West Coast is the Common Murre, although it is second in abundance and biomass to Sooty Shearwaters, a Southern Hemisphere migrant which is the most abundant species overall (Table 3.5). Phalaropes migrate to the continental shelf in large numbers in spring and Laysan and Black-footed Albatrosses forage in these waters even when feeding chicks on the Hawaiian colonies. Short-tailed Albatrosses also forage in these cool productive waters.

Many seabirds, including shearwaters, phalaropes, and auklets appear to be attracted to thermal fronts (63), some associated with upwelling centers (2, 15). Moreover, several species that primarily breed inland and several others from more northerly regions (e.g., kittiwakes) move to the coastal region to over-winter. Migrants from inland include several gull species (California, Ring-billed, Bonaparte's, Mew, Herring), and Double-crested Cormorants (64). Migrant waterfowl from the north include loons (Common and Arctic), grebes (Eared, Red-necked), and scoters (Black and White-winged); these species are often found in nearshore areas. Beyond the shelf and slope region, *Pterodroma* petrels and storm-petrels (primarily Leach's) are the numerically dominant species in the summer, while Cassin's Auklets and phalaropes, along with Leach's Storm-Petrels, are dominant during the winter (Table 3.4).

During the breeding season, California Current seabirds are often found relatively close to their colonies, as they are limited in their foraging range by incubation and chick-feeding duties (53). After the breeding season, the majority of breeding seabirds along the U.S. West Coast remain in this region, although their distributions may shift north or south. Such species include Brown Pelicans, Ashy Storm-Petrels, Brandt's, Pelagic, and Double-crested Cormorants, and all of the alcids (Common Murres, Tufted Puffins, Rhinoceros Auklets, Pigeon Guillemots, and Cassin's Auklets).

Several species migrate out of this region after breeding, including most of the terns (Caspian, Elegant, Gull-billed, and Least). Forster's Terns disperse south to Mexico and Central America, although some remain in southern California. The majority of Black Storm-Petrels disperse to Central and South America, with a small portion remaining in California (64).

Temporal Variability in Seabirds at Sea

Variability in seabird community structure and individual species dispersion results from oceanographic variability. Short-lived increases in abundance of subtropical species, for example, are common during warming episodes off southern and central California. During the 1992 and 1997-98 El Niño events, southern species, such as the Black-vented Shearwater and the Pink-footed Shearwater, shifted their distributions northwards (36, 57).

At larger temporal scales, analyses of long-term (1980s - present) surveys have revealed shifts in the prevalence of subtropical versus subarctic species off the west coast of North America (36, 53, 64, 65). In particular, Sooty Shearwaters (36, 64) and other species with subarctic affinities, including Common Murres and Cassin's Auklets (53), have declined since the mid-1980s. These pervasive changes suggest that the avifauna of the West Coast indicate a shift from a "high-productivity" assemblage typical of eastern boundary upwelling systems to a "low-productivity" community similar to those inhabiting subtropical gyres (66, 67).

At sea, changes in seabird communities and populations in the CCS may be related to variability in the PDO, although results are unclear. Veit et al. (68), in studying the seabird community off southern California, reported that overall seabird abundance decreased by 40% between 1987-1994, mostly due to the 90% decline in the dominant cold-water species, the Sooty Shearwater. Hyrenbach and Veit (57) have extended these observations, noting that, since 1994, total seabird abundance and Sooty Shearwater numbers have remained consistently lower than during 1987-1994, suggesting that long-term changes to the ecosystem persist.

In central California, Ainley et al. (69) and Oedekoven et al. (53) demonstrated interannual and long-term avifaunal changes and declines in many cold-water, locally breeding species, including Common Murres and Cassin's Auklets.

The most parsimonious explanation for changes in seabirds at sea in southern and north-central California in the late 1980s is probably a response to ecosystem change at that time (~1989-1990), rather than a lagged response to the 1976-1977 regime shift. Wahl and Tweit (70) studied decadal trends in seabird populations off the coast of Washington, and demonstrated a decline in cold-water species and a concomitant increase in warm-water species over the past three decades.

Finally, in recent reports on the state of the California Current developed as part of the California Cooperative Oceanic Fisheries Investigation (71-73), combined colony and at-sea datasets have been used to investigate seabird response to a purported shift in the PDO in 1998-1999.

Colony data from the Farallon Islands clearly demonstrate an increase in productivity for six species of seabirds after 1998. Moreover, Schwing et al. (73) demonstrate not only an increase in mean reproductive performance after 1998 but also a decrease in variance. In contrast, the overall abundance of seabirds at sea in southern California has not changed simultaneously; numbers remain low when compared with the seabird communities of the late 1980s. However, in both 1999 and 2001, coldwater, subarctic species comprised a greater proportion of the avifauna. Future surveys will reveal if this represents a consistent long-term change in seabird community composition or an intermittent change associated with coldwater intrusions during these years.

Table 3.4 - Comparison of seabird assemblages of the North Pacific central water mass and the upwelling domain off the west coast of North America during summer (July - Aug.) and winter (Jan. - Feb.). Three feeding methods are considered: Surface-feeding (S), diving (D), and plunging (P).

<i>Variable</i>	<i>Upwelling Domain</i>	<i>North Pacific Central Water</i>	<i>References</i>
<i>Mean Bird Density (Birds / km²)</i>	<u>Summer</u> 23 <u>Winter</u> 11	<u>Summer</u> < 2 <u>Winter</u> < 1	Wahl et al. 1989 Gould 1983 Tyler et al. 1993
<i>Prevalent Feeding Method (% Total Birds)</i>	Divers (80%) Surface Feeders (20%)	Plungers (55%) Surface Feeders (45%)	Wahl et al. 1989
<i>Numerically Dominant Species (Feeding Method)</i>	<u>Summer</u> <u>Winter</u> SOSH (D) CAGU(S) PFSH (S) NOFU (S) WEGU (S) RHAU (D)	<u>Summer</u> <u>Winter</u> BRNO (P) BFAL (S) WTSH (S) BWPT (S) SOTE (P) RTTR (P)	Gould 1983 Wahl et al. 1989 Tyler et al. 1993

BFAL – Black-footed Albatross

BRNO – Brown Noddy

BWPT – Black-winged Petrel

CAGU – California Gull

NOFU – Northern Fulmar

PFSH – Pink-footed Shearwater

RHAU – Rhinoceros Auklet

SOSH – Sooty Shearwater

SOTE – Sooty Tern

WEGU – Western Gull

WTSH – Wedge-tailed Shearwater

RTTR – Red-tailed Tropicbird

Table 3.5 - Comparison of conditions within offshore (depth > 2000 m) and onshore (depth < 2000 m) domains of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) grid in summer (July-Aug.) and winter (Jan.-Feb.), between May 1987 and Sept. 1998. Percent importance is defined as the proportional contribution to overall bird abundance. Table modified from Hyrenbach and Veit 2003.

<i>Variable</i>	Onshore		Offshore	
Chlorophyll Concentration (0 – 200 m) (mg chl / m ³)	<u>Summer</u> 41.20	<u>Winter</u> 41.67	<u>Summer</u> 27.89	<u>Winter</u> 27.54
Macrozooplankton Biomass (0 – 200m) (ml / 1000 m ³)	<u>Summer</u> 470.82	<u>Winter</u> 56.71	<u>Summer</u> 30.56	<u>Winter</u> 42.33
Seabird Density (Birds / km ²)	<u>Summer</u> 6	<u>Winter</u> 4	<u>Summer</u> 0.6	<u>Winter</u> 0.4
Numerically Dominant Bird Species (1987 – 98)	<u>Summer</u> SOSH PHAL WEGU	<u>Winter</u> CAGU CAAU BVSH	<u>Summer</u> LESP SOSH COPT	<u>Winter</u> LESP PHAL CAAU

BVSH – Black-vented Shearwater

CAGU – California Gull;

CAAU – Cassin's Auklet;

COPT – Cook's Petrel; **LESP**: Leach's Storm-Petrel;

PHAL – Red and Red-necked Phalaropes;

SOSH – Sooty Shearwater;

WEGU – Western Gull

Table 3.6 - Mean at-sea density (birds/km²) of seabirds in the CCS during July and December, designation of breeding status (breeder or visitor), and total density (Sum Total). Species are ranked from highest overall (July and Dec.) density to lowest density. Table modified from Tyler et al. 1993.

Rank	Common Name	Scientific Name	Breeder/ Visitor	July	Dec.	SUM TOTAL
1	Sooty Shearwater	<i>Puffinus griseus</i>	V	33.8	0	33.8
2	California Gull	<i>Larus californicus</i>	V/B	0.1	14.1	14.2
3	Common Murre	<i>Uria aalge</i>	B	7.0	5.1	12.1
4	Phalarope spp.	<i>Phalaropus spp.</i>	V	5.6	0.9	6.5
5	Northern Fulmar	<i>Fulmarus glacialis</i>	V	3.0	3.4	6.4
6	Cassin's Auklet	<i>Ptychoramphus aleuticus</i>	B	3.3	2.7	6.0
7	Western Gull	<i>Larus occidentalis</i>	B	4.5	1.1	5.6
8	Rhinoceros Auklet	<i>Cerorhinca monocerata</i>	B	0.2	4.2	4.4
9	Pink-footed Shearwater	<i>Puffinus creatopus</i>	V	2.5	0	2.5
10	Herring Gull	<i>Larus argentatus</i>	V	0.1	2.4	2.5
11	Black-legged Kittiwake	<i>Rissa tridactyla</i>	V	0	2.4	2.4
12	Leach's Storm-Petrel	<i>Oceanodroma leucorhoa</i>	B	2.4	0.1	2.5
13	Fork-tailed Storm-Petrel	<i>Oceanodroma furcata</i>	B	1.8	0.2	2.0
14	Brandt's Cormorant	<i>Phalacrocorax penicillatus</i>	B	1.8	0.2	2.0
15	Pacific Loon	<i>Gavia pacifica</i>	V	0	1.4	1.4
16	Glaucous-winged Gull	<i>Larus glaucescens</i>	B	0	0.8	0.8
17	Black-footed Albatross	<i>Phoebastria nigripes</i>	V	0.9	0.1	1.0
18	Bonaparte's Gull	<i>Larus philadelphia</i>	V	0	0.9	0.9
19	Heermann's Gull	<i>Larus heermanni</i>	V	0.1	0.7	0.8
20	Brown Pelican	<i>Pelecanus occidentalis</i>	B	0.3	0.3	0.6
21	Tufted Puffin	<i>Fratercula cirrhata</i>	B	0.3	0	0.3
22	Buller's Shearwater	<i>Puffinus bulleri</i>	V	0.2	0	0.2
23	Common/Arctic Tern	<i>Sterna hirundo /S. paradisaea</i>	V	0.2	0	0.2
24	Ashy Storm-Petrel	<i>Oceanodroma homochroa</i>	B	0.1	0	0.1
25	Pomarine Jaeger	<i>Stercorarius pomarinus</i>	V	0	0.1	0.1
26	Xantus's Murrelet	<i>Synthliboramphus hypoleucus</i>	B	0	0.1	0.1
27	Ancient Murrelet	<i>Synthliboramphus antiquus</i>	V/B	0	0.1	0.1
28	Black-vented Shearwater	<i>Puffinus opisthomelas</i>	B	0	0.1	0.1
29	Laysan Albatross	<i>Phoebastria immutabilis</i>	V	0	0	0

3.3 RESEARCH AND MONITORING RECOMMENDATIONS

1. Work in cooperation with agencies to protect important seabird habitats from human disturbance and introduction of non-native species.
2. Develop and implement programs to eradicate introduced predators and prevent further predatory mammal introductions on islands.
3. Restore colonies that have been damaged by human disturbance and mammalian introductions. Develop a plan to restore and expand breeding populations on islands from which seabirds have been extirpated or reduced.
4. Regulate areas with high boat traffic, such as ferries, recreational boaters and kayakers, that affect seabird colonies.
5. Increase enforcement of airplane and helicopter ceiling regulations.
6. Monitor and evaluate effectiveness of artificial habitat (e.g., nest boxes) on populations of select species.
7. Continue to use social attraction methods as needed for restoration and management. Identify and monitor locations and species for which this technique may increase population size.
8. Facilitate projects that involve vegetation restoration for burrow-nesting seabirds.
9. Work to decrease attraction of egg and chick predators to seabird nesting habitats (e.g., the interaction of campgrounds with corvids and Marbled Murrelets in coastal forests).

3.4 CONSERVATION AND MANAGEMENT RECOMMENDATIONS

1. Identify important roosting and breeding habitats within the CCS, and their protection status.
2. Identify important historic breeding and roosting sites, the causes for change in use of these areas, and whether restoration is warranted.
3. Identify locations where introduced plants and animals limit seabird breeding opportunities.
4. Identify cases where seabird breeding is limited by interactions with overabundant species (e.g., gulls).
5. Identify areas of high boat or air traffic that cause potential or actual disturbance to seabird colonies.
6. Identify the principle predators at colonies, and those colonies that are most threatened by predators.
7. Identify major threats to seabirds during their migration through the CCS and/or at their wintering grounds.
8. Investigate the effects of native animal disturbance at seabird colonies (e.g., pelicans, geese, eagles, pinnipeds).
9. Evaluate the effects of reintroduction of eagles and falcons on seabird populations.

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The California Current Marine Bird Conservation Plan

Chapter 4

Demography and Population Dynamic Models as a Cornerstone of Seabird Conservation
and Management in the California Current



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The California Current Marine Bird Conservation Plan Chapter 4

*Demography and Population Dynamic Models as a Cornerstone of Seabird
Conservation and Management in the California Current*

Version 1.0

Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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CHAPTER 4. DEMOGRAPHY AND POPULATION DYNAMIC MODELS AS A CORNERSTONE OF SEABIRD CONSERVATION AND MANAGEMENT IN THE CALIFORNIA CURRENT

Seabirds of the CCS face many conservation challenges. The primary challenge is to maintain or restore populations in the face of habitat destruction, introduction of nonnative predators, prey depletion and bycatch mortality from fisheries and oil spills, among others.

Population dynamics for all species reflect, ultimately, four processes: reproduction, survival, recruitment and movement (combination of immigration and emigration). Seabird life histories are characterized by long adult life spans, low reproductive rates and deferred maturity. Once breeding begins it can be intermittent (in some species not all breeding-age adults attempt to reproduce every year) (1, 2). These life history characteristics make seabirds of the CCS vulnerable, particularly to events that kill breeding age birds (3).

The past few decades have been characterized by a multitude of disturbances to seabirds, including several major oil spills, of which the Exxon Valdez Oil Spill is surely the most prominent (4, 5).

Events such as these oil spills have focused the attention of the public, government agencies, and the scientific community on two linked questions: What are the long-term impacts to seabird populations of anthropogenic disturbance? And, can seabirds recover from these impacts? An increased understanding of major oceanographic perturbations, such as El Niño (ENSO) and the Pacific Decadal Oscillation (PDO), and the various impacts of commercial fisheries has led to a growing recognition of the complexities involved in trying to address these two important questions.

Yet despite these serious challenges, there are two recent developments providing additional hope and tools for the conservation biologist and wildlife manager. The first is that in the past few decades there have been great advances in our understanding of seabird population biology; in part, this has been fueled by the recent development of sophisticated methods to estimate demographic parameters (6). The second is that there has been extensive elaboration of theoretical models and frameworks with the potential to be applied to seabird populations. These include metapopulation models (7), source/sink models (8), and stochastic population models, including population viability analyses (9, 10).

The time is ripe to review information on relevant seabird demographic processes, as well as potentially relevant population models, with the aim of encouraging their application to seabird conservation programs.

In this chapter we review aspects of demography relevant to the issue of seabird conservation in order to provide a conceptual, biological framework for developing and evaluating conservation and management efforts. We also summarize points especially relevant for individuals developing and evaluating seabird conservation and management programs.

In this review we focus on seabirds, but in considering previous applications of population-dynamic models (e.g., metapopulation models) we also include other bird species.

4.1 THE DEMOGRAPHIC COMPONENTS OF POPULATION CHANGE

We view population dynamics (and as discussed later, metapopulation dynamics) as fundamentally important in formulating and evaluating all conservation and management programs (11), because we must be able to detect and subsequently effect change in population dynamics for conservation to succeed. These changes must be detectable at the level of both an entire population and a sub-population.

Therefore it is helpful to consider what we call the Fundamental Law of Population Dynamics. Versions of this law have been introduced by various authors; here we present a relatively simple version (see McDonald and Caswell (12) for a more comprehensive treatment).

For ease of explanation we consider a simple life history, one that corresponds to no known seabird. Suppose, for a hypothetical seabird species, that individuals attain sexual maturity at age 1 year, that they breed (or at least can breed) at that age, and that every year thereafter they may or may not breed (if still alive). Given that, the seabird version of the Fundamental Law states that the number of adults at time, $t+1$, symbolized $N_{\text{adults}}(t+1)$, is a function of just four demographic processes: (1) adult survival from time t to $t+1$; (2) reproductive success per adult, at time t ; (3) survival of those offspring from time t to $t+1$; and (4) net immigration (net immigration = immigration - emigration) of individuals during the interval $(t, t+1)$.

As an equation we can write:

$$N_{\text{adults}}(t+1) = N_{\text{adults}}(t) \times \{\text{adult survival from } t \text{ to } t+1 \\ + \text{reproductive success at time } t \times \text{offspring survival from time } t \text{ to } t+1\} \\ + \text{net immigration (= immigration - emigration) from } t \text{ to } t+1.$$

Note that the middle line of the equation corresponds to new 1-year-olds (i.e., new adults or “recruits”) who were born the previous year.

For species with more complex life histories, the notation gets a bit more complicated, but the idea is the same: population dynamics can be explained in terms of just these four processes, which in theory, can be directly observed—some more easily than others.

One complication is that, in almost all seabirds, adulthood is not reached at age 1 year. For simplicity, we might treat age of first breeding as being fixed at some age, but it would be more realistic to treat it as a demographic parameter (usually symbolized as α), meaning that, even

within a single seabird population, individuals show variation in the age at which they first breed. For this reason we prefer to reformulate the parameter “age of first breeding” and instead consider “probability of breeding among those who have never bred before,” which we will symbolize β . Thus, β can be thought of as a measure of recruitment probability. Furthermore, β will demonstrate age specificity, just as survival and reproductive success are also age specific. At a young enough age, β will be zero; minimum age of first breeding corresponds to the youngest age at which β is greater than zero.

As formulated above, all adults are being followed through time, whether or not they are breeders. Hence “reproductive success” is averaged over all adults. For studying population dynamics (analytically and from a monitoring point of view), it is helpful to separate this process into two separate components: probability that an adult breeds (or attempts to breed), and reproductive success among those individuals that breed (or attempt to breed).

What we refer to as “breeding probability” has also been termed “breeding propensity” (13). Furthermore, “breeding probability” is divided into two parameters: first, the probability that an individual that has never bred before is breeding in that year, what we have called β , and second, the probability an experienced adult attempts to breed that year, which we shall refer to as γ . Thus, we have added two parameters to the original four, i.e., β and γ .

Finally, it may be helpful to separate survival probability among juveniles (young of the year, also termed Hatching Year birds) from survival probability among subadults, thereby creating one more parameter.

Thus, we can parameterize seabird demographic processes determining population growth in terms of seven parameters: (1) adult survival, (2) subadult survival, (3) juvenile survival, (4) reproductive success per breeder, (5) probability that an adult that has never bred before breeds in a given year, (6) probability an experienced adult breeds in a given year, and (7) net immigration. This formulation, developed for seabirds, would be entirely appropriate for other long-lived birds, such as eagles (14).

Many different parameterizations of population dynamics are possible. We justify this particular parameterization for two reasons. First, this parameterization has a strong empirical, biological basis. For example, there is good evidence that juvenile and subadult survival differ substantially, but—more to the point—juveniles and subadults often spend their lives in disparate regions and therefore are likely influenced by different mortality factors.

Another example is the value of distinguishing reproductive success among breeders from the probability an adult attempts to breed. Different factors are likely to affect these two parameters. For example, if nest sites are indeed limiting, provision of additional nest sites will markedly improve breeding probability but will have little influence on reproductive success.

Second, the parameters identified are accessible to monitoring. For example, many long-monitoring programs (including many ongoing studies on the Isle of May, Britain (15, 16); on the Farallon Islands, USA (17); and research conducted by the British and French Antarctic research programs in the Southern Ocean (18, 19)) estimate reproductive success per breeder (or per breeding pair) on an annual basis, (i.e., parameter 4 above). Uniquely banded individuals are not required to estimate reproductive success. As a result, good comparative data are available (comparing years, populations, and species).

It is more difficult, however, to estimate adult breeding probability. Good estimates require monitoring banded individuals (20, 21). Separating these two parameters is useful because it allows us to address uncertainty regarding one parameter (breeding probability) but not the other (reproductive success).

Finally, we note that reproductive success has been variously defined; here we consider reproductive success to be the number of chicks (offspring) reared to fledging (or independence) per breeding individual or per breeding pair. Thus, reproductive success subsumes components such as clutch size, hatching success, fledging success, “breeding success” (number of chicks fledged per egg laid), number of broods, etc.

Below we consider each demographic parameter, focusing on the significance of each parameter for determining seabird population dynamics and summarizing the state of knowledge regarding this parameter.

A parameter may be significant with respect to conservation efforts because it constrains population growth, but the parameter must be labile if it is to serve as a management tool. For example, theoretical investigations demonstrate that reduction in age of first breeding can have a sizeable impact on the population growth rate, γ (22). However, some evidence suggests that minimum age of first breeding is genetically constrained (23, 24), and therefore aiming to reduce minimum age of first breeding is unlikely to be an effective means of conserving seabirds.

4.2 REVIEW OF DEMOGRAPHIC PARAMETERS

(1) Adult survival.

Earlier views of adult survival considered this a species-specific, time-constant parameter. There is now evidence that adult survival in seabirds varies temporally, spatially, and age-specifically, and that changes in adult survival are associated with corresponding population fluctuations (25-30).

A recent example of temporal variability in adult survival was Jones et al.’s (30) study of Least Auklets (*Aethia pusilla*) breeding in the western Aleutian Islands, Alaska from 1990 to 2000. Annual adult survival probability varied from 74.7% to 95.3% and averaged 87.3% during the study period. Annual variation in adult survival was most parsimoniously explained by annual variation in the North Pacific Index (NPI), a measurement of atmospheric pressure in the north Pacific that indicates relative sea surface temperature and primary productivity in the region. This was the first direct evidence that variation in adult survival of a Pacific alcid species was related to large-scale climatic/oceanographic variation. Because of the Auklet’s low trophic position as a planktivore, adult survival for this species was positively correlated with ocean climate through the influence of climatic variation on primary productivity. The strength of this interaction was compounded by increased gull predation during low productivity years, when the gulls’ usual fish prey was scarce.

In the case of Brandt’s Cormorants (*Phalacrocorax penicillatus*) breeding on the Farallon Islands, adult survival was positively correlated with sea surface temperature, a well-established index of local food availability (31). These results implicate variability in food resources due to ocean climate as a major source of variation in adult survival, as well as in breeding probability and reproductive success (see below). This variation has significant effects on population trajectories.

Another example of annual variation in adult survival was provided by Harris et al.’s (32) study of Atlantic Puffins (*Fratercula arctica*). Between 1973 and 1980 survival averaged an astounding 97.5%; between 1981 and 1994 survival was only 92.4%. In other words, in the latter period adult mortality tripled compared with the 1970s. In addition, in 1990/1991 survival was only 80.6% (S.E.=2.6%), a more than doubling of mortality compared with the rest of the 1981-1994 period. The authors concluded that the “catastrophically low” survival in 1990/91 and the decadal shift in baseline survival were due to environmental perturbation, but there was no direct evidence for this.

A species showing marked decadal changes in adult survival due to fisheries-induced mortality (bycatch) is the Wandering Albatross (*Diomedea exulans*). This species has been especially well-studied demographically; two detailed long-term studies have been conducted at sites in different oceanographic regions, one in the Crozet Islands in the Indian Ocean (18, 33, 34), and the other at South Georgia Island in the South Atlantic Ocean (19). Weimerskirch (33) found that adult survival from 1966 to 1976 was just under 90% compared with 96% in more recent years (1986-1994), and concluded that low adult survival in the earlier time period (due to entanglement in fishing gear and shooting by fishermen) was the most significant factor contributing to substantial population declines. Conversely, the increase in adult survival in recent years was associated with population stability.

Both food supply and predation pressure had significant effects on adult survival of Black-legged Kittiwakes (*Rissa tridactyla*) in Britain and Ireland. Oro and Furness (35) found that annual variation in adult survival was best modeled as a function of both sandeel and Great Skua (*Catharacta skua*) abundance, the main prey and predator of the Kittiwake.

Not only does adult survival for a given species vary temporally, but there is ample evidence that adult survival also varies spatially. A striking example is provided by Spendelov et al. (36) who demonstrated substantial differences in survival of adult Roseate Terns (*Sterna dougallii*) among four colonies in New York State and New England (USA). To complicate the picture even further, the pattern of annual variation in adult survival differed among the four sites.

Another species for which extensive data on adult survival have been gathered at separate sites is the European Shag (*Phalacrocorax aristotelis*). Earlier work on the Isle of May (16, 37, 38) considered that adult survival was fairly constant from year to year. This was in contrast to the situation for European Shags on the Farne Islands, Britain (less than 100 km distant), which experienced several episodes of high adult mortality, owing to "red tide" (paralytic shellfish poisoning; (16)). More recently, however, high adult mortality for European Shags on the Isle of May was reported by Harris and Wanless (39) in winter 1994, apparently due to poor feeding conditions. Common Guillemots (*Uria aalge*) at three Scottish colonies also demonstrated spatial variation in adult survival (38, 40, 41).

Adult survival typically does not remain constant with increasing age. A common theoretical pattern of age-dependent survival is an increase in survival with age to a midlife optimum, followed by decline as the oldest birds senesce (42-47). Previous studies on age-dependent survival in seabirds have described the curve as a constant (31, 48, 49), negative-linear function (43, 50, 51), or a constant that exhibits senescent decline in older ages (19, 32, 37, 52-56). One study, Ainley et al. (57), found increased survival for birds age > 10. Rattiste and Lilleleht (58), and Ratcliffe et al. (59) fit the fully quadratic age-dependent survival function that Botkin and Miller (43) predicted for long-lived birds. Data from the Farallones for Western Gulls, Brandt's Cormorants, Common Murres, and Cassin's Auklets all showed some level of age-dependent relationship with survival and some showed age-dependent breeding propensity as well (PRBO unpublished data).

Population modeling results bear out the potential significance of even small changes in adult survival, a point we return to later. For example in the Common Murre (*Uria aalge*) population model developed by Nur et al. (60), a decrease in survival from 0.933 to 0.905, resulted in a change in population growth rate from +1.1% per year to -1.9%; in other words, a decrease of 3.0% in adult survival (in relative terms; absolute difference = 0.028) produces a change of 3.0% in the population trajectory. Similar results have been obtained for other species (18, 19, 61).

(2) Subadult survival.

Knowledge of this parameter is fragmentary at best for nearly all seabird species. And although it may be desirable to distinguish juvenile survival from subadult survival, many studies have been unable to make this distinction.

An additional problem is that studies of subadult survival based on capture/recapture (as opposed to band recovery) are unavoidably biased because of dispersal (11, 23). This is less of a problem for studies of adult survival because of high breeding philopatry. If the strength of natal philopatry varies from year to year, this will bias estimates of temporal variation in subadult survival. Studies of subadult survival based on band recoveries, on the other hand, have not usually had enough resolution to identify temporal or spatial variation in survival rates. An exception to this generalization is provided by the work of Baillie and Mead (62): they used band recoveries to determine that subadult Common Murres (as well as juvenile, first-year birds) suffered high mortality as a result of severe oil pollution during winter 1980/81.

Despite incomplete data, the picture that emerges is that subadult survival is apparently quite variable between years or between decades. For example, there was marked variation in immature survival for Wandering Albatrosses in the Crozet Islands; overall survival in the first four years of life after fledging varied from as little as 21% (for cohorts born in 1970-1976) to 50% (for those born in 1986-1994; (18)).

Furthermore, variation in immature survival (but not adult survival) was strongly correlated with fishing effort (18). The study by Croxall et al. (19) similarly concluded that mortality of Wandering Albatross subadults due to long-line fishing was responsible for a large proportion of the overall population decline. Murphy et al. (63) suggested that the population decline of Common Murres at Bluff, Alaska, was due principally to an increase in over-winter mortality of subadults, which may have resulted from competition with a fishery. Annual variation in the mortality of immature Black-legged Kittiwakes (*Rissa tridactyla*) was not in concert with that of adults, indicating that the decline in numbers of adults at a colony in England during the late 1960s was due to mortality factors acting during the subadult period (64). Among European Shags, survival of immatures (juveniles and subadults) was much more variable between years than was survival of adults (37).

Temporal variation in survival during the immature period (including both juvenile, post-fledging survival, and subadult survival) was also suggested for Roseate Terns (65), Atlantic Puffins (66), and Brandt's Cormorants (67). For the last-mentioned species, Nur and Sydeman (31) demonstrated that immature survival was correlated with environmental conditions (as indexed by sea surface temperature) during both the first year of life and the third year of life (when individuals first return to the natal colony).

For additional studies of subadult survival see Spear et al. (51); Ainley et al. (57); Gaston et al. (68); and a review by Hudson (69). Beissinger and Nur (70) provide re-analyses of data originally presented by Birkhead and Hudson (71); these analyses demonstrated that subadult survival (but not juvenile survival) was similar among different Common Murre populations and similar among Common and Thick-billed Murres (*Uria lomvia*). We might expect subadult and adult survival to be more similar (year by year and site by site) than are juvenile and adult survival; nevertheless, because subadults and breeding adults are usually found in disjunct areas, different mortality influences may be at work.

(3) Juvenile survival.

Even less is known about juvenile survival than about subadult survival. For this parameter there appears to be great variation among populations. For example, four different population estimates for first-year survival in Common Murres varied from 0.47 to 0.67 (70); yet for other populations, first-year survival may be 0.40 or less (60). Estimates from five studies of Herring Gulls (*Larus argentatus*) (72), ranged from 50-82% (median = 78%).

Some of the studies cited in the previous section may bear more directly on variation in juvenile survival than subadult survival, but it is not possible to disentangle the two. Not surprisingly, such large variation in first-year survival can have large impacts on population growth trajectories (see "Sensitivity to Population Parameters," below). An example of the great magnitude of variation possible was already presented for Wandering Albatrosses; survival from the time of fledging (at an age of c. 12 months) to age 5 was more than twice as high for the 1980s than the 1970s (50% vs. 21%). These results indicate a great potential for improvement in survival of juveniles and subadults as a means to restore or to stabilize declining or depleted populations.

Hatchwell and Birkhead (27) examined which demographic parameters were responsible for growth of the Skomer (Britain) Common Murre population in the 1980s, compared with the 1970s. They concluded (from indirect evidence) that a change in juvenile or subadult survival, or both, was the major factor explaining why the population grew in the 1980s, but not in the 1970s.

Population modeling for the Common Murre on the Farallon Islands (60) demonstrated that 40% juvenile survival results in average population growth of only 1.1%, whereas 60% juvenile survival results in a rapidly growing population, at the rate of 8% per year; both survival estimates are within the range observed for this species (70). Note also that juvenile mortality is less than three times that of adult mortality in the Herring Gull (on average, 0.28 vs. 0.12, respectively; (72)), while it is five to eight times that of adult mortality in the Common Murre. While there will be, inevitably, a gap between adult and juvenile mortality, conservation efforts may be successful in closing that gap somewhat.

By using a Leslie matrix and assuming that a population is censused immediately before the breeding pulse (e.g., immediately before offspring production), it is easy to show that the effect of a specified change in juvenile (i.e., first-year) survival is identical to the same magnitude change in reproductive success (12, 73). This is because the elements of the top row of the projection matrix are the number of female offspring produced which survive to age 1 per female. Thus the population consequences are identical whether 80% of breeders raise a chick and 50% of the chicks survive to age 1 or 50% of breeders raise a chick and 80% of the chicks survive.

(4) Reproductive success.

More data are available on this parameter than any other. It is well-established that reproductive success varies from year to year, from decade to decade, and that much of this variation is related to food availability for breeders (16, 74-80).

For example, a decline in North Sea herring stocks was associated with decline in Black-legged Kittiwake reproductive success (chicks fledged per pair) and a decline in population growth rate (81). Whereas a major decline in reproductive success is likely to presage a population decline, it does not follow that all fluctuations in reproductive success are similarly influential. Furthermore, at least for some species, as stated by Harrison (82), "an occasional bumper crop of young may be a more important attribute of an enduring species than the vicissitudes of success and failure in individual years."

For species with single-egg clutches (procellariiforms, many alcid), reproductive success is usually high (67-80%). There is little evidence that for such species, boosting reproductive success beyond levels that are already relatively high will be effective in raising seabird numbers; a point that is quantitatively demonstrated below (see "Sensitivity of Population Growth to Population Parameters"). Few studies have reported average reproductive success as high as 80%; this may present an upper bound to what a seabird can achieve. However, where reproductive success is unusually low, management efforts would be particularly well rewarded.

Seabirds can be divided into two categories: those with single-egg clutches and those with multiple-egg clutches. The recovery potential for species with multiple-egg clutches (and especially those with a clutch of 3 or more) is much greater than for those with single-egg clutches. For example, a review of population studies of seabirds (83) indicated that Common Murre populations (clutch of one egg) rarely grew at more than 10% per year (excluding cases with known immigration), yet often cormorant or gull populations (typically with clutches of 3-4 eggs, and 2-3 eggs, respectively) grew at much faster rates. The small clutch size for some seabirds, therefore, constrains their ability to recover or to take advantage of good conditions.

As a result, the effects of good and bad years are not symmetric: in a bad year, reproductive success can be depressed much more (relative to the long-term average) than it can be elevated in a good year. This asymmetry is applicable to all seabirds, but appears to be stronger for the single-egg clutch species (75). For example, for Common Murres on the Farallon Islands, in an exceptionally good year reproductive success increases by 20% relative to the long-term average, while for two cormorant species, reproductive success in an exceptionally good year is 100% above the long-term average.

Finally, we note that reproductive success is affected by age of mate and years of experience with the same mate (84-87). The dependency of reproductive success on these factors should be taken into account when considering the impact of oil spills and other perturbations. That is, individuals that lose their mate or simply change mates, generally have lower reproductive success in their first and subsequent seasons (up to the fourth year in Short-tailed shearwaters (*Puffinus tenuirostris*) (87), when breeding with the new mate).

(5) Probability of first breeding, β .

Recall that we divided breeding probability into two components: (1) the probability an individual of breeding age breeds for the first time, β , and (2) breeding probability among experienced breeders, β . Good information on β is difficult to obtain for the reasons given below; a good example, however is provided by McDonald and Caswell (12) for the Florida Scrub-jay (*Aphelocoma coerulescens*).

It is helpful to think of β for a given age (call it β_x) as the ratio of two quantities:

$$\beta_x = V(x)/N(x)$$

where $V(x)$ is the number of first-time breeders of age x , and $N(x)$ is the number of individuals of age x who have not bred at a younger age.

Rather than reporting β_x , many studies report the age-specific distribution of first-time breeders, i.e., they report $V(x)$. This is surely useful information, but only provides limited insight into β_x . There are two difficulties with inferring β_x (even qualitatively) on the basis of $V(x)$ alone.

The first difficulty is that individuals first observed breeding at a given age may have bred before, but were not observed by the investigator. Pradel et al. (23) describe how this probability can be estimated using capture-recapture (or sighting-resighting) data. Thus, differences between populations (between species, between years, etc.) may confound attempts to detect differences in β_x .

The second difficulty is that, though $V(x)$ may be directly observable (notwithstanding differences in detection probability), $N(x)$ is generally not directly observable for seabirds. $N(x)$ reflects the total number of individuals who have yet to breed, some of which may attempt to breed at age x (and thus be observed) and some of which may remain non-breeders at age x . Non-breeders may not attend the breeding colony or are otherwise not observed, which presents difficulty in estimating the denominator. Note that $N(x)$, which represents the pool of individuals available to first breed at age x , is simply the difference between total number of individuals of age x (thus reflecting survival to age x) and the number of individuals of age x who have previously bred (thus reflecting β at age $x-1$, $x-2$, etc.). Thus, differences in survival (of immatures and adults) can also confound attempts to detect differences in β_x .

As noted, few studies have attempted to estimate β_x ; instead observed ages of first breeding have been reported. These latter studies have indicated much interspecific variation in age of first breeding, for example with respect to body size (24, 88). In addition, there appears to be variation within species as well. For example, Common Murres on the Isle of Canna (Britain) were observed first breeding at ages 3 and 4 (89). Skomer Common Murres bred at ages 4 to 6 years (71).

Age of first breeding is likely to reflect, in part, breeding opportunities; the colony on the Isle of Canna was a fast-growing one with (presumably) many available breeding sites. Brooke (20) observed that age of first breeding for Manx Shearwaters (*Puffinus puffinus*) increased from 6 yrs in the 1970s to 7 yrs in the 1980s on the island of Skokholm (Britain). Age of first breeding may be flexible, but there are likely physiological limitations on the ability of any restoration program to reduce age of first breeding beyond a certain age.

It is unrealistic to assume that all individuals will begin breeding at the same age; instead, there is usually a range of ages in which β increases as age increases, eventually (but not always) reaching a plateau (23, 90). As a result, age of first breeding can vary substantially even within a year and within the same population.

For example, some Western Gull (*Larus occidentalis*) females start breeding at age 4, but a considerable number do not start breeding until ages 7, 8, 9, or 10 (91). Spear et al. (51, 91) attribute this variation, in part, to intense competition for mates, due to a skewed sex-ratio in the population. As a result of this competition, age of first breeding is delayed. A similar wide range of age of first breeding was reported for Common Murres by Harris et al. (92), and for Cassin's Auklets by Pyle (84).

In summary, parameter β appears to be very flexible. For many species, a large pool of non-breeders provides a potential source of first-time breeders, if competition is lessened (93), if excess sites are provided, or as a result of high mortality of established breeders. An example is provided by catastrophic red tide mortality of European Shags on Farne Island, which allowed many new individuals to recruit (49). We view this pool of non-breeders as a source to be tapped by restoration efforts.

(6) Breeding propensity (breeding probability among experienced breeders), γ .

This parameter also shows much variation between and within species. Fisher (94) found that many Laysan Albatrosses (*Diomedea immutabilis*) on Midway Island skipped breeding in 1964/65 and 1968/69; the 1964/65 observations were associated with an El Niño event in 1965. On the other hand, among Western Gulls (*Larus occidentalis*) on the Farallon Islands who are experienced breeders, breeding probability is close to 100%, year in and year out (95).

Skipping (i.e., non-breeding among experienced breeders) reflects individuals present at the colony not attempting to breed and individuals absent from the colony; the extent of skipping is undoubtedly underestimated, because skipping birds are often absent or inconspicuous.

In the Short-tailed Shearwater (21), 12% of adults did not attend the colony in a given year and 19% maintained burrows but did not lay an egg. In the Newell's Shearwater (*Puffinus auricularis newelli*), breeding probability was estimated to be less than 55% (185) in contrast with the closely related Manx Shearwater where it was estimated to be 80% (20). In the Sooty Shearwater, Hamilton and Moller (96), based on data provided by Richdale (97), estimated that 55% of breeding-age individuals did not breed in a given year. Use of that parameter value in a population-dynamic model produced a sharply declining population (96). Ainley et al. (185) also attributed declining population trends of Newell's Shearwaters to the low proportion of breeding-age adults that actually bred.

Albatrosses generally skip breeding in the year following successful breeding; Croxall et al. (19) also found that some successful breeders skipped two years in a row, and that some individuals also skipped breeding in the year following unsuccessful breeding. At least among Procellariiformes, the failure to attempt breeding (among experienced breeders) is commonplace.

Skipping of breeding appears commonplace among cormorants and shags as well, and the incidence of such appears quite variable. Aebischer (38) attributed a population crash among European Shags on the Isle of May to extensive non-breeding of experienced adults. Aebischer and Wanless (16) report that a second population crash could also be attributed to failure to breed among adults. Other cormorant species demonstrating a pattern of intermittent breeding include the Guanay Cormorant (*Phalacrocorax bougainvillea*) (98) and Galapagos Flightless Cormorant (*Nannopterum harrisi*) (99). Nur and Sydeman

(100) found that breeding probability of Brandt's Cormorants (who had previously bred) varied markedly between years, ranging from 8% to 85% (mean = 59%), and that the variation was related to food availability. Intermittent breeding has also been reported for gulls and terns (101-103) and for Common Murres (104).

The effect of this non-breeding is similar to that of reproductive failure among those attempting to breed. That is, production of young is the same whether 100% of adults attempt to breed with 40% success or 50% attempt to breed with 80% success. However, attempting and failing to raise young is likely more stressful to parents than not breeding at all (105).

(7) Immigration and emigration.

Population growth of seabird colonies is undoubtedly influenced by immigration and emigration, yet we have little good information on these parameters. Models of single populations have de-emphasized the role of immigration/emigration because it is difficult to incorporate into the usual age-structured or unstructured models. As long as immigration equals emigration, then the population dynamics of a single population would not be sensitive to the actual immigration rates (though genetic variability would be affected).

In contrast, immigration/emigration is an explicit part of metapopulation models (see below), and so this parameter cannot be ignored in such models. Emigration is difficult to study because individuals are leaving the focal colony (by definition) and death is hard to distinguish from emigration. The number of immigrants can, in some cases, be quantified, but the pool from which they come is much harder to identify.

Species vary in their tendency to immigrate/emigrate in regard to both dispersal of young and dispersal of adults. Terns and cormorants, for example, show a great deal of dispersal, even among breeding adults (1). Or, to put it another way, site tenacity is low; this makes it difficult to designate critical breeding areas to be acquired and managed. Spedelow et al. (36) found that dispersal of breeding adult Roseate Terns was considerable, and it varied among colonies, ranging from 1% to 12% per year.

In general, seabird species show a considerable amount of dispersal at the post-fledging juvenile stage. Dispersal during the juvenile stage may or may not lead to effective emigration among breeding individuals. Harris (26) found that pre-breeding Atlantic Puffins from the Isle of May visited colonies at other islands, and appeared to return to the natal colony only if there were few breeding vacancies at the visited colony. The fact that many puffins returned to their natal colony to breed should not be taken to imply that puffins are constrained to do so. Another example is offered by Ainley et al. (57) who found that skuas visited a number of colonies as young pre-breeders, but most eventually returned to within meters of their natal sites and those that emigrated were attracted by unusual opportunities of ample food availability.

This tendency to sample a number of colonies before settling improves the likelihood of successful restoration and emphasizes that dispersal (immigration/emigration) needs to be explicitly included in restoration models.

A review of population recovery of marine birds indicated that immigration played a role in many growing populations (83). Immigration can play a role in restoration in several ways. In establishing a new colony (or reestablishing an extirpated colony) all individuals are, at first, immigrants. Among growing colonies, immigration will often reinforce population growth. On the other hand the establishment of a new colony may siphon off individuals (increased number of emigrants from the established colony) leading to no net change in the larger metapopulation.

Many seabirds are specifically attracted to extant colonies. Coulson (106) found that, among growing colonies, small colonies were the most attractive to Black-legged Kittiwakes seeking to breed. In contrast, Birkhead (107) found that Common Murres were most attracted to high-density subcolonies, but were most likely to settle in medium-density subcolonies (because high-density subcolonies had few vacancies). Heubeck et al. (108) observed that small kittiwake colonies declined at faster rates than did large colonies, suggesting that kittiwakes were more likely to emigrate from small colonies. As a consequence, the recovery prospects for a small colony that has been severely depleted may be poor. The prospects for a completely extirpated colony are even worse.

Whereas a number of studies have provided insight into patterns of immigration and emigration, it has been much more difficult to estimate actual immigration and emigration rates. A common assumption has been that immigration and emigration are negligible. In some cases, this view may be justified (38). However, at least some studies seem to contradict that view.

For example, Harris (26) concluded that 23% or more of Atlantic Puffin chicks fledged on the Isle of May and surviving to breed, breed at a different colony, i.e., not on the Isle of May. Austin et al. (109) concluded that Short-tailed Shearwaters showed “substantial, and probably opportunistic immigration.” Wandering Albatross female dispersal was estimated to be 24% (i.e., that fraction of individuals bred in a colony other than their natal colony); even among females that bred in one colony, 11% switched colonies and bred in a second colony (18). The same statistics for males were half that of females. Immigration of Common Murres was considered by Parish (110) to be an important factor in explaining rapid population growth of Tatoosh Island (Washington state) in the 1980s.

Multi-strata mark-recapture models are important tools that can be used to quantify movement of animals between physical sites as well as transition probabilities between states such as breeding/non-breeding (111, 112). These methods can provide unbiased estimates of site fidelity (113), movement rates between subpopulations (36), and can even estimate probabilities associated with unobservable states (114).

(8) Sex ratio and mating system.

In addition to the seven primary demographic parameters enumerated above (which are the focus of this section), there are two factors that will also influence population dynamics: the sex ratio and the mating system.

Often, population dynamic models of seabirds assume an equal sex ratio. There is evidence that the sex ratio is not uniform, either among offspring (115-117), or among adults (51). Mating systems will also influence population dynamics if individuals of one sex mate with several individuals of the other sex. Although monogamy is the norm in seabirds (86), there are exceptions (118). As a result of deviations from either an equal sex ratio or monogamy, one sex will be the limiting sex.

Population models need to take into account which sex is limiting or if both are (though perhaps at different times of the life cycle). We do not discuss this further but note that software is now available to model such complexities (RAMAS/GIS 4.0).

(9) Stochasticity.

In the last decade, population models that incorporate stochasticity (i.e., variation in demographic parameters due to random effects) have become increasingly prevalent. The result is a model that is probabilistic, rather than deterministic. The reasons for developing stochastic, probabilistic models are manifold.

The first is that nature is in fact stochastic. Not only is the environment unpredictable, but so, too, are demographic responses to the environment. More realistic and accurate predictions can be made if stochasticity is incorporated.

A second reason is that without a probabilistic framework, no sense of variability of outcome is possible. For example, a stochastic population model for the Farallon Common Murre developed by Nur et al. (60), predicted that on average the population would grow by 1.1% per year. Most interestingly, in the face of a very variable, unpredictable environment (as observed on the Farallones), there was a 10% chance the population would shrink by 21% or more after 10 years and a 10% chance that the population would grow by 53% or more after 10 years.

A third reason for incorporating stochasticity is that deterministic models do not accurately predict average response. Instead, greater environmental and demographic variability tends to depress population growth rates (119). The final reason for incorporating stochasticity is that the deleterious effects of stochasticity are strongest for the smallest populations (e.g., incipient or decimated colonies; see Allee effect below).

The effects of stochasticity on populations are often categorized in a four-part manner (120, 121):

1. Genetic variability. Even in identical environments the genotypic makeup of two populations will differ due to genetic drift and founder effects. This source of variation will in turn affect vital rates.

2. Demographic stochasticity. This can be thought of as “The Law of Small Numbers.” The number of adults surviving in a finite population from one year to the next reflects the true underlying survival probability (which may vary among years, see “Environmental stochasticity,” below) and sampling effects.

To see this, suppose we have a population of 10 individuals, each with a survival probability of 0.5. There is a 0.1 % chance that in any one year, all 10 individuals will die ($= (.5)^{10}$, assuming each individual lives or dies independently of the others) and an equal chance that all 10 will live. Similar arguments apply to production and survival

of young. Demographic stochasticity also applies to each sex. Suppose there are 5 males and 5 females in the population with survival probability of 0.5 each. There is a 3% chance that all males will die ($= (.5)^5$) and a 3% chance that all females will die. Thus there is only a 94% chance ($= .97 \times .97$) that at least 1 male and 1 female will survive among the initial 10 in a single time period (e.g., 1 year). Conversely, there is a 6% chance that either no males survive or no females survive.

3. Environmental stochasticity. This refers to variations in demographic parameters due to environmental fluctuation. For example, if feeding conditions are good in a given year, survival and fecundity tend to be high.

4. Environmental catastrophe. This is a variation on #3 but is rare and drastic in its effects.

Stochastic forces #3 and #4 apply to both small and large populations, but forces #1 and #2 are negligible for very large populations.

Because Farallon Common Murre population size is very large (60,000 or more individuals), the stochastic population model of Nur et al. (60) only included environmental stochasticity (catastrophic or mundane). However, anyone wishing to investigate small populations should include the effects of genetic and demographic stochasticity.

Not only are small populations more subject to stochasticity, but their vulnerability to stochastic variation decreases the probability of long-term persistence. An anomalous year in which few or no individuals survive has greater impact on long-term population growth than an anomalous year in which everyone survives.

Because no environment is truly constant with time, environmental stochasticity should always be considered in the development of realistic population models.

However, in using empirical data as a basis for estimating the magnitude of environmental stochasticity to be included in a model, one needs to be careful to exclude sampling variance from that estimate. Even if, in the extreme case, a parameter is truly constant with time, any empirical study will detect year to year variation in the estimate of that parameter for each year studied, simply because the estimates are drawn from a finite sample size. Failure to exclude sampling variance could lead to overestimating the magnitude of environmental stochasticity in a parameter.

Finally, a literature search was conducted on all the breeding species of the CCS to determine what is known of the demographic parameters and to identify the gaps in knowledge. This exercise revealed a number of gaps (Table 4.1) for most of the species.

Table 4.1 – Demographic parameters of CCS breeders and knowledge gaps (indicated by blank cells).

COMMON NAME	Distribution	Population Status	Age at First Breeding	Adult Survival	Breeding Propensity	Reproductive Success	Juvenile Survival	breeding (b.f.) natal (n.f.) fidelity
Laysan Albatross <i>Diomedea immutabilis</i>	MX	increasing	8 (8-9)	0.95	.76 (.59-.86)	.64 (.49-.78)		
Black-vented Shearwater <i>Puffinus opisthomelas</i>	MX	decreasing				.36		
Leach's Storm-petrel <i>Oceanodroma leucorhoa chapmani</i>	CA, OR, WA, CN, MX		5-7 (3-7)	0.79-0.93		1st=.67, 2nd=.76, 3rd=.796, 6-27th=.861		
Leach's Storm-petrel <i>O. l. socorroensis</i>	MX							
Leach's Storm-petrel <i>O. l. cheimomnestes</i>	MX							
Black Storm-petrel <i>Oceanodroma melania</i>	CA, MX					1989=0.45 / 1990=0.5		
Ashy Storm-Petrel <i>Oceanodroma homochora</i>	CA, MX					0.694		
Fork-tailed Storm-petrel <i>Oceanodroma furcata</i>	SEFI					0.689 (0.39-0.95)		
Least Storm-petrel <i>Oceanodroma microsoma</i>	MX							
Magnificent Frigatebird <i>Fregata magnificens</i>	MX					0.5-0.75		
Brown Pelican <i>Pelecanus occidentalis</i>	CA, MX		3 (2-4)	~ 0.80		1980-99 = (0.3-1.2)	0-1st = 0.3	
Double-crested Cormorant <i>Phalacrocorax auritus</i>	CA, OR, WA, MX	increasing	2.7 (1-4)			CA:1.27, WA:0.29, CN:2.0-2.5	1st=.48, 2nd=.74, 3rd+=.85	
Brandt's Cormorant <i>Phalacrocorax penicillatus</i>	CA, OR, WA, CN, MX		3 (2-9)	0.74		1971-96 = 1.35 (1.0-2.2)		
Pelagic Cormorant <i>Phalacrocorax pelagicus</i>	SEFI	increasing	3	0.785 (0.48-0.93)	0.41(0.07-0.86)	1.44 (0-2.86)		
	CA, OR, WA, CN, MX	dec or =; WA incr	2/3			(1.69-2.64)		
	SEFI					0.922 (0-2.24)		
Heermann's Gull <i>Larus heermanni</i>	MX	increasing	4 (3-4)					
Ring-billed Gull <i>Larus delawarensis</i>	CA, OR, WA		3 (3-4)			1.48 +/-0.46 (0.77-2.53)		
Mew Gull <i>Larus canus</i>	CN		m=3, fem=4 (2-4)	0.87		(0.19-0.52)	1st=.59, 2nd=.71, 3rd=.81	90% b. f.
California Gull <i>Larus californicus</i>	CA, OR, WA	increasing or =	3-4	(0.79-0.92)		SF = 0.42	(0.55-0.90)?	

Table 4.1 – Demographic parameters of CCS breeders and knowledge gaps (indicated by blank cells).

COMMON NAME	Distribution	Population Status	Age at First Breeding	Adult Survival	Breeding Propensity	Reproductive Success	Juvenile Survival	breeding (b.f.) natal (n.f.) fidelity
Western Gull <i>Larus occidentalis</i>	CA, OR, WA, CN, MX		5 (4-6)	0.9 (ENSO = 0.7)	0.945 (.78-.99)		fl-1st:<0.5, 1st-2nd:0.65	75% b. f., 42% n. f.
	SEFI			0.826 (.69-.92)		1.09 (0.31-1.62)		
Glaucous-winged Gull <i>Larus glaucescens</i>	OR, WA, CN	increasing	5.4 (4-7)	0.83-0.87		1.67 (1.4-1.8)	1st=4, 2nd=6, 3rd=62	
Gull-billed Tern <i>Sterna nilotica</i>	CA	decreasing	5			0.68		
Caspian Tern <i>Sterna caspia</i>	CA, OR, WA, CN		3 (2-4)	0.87-0.91		1.1 (0.6-1.6)	0-1:0.55 ; 1-4:0.57	85-94% b. f.
Royal Tern <i>Sterna maxima</i>	CA, MX		(2-6)	(0.69-0.77)			0-2:0.86, 2-4:0.94, 4-7:0.72	
Elegant Tern <i>Sterna elegans</i>	CA, MX					0.97		
Arctic Tern <i>Sterna paradisaea</i>	WA	decreasing	3-4	0.82-0.87		Gulf of AK:1.16; Cooper I.:(0.21-0.86)		
Forster's Tern <i>Sterna forsteri</i>	CA					(0-1.6)		
Least Tern <i>Sterna antillarum</i>	CA, MX1	increasing	3 (2)	0.88 (0.84-0.94)		0.47	0.80-0.82	36-86% b.f., 16% n.f.
Black Skimmer <i>Rynchops niger</i>	CA		3 (2-4)			NY(0.25-0.91) TX(0-2)		76% b.f.
Common Murre <i>Uria aalge</i>	CA, OR, WA, CN		4(2-9)	0.87-0.95		CA:8(1-9); WA:35(.09-.71)	0-1st breed= .17-.37	57-78% n.f.
	SEFI			0.89-0.96 (.72-.99)	0.90-0.95 (.73-.98)	0.75 (0.04-0.91)		
Pigeon Guillemot <i>Cepphus columba</i>	CA, OR, WA, CN	decreasing?	3	0.8 (.76-.89)	(0-0.8)	CA:1.0; WA:0.82, 0.89	0-1st breed=0.4	
	SEFI							
Marbled Murrelet <i>Brachyramphus marmoratus</i>	CA, OR, WA, CN	decreasing?				0.833 (0-1.53)		
						0.28, 0.3		
Xantus's Murrelet <i>Synthliboramphus hypoleucus</i>	CA, MX2					0.72 (0.3-1.36)		
Craveri's Murrelet <i>Synthliboramphus craveri</i>	MX							
Ancient Murrelet <i>Synthliboramphus antiquus</i>	WA, CN	decreasing	3 (2-4)	Reef I.: 0.77		1.44-1.69		
Cassin's Auklet <i>Pychooramphus aleuticus</i>	CA, OR, WA, CN, MX	decreasing	3 (1-4)	0.75		CN: 0.65		
	SEFI	1 = 0.94 (*72-'03)	3 (2-7)	.775-.804(0.32-0.93)	.80-.86 (.32-.92)	0.63 (0.10-0.84)	0.53-0.57 (0.21-0.74)	68% b.f. (same box)
Rhinoceros Auklet <i>Cerorhinca monocerata</i>	CA, OR, WA, CN		3			0.62		
	SEFI					0.563 (0.13-0.92)		
Tufted Puffin <i>Fratercula cirrhata</i>	CA, OR, WA, CN				(0.45-0.75)	0.3 (0-0.77)		

4.3 ENVIRONMENTAL VARIATION IN EACH PARAMETER

Studies conducted in the CCS and other temperate as well as polar areas indicate a large degree of annual variability in demographic parameters (100).

Reproductive success is the best documented of the seven parameters, but adult survival and juvenile/subadult survival also show marked variation.

With the ENSO events of 1982/1983, 1991/1992, and 1997/1998 there has accumulated a large body of evidence that demographic parameters can be strongly influenced by such global-climate events. The concept that decadal-scale variation can also be strongly evident in demographic parameters has emerged recently. In many cases, changes at this longer timescale (c. decadal) are associated with changes in oceanographic regimes.

A major oceanographic regime shift was observed in about 1976 (122) and more recently in about 1999 as well. For Cassin's Auklets on Southeast Farallon Island, there was a marked change in nearly all demographic parameters before and after the shift in 1999: reproductive success increased by 50% comparing 1991 to 1997 with 1999 to 2002; adult survival increased by 9% during the same time period; and breeding probability increased by 10% (Nur et al. in review).

Other examples of decadal-scale changes in adult survival are summarized in Nur and Sydeman (100). In the Antarctic, Jenouvrier et al. (123) observed decadal changes in southern fulmar adult survival, while Barbraud and Weimerskirch (124) observed long-term changes in Emperor Penguin survival.

With respect to reproductive success, two different temporal patterns for birds of the CCS can be identified. The Common Murre on SEFI displays a skewed pattern of moderately high success in most years, with a few exceptional years of very low (or no) success (e.g., in strong ENSO years (25)). Brandt's Cormorants on SEFI provide an example of a second pattern: reproductive success varies strongly between years, but deviations are both positive ("boom" years) and negative ("bust" years). Thus, Brandt's Cormorants show a normal distribution of reproductive success by year, but Common Murres do not.

Spatial Variation

Relatively few studies have examined spatial variation in demographic parameters for the same species or subspecies, but there are some examples relevant to the California Current. Examples include variation in juvenile and subadult survival in Common Murres (125), variation in adult survival in Cassin's Auklets (126-128), and variation in reproductive success and adult survival for Rhinoceros Auklets (129).

In particular, a recent study examined variation in reproductive success parameters across the California Current and Alaska Current (Sydeman et al. unpublished) at 12 colonies, for three seabird species, comparing reproductive success before and after the El Nino event of 1997/1998. Whereas these researchers found strong effects on marine birds throughout the CCS and southern Gulf of Alaska, they also found that different populations demonstrated differences in the timing of the diminishment of breeding success: some populations showed a decline in 1997 while others declined in 1998.

The magnitude of spatial variation (and correlation across populations) in demographic parameters will depend on which factors are most important in determining the realized values. To the extent that basin-wide factors (oceanographic regime and ENSO events) are most important, we would expect that spatial variability would be muted. To the extent that local factors are most important we would expect substantially higher spatial variation. Oil spills and predation are examples of local factors, especially predation at the colony. Prey can vary on a local scale and there is increasing evidence that local factors (at least as indicated by oceanographic conditions) are associated with variation in reproductive success at Triangle Island (130) and on the Farallon Islands (131).

4.5 ENVIRONMENTAL INFLUENCES ON DEMOGRAPHY

Evidence of the strong influence of food availability on demography, often driven by climate variability, is presented in Chapter 5. Adult survival, breeding probability (including both beta and gamma), and reproductive success have all been shown to vary with indices of food availability (31, 35, 59, 100, 131, 181).

For example, for Western Gulls and Pelagic Cormorants breeding on Southeast Farallon Island, there was a strong relationship between indices of rockfish abundance (direct or indirect) and reproductive success (132). In some cases, a correlation with an environmental index has been demonstrated and it has usually been inferred that such a correlation implies a link with food availability (123, 132).

Juvenile survival and subadult survival have been much more difficult to study. Nevertheless, studies of Brandt's Cormorants on the Farallon Islands have demonstrated that the probability a locally fledged bird survived until age 3 (when large numbers of individuals begin breeding) was correlated with SST recorded both for the year of fledging and SST in the third year of life when individuals first return to the colony to breed (31). For Cassin's Auklets on the Farallon Islands, Nur et al. (in review) demonstrated a correlation between the proportion of a cohort recruiting and the Northern Oscillation Index (NOI) in the winter before the fourth year of life, the modal year of recruitment for this population.

Predation is also a strong influence on seabird populations (see Chapter 6), especially predation at seabird colonies (both of breeding adults and of eggs or chicks). In some cases, predators are native predators while in others they are non-native. Studies by Sydeman et al. (133) and Nur et al. (134) identified predation as the most important factor influencing population status and population vulnerability for Ashy Storm-Petrels and Xantus's Murrelets. For the former, predation on adults and subadults by Western Gulls (a native species, which has increased its spread on Southeast Farallon Island, overlapping with the Ashy Storm-Petrel population) has been the concern; for Xantus's Murrelet, both mouse and Barn Owl (*Tyto alba*) predation of both chicks and adults was the issue.

Predation rates may appear relatively small yet still have population-level impacts. For example, the predation rate may be on the order of 3% of the population for Ashy Storm-Petrels mentioned above (133), but even additional mortality of this magnitude can mean the difference

between a declining and an increasing population.

A study on Black-legged Kittiwakes in the Shetlands, demonstrated that both food, mediated through the abundance of juvenile sand lance, and predation by Great Skuas, were significant influences on demographic parameters (35). In particular, sand lance abundance influenced both adult survival and reproductive success. Great Skuas in the Shetlands (at Foula Island) surprisingly also demonstrated adult survival rates that were dependent on sand lance abundance (59). That is, both the seabird prey and the seabird predator demonstrated a correlation of adult survival with sand lance (principal prey of the kittiwake).

4.6 MORTALITY DUE TO ANTHROPOGENIC PERTURBATION

Mortality due to fisheries is discussed in Chapter 6 and that due to oil pollution in Chapter 7. Both have serious impacts on seabird populations and are of grave concern. With regard to bycatch, as noted above, even a relatively low mortality rate (of 1 to 3% per year of the total population) can cause population decline where otherwise there would be stability. For Common Murres, mortality due to gillnetting has been considered to be instrumental in diminishing population size in Central California (135).

Oil pollution exerts an impact both episodically, due to major oil spills, and chronically, due to chronic oiling. Major oil spills receive the most attention (136, 137) and rightfully so, since mortality can be very high. This mortality usually consists of both adults and immatures. Loss of breeding-age adults is the greatest concern with loss of immatures less so, since only a fraction of these age classes would otherwise recruit into the breeding population. Other impacts on demography can be more subtle. For example, reproductive success can be disrupted if an individual loses its mate; a “widowed” bird may not pair at all in the subsequent season or may have reduced success if it does.

However, chronic oiling is also a serious concern. Nur et al. (138) evaluated oiling rates obtained from beached bird surveys for several CCS seabird species. For Common Murres in central California, they estimated that chronic oiling accounted for an additional adult mortality of 2% per year and for juveniles an additional mortality of 7%. Data from other species (grebes, loons, and scoter species) did not suggest mortality rates as high as for Common Murres, consistent with the finding of Page et al. (136), who investigated mortality of seabirds as a result of the Apex Houston spill.

4.7 DENSITY DEPENDENCE: NEGATIVE AND POSITIVE

Density dependence has been discussed extensively with respect to seabirds (2, 139). Density dependence can be negative (survival and reproduction decrease with increasing population density) or positive (increase in these parameters with increasing population size). In addition, dispersal can be a function of population size.

Density dependence is of great conservation significance since it can lead to population regulation (i.e., stabilization of population size) if the dependence is negative, or can lead to population destabilization (thus increasing the probability of population crashes and extinction) if it is positive. The decrease in survival and/or reproduction as population size or density gets to be especially small is referred to as the Allee effect and was first described for animal species 70 years ago.

Recent analyses by Nur and Sydeman (132) examined density dependence in four species on the Farallones that have been studied over a 23 to 30 yr period (Western Gulls, Brandt’s Cormorants, Pelagic Cormorants, Common Murres). These authors found no correlation between breeding population size in a given year and reproductive success in the same year, in fact the correlations tended to be positive (though not significant). Other parameters were not examined in this study, though Nur and Sydeman (31) found no relationship between adult survival and population size for Brandt’s Cormorants.

In contrast, Frederiksen and Bregnballe (140) found evidence for density dependence in adult survival of European Cormorants (*Phalacrocorax carbo sinensis*), which appeared to be a result of differences in over-winter survival. This subspecies is found in freshwater and sheltered marine habitats, and so the relevance of this example is low for the CCS.

For seabirds breeding in the CCS or in the Gulf of Alaska, there is no evidence that we know of indicating either negative or positive density dependence for any demographic parameter. However, both remain of potentially great concern. As population size increases to especially high levels (e.g., colonies with more than 100,000 breeding pairs), density dependence may be a factor, especially for breeders that must forage for food for the chick. At the same time, were colonies or populations to decrease to very low levels, this may be of concern, too.

4.8 ALLEE EFFECT

In contrast to the lack of direct evidence for negative density dependence, positive density dependence appears to be an important factor in a wide range of seabird species—but only at low population densities. For many species, if population size or density falls below a certain threshold value, this results in reduced population growth rate, termed the “Allee effect” (named after the ethologist W.C. Allee).

The Allee effect is discussed by Lande (141) and Simberloff (142) and has been incorporated into population models of the Spotted Owl (*Strix occidentalis*). In the Common Murre, there is good evidence that reproductive success increases with density at the colony (71), apparently due to better protection from predators at high density compared with low. Other examples of deleterious effects on seabirds of breeding at low density are given by Wittenberger and Hunt (143). Hudson (69) considered implications of positive density dependence for murre population dynamics. He modeled a scenario where an oil spill (or similar catastrophic mortality) could lead to long-term population decline, which accelerates as density decreases, eventually resulting in population extinction.

Because positive density dependence (a generalization of the Allee effect) appears to be of widespread significance for colonially-breeding seabirds, it would be important to minimize the Allee effect for target populations. For some species, this may mean taking steps to ensure that colony size or population density does not dip below the threshold level at which the Allee effect exerts itself.

Small colonies suffer a double penalty; in addition to the Allee effect, they are subject to the deleterious effects of demographic and genetic stochasticity. For seabirds, which generally display low fecundity, the most expeditious way to increase colony size is through immigration. This may include recruitment of additional individuals to a colony using attraction techniques (144).

4.9 RELATIONSHIPS BETWEEN DEMOGRAPHIC PARAMETERS

An empirical question rarely addressed in the seabird literature is, “How correlated are the demographic parameters with each other?”

Population fluctuations will be much stronger if demographic parameters positively covary; conversely, fluctuations will be dampened, and population stability will be enhanced, if parameters covary negatively. Where patterns of covariation over time have been examined, positive covariation has generally been present. Examples include Cassin’s The Auklet (Nur et al. in review) and Southern Fulmar (123). For Black-legged kittiwakes, reproductive success and adult survival were both related to prey availability (35). More studies are needed, but so far the indication is that parameters covary positively.

How much does each parameter contribute to changes in population growth?

From a management perspective, this question is of great interest. However, answering it has not been easy. One approach has been to vary each demographic parameter a fixed percentage and examine effects on population growth.

A second approach has been to examine elasticity or sensitivity of the Leslie population matrix (145). In this second approach, one examines the absolute or proportional change in the population growth rate as a result of infinitesimally small changes in individual demographic parameters. Both approaches usually yield similar results; often, adult survival is identified as the parameter most sensitive with respect to determining population growth, while population growth rate is not very sensitive to changes in reproductive success.

There are some complications to consider. First, conclusions may be affected by the choice of which rate to vary, mortality or survival. Thus, one investigator may vary mortality by a relative 5% (e.g., change adult mortality from 0.20 to 0.19, implying that survival changed from 0.80 to 0.79), while the other may vary survival by a relative 5% (e.g., change adult survival from 0.90 to 0.95, implying that mortality changed from 0.10 to 0.05). If we do not realize this, we may be led to conclude that population growth rate is sensitive to differences in survival but not to differences in mortality, which is logically inconsistent.

Calculation of elasticity and sensitivity avoids this problem, though one needs to develop a population matrix model in order to derive these measures. In addition, a second complication is that the number of age classes in the model will determine the magnitude of sensitivity and elasticity for each age class. Thus, if one models a seabird with 9 age classes (e.g., 0, 1, 2, 3, 4, 5, 6, 7, and 8+ year olds), one may include that the parameter with the greatest sensitivity is survival of 8+ year olds. However, if one models the same population, this time with 50 age classes, one might conclude that sensitivity is greatest for survival of 0 year olds (i.e., juvenile survival). The only difference is that one model lumped individuals of 8 to 50+ years of age (thereby creating one large “older adult” age class) and the other did not.

However, there is a third and most serious complication: the approach of calculating elasticity and sensitivity does not take into account the magnitude of variability in a demographic parameter and how sensitive it is to changes in the environment. That is, if we are interested in comparing “good” (e.g., cold water) years with “poor” years (e.g., warm water), one should take into account that adult survival may only change by 5% between a good and bad year, but reproductive success may change by 50%. This was the magnitude of the difference in parameters observed for Cassin’s Auklets by Nur et al. (in review). These authors concluded that the observed change in reproductive success (a change of 50%, comparing the warm-water regime of the 1990s prior to 1998 to the cold-water regime starting with 1999) was as influential in determining a change in the population growth rate as a change in adult survival of 5%. As a result, they concluded that reproductive success and adult survival were equally important in explaining changes in population trajectory for this population.

4.10 STABILITY VERSUS VOLATILITY OF SEABIRD POPULATIONS

In the CCS little negative density dependence is apparent, thus stability is rare. What apparent stability of seabird populations is observed is not mainly a result of regulation. In addition, demographic parameters fluctuate strongly over time (from year to year and from decade to decade), this leads to further population fluctuations. Climate-driven changes in ocean regimes appear to be cyclical (cold-water and warm-water phases alternating, for example (122)).

Thus, conditions for population growth alternate between favorable and unfavorable, leading to corresponding population growth and decline, respectively. This alternating pattern can both abate unchecked growth and lead to reversals of population declines of CCS seabird species. However, to the extent that populations decline to extremely low levels and are subject to the Allee effect (an effect yet to be confirmed by CCS seabird populations), there is concern for the inherent instability that may result.

4.11 METAPOPULATION MODELS

The first metapopulation model was that of Levins (146). The general idea is that a metapopulation consists of several distinct populations that are linked by dispersal (immigration and emigration).

In Levins' model there are an infinite number of available patches and each empty patch is colonized, with a certain probability; if the patch is occupied with a population then that population may go extinct with a certain probability. In Levins' model there are no internal population dynamics: local populations are either extinct or full.

In more recent years, more realistic models have been developed (7, 147-151), and application of metapopulation models to problems of conservation and management has proliferated (152). Examples of recent bird metapopulation models include Stith et al., (153); Smith et al., (154); Akcakaya et al., (155); LaHaye et al., (156); Buckley and Downer, (1); Wootton and Bell, (157); Stacey and Taper, (158); we discuss most of these below. Source/sink models (see below) can be considered a particular kind of metapopulation model.

Stith et al. (153), drawing on previous work of Harrison (149), present a good overview of types of population structure that are either examples of types of metapopulations or are examples of population structures that would not qualify as true metapopulations.

The central idea is that a metapopulation consists of populations that are semi-isolated. If populations are so isolated that they virtually never exchange immigrants, then this would not qualify as a metapopulation.

In contrast, according to Harrison (149), a patchily-distributed species is not a metapopulation if dispersal between patches is very common and/or individuals inhabit several patches in one lifetime. Other investigators disagree, however (e.g., Spindel et al., (36); Buckley and Downer, (1)), and consider any set of populations linked by dispersal to constitute a metapopulation.

A second important point is that a common configuration for a metapopulation may consist of a single large "core" or "mainland" population surrounded by a number of smaller "satellite" or "island" populations. The latter would be prone to extinction, but the core population is considered to have high probability of persistence.

The single population models discussed above (e.g., that of the Farallon Common Murre (60), can be thought of as a special case of a metapopulation model.

However, even a small amount of dispersal can affect persistence of local populations, especially if the local populations are small (and thus prone to extinction, see above). This last point was demonstrated by Stacey and Taper (158) in modeling the fate of small, local Acorn Woodpecker (*Melanerpes formicivorus*) populations. In the absence of immigration, these populations would rapidly go extinct, but a moderate immigration rate would suffice to maintain the metapopulation for hundreds of years.

Metapopulation models can be used to assess the persistence (or other aspects of the population dynamics) at the level of an individual, localized population, or to assess the dynamics of the entire metapopulation.

Two factors influencing metapopulation dynamics are dispersal rates between local populations (as mentioned above) and environmental correlation among the patches. The more correlation among populations, the more likely several populations will suffer the same environmental catastrophe at once. This point relates to the concept of “spreading of risk” (159, 160). If, however, all local populations are subject to the same red tide or same oil spill, then no risk has been spread at all.

Akcakaya and Ginzburg (161) used a metapopulation model to consider the long-term persistence of Mountain Gorilla (*Gorilla gorilla beringei*) metapopulations. In an uncorrelated environment the long-term persistence of several small populations was indeed greater than a single large population, thus demonstrating “spreading of risk.” However this advantage was overcome if correlation among the several small populations was moderately strong. For strong environmental correlation in demographic parameters (156), a single large population will persist longer than several small populations, even if they are connected by dispersal.

Definition of sinks and sources

Pulliam and colleagues have recently focused attention on the importance of sink and source populations with respect to population dynamics on a local and regional scale (162, 163).

A “sink” population is one in which local production of new recruits is less than mortality of established individuals, and therefore the population is not self-sustaining; it can only be sustained by immigration from other, more productive populations.

A “source” population, on the other hand, is productive enough so that an excess of potential recruits is produced. This can lead to growth of the source population or to emigration of potential recruits to other, mostly sink, populations, or to both. A network of source and sink populations can be formed, joined by immigrants/emigrants; this may be referred to as a “landscape” of populations.

An important implication of the source/sink paradigm is that population dynamics cannot be understood at the level of a single population, which may either be a source or sink, but rather at the level of the entire network or landscape. Furthermore, Pulliam (163) demonstrated that a single source population can effectively maintain a large number of sink populations; in fact, most of the individuals in a metapopulation may be breeding in sink populations and yet the overall network of source/sink populations may be self-sustaining.

In short, conservation efforts need to be directed, above all, at source populations not sinks; it is only source populations that allow sink populations to persist.

One difficulty with the sink/source paradigm is that it is empirically difficult to identify which populations are actually sources and which sinks. At minimum one would require information on survival, recruitment, and reproductive success specific to each population; information that is rarely available. But even this information may not be sufficient: Watkinson and Sutherland (164) demonstrate that with high immigration and negative density dependence, what appears to be a sink population may actually be a source population. That is, in the absence of immigration/emigration a population may be self-sustaining (thus meeting the definition of a source population) but when there are many immigrants, fecundity or survival, or both, may be depressed at the higher population density.

A second difficulty with the sink/source paradigm is that a population may be a source at one point in time and a sink at another point in time.

Wootton and Bell (157) developed a metapopulation model for the Peregrine Falcon (*Falco peregrinus*) in California. They considered there to be two subpopulations linked by dispersal: the Northern California population, which they argued is a source population, and the Southern California population, which they argued is a sink population. Current management efforts are geared towards the Southern California population, and involve release of captive-bred individuals. Management efforts, they argue, would be more productive if they were directed at stabilizing and increasing the Northern source population rather than the Southern sink population.

Implications of sink/source population dynamics

The future of a metapopulation does not lie with sink populations, it lies with source populations. For colonial seabirds, small populations are especially likely to be sinks. This is due to the manifestation of the Allee effect, which appears to apply to all vertebrate species, at least to some degree (150).

For species, such as Common Murres, the Allee effect appears to be prevalent over a considerable range of population sizes and population densities (see above). Examples of likely sink populations would be small colonies that are being re-established or being “incremented”—i.e., exactly the targets of some restoration programs (165).

A conservation program that invests in sink populations rather than in source populations is unlikely to succeed in the long-term. Sink populations, by definition, are incapable of sustaining their own growth. However, as stated above, population status can change over time, with the possibility of sink populations becoming source populations with changing conditions.

In contrast, it is precisely source populations that are incapable of sustaining the growth rate of the entire metapopulation. Pulliam and colleagues (162, 166) have shown that a stable metapopulation may be sustained by only a few source populations, in the midst of many sink populations. Since it is only the source populations that are sustaining the population, and only the source populations that are capable of leading to future growth, then clearly the lion’s share of attention in a conservation program should be paid to source, or *potential* source, populations.

The long-term value of a sink population is minimal. It is simply wishful thinking to think that a sink population will be able to repopulate the geographic range of a metapopulation should the mother colony undergo a population crash. Alternatively, one can investigate ways in which sink populations can be improved, thus transforming sink populations into self-sustaining populations.

In other words, a valuable objective of a conservation program would be to improve reproductive success in relation to mortality, on a site-by-site basis, thus turning sink populations into source populations. Since a newly (re)established colony will almost always be small, it is more likely to be a sink than a source—at least in its initial phase. Once an erstwhile sink population reaches a threshold population size it may now be self-sustaining, but the initial increase in population size (from small, sink colony to large, self-sustaining colony) will not be due to internal recruitment but rather due to recruitment from elsewhere. This is not to say that all small colonies are sinks, but just that it is more likely for a small colony to be a sink than for a large colony.

4.12 UTILITY OF POPULATION MODELS

Caswell (145) explained the utility of population models to conservation biology by way of an analogy to medical practice. A patient (the population) is examined to assess its condition, the causes of any problems are diagnosed, treatments are prescribed to address the problems, and a prognosis predicts eventual outcomes of treatment.

Population **assessment** is primarily a matter of determining the population growth rate (λ). This may be accomplished either by examining changes in population numbers (directly or via index), or by well-designed mark-recapture studies that provide data for estimation of vital rates that can be used to construct a model, then derive the model's dominant eigenvalue (λ). Although assessment can be made without knowledge of vital rates, they are necessary for diagnosis and treatment, and are ultimately the best means of assessment as well.

Diagnosis attempts to determine why the population is in trouble. The best tool for this is retrospective perturbation analysis. Diagnosis requires examination of differences in vital rates and population growth rates from the population of concern versus either a) itself during a time period when the population was not in trouble, or b) a separate population that is not currently in trouble. Life table response experiments (LTRE) provide the framework for the diagnosis (145, 182). Given actual comparative data from the population during periods with different population trajectories, LTRE will quantify the contributions of vital rates to the change in λ .

Prescriptions are perturbations enacted by management on specific vital rates in order to alter λ . Because this approach is forward looking, the proper tool for evaluating management prescriptions is prospective perturbation analysis. This technique investigates the relative effects of changing different vital rates on overall population growth rate. Such analyses are generally made by sensitivity (183) or elasticity calculations (184). Sensitivity is the incremental change in λ due to an incremental change in a vital rate; however, such calculations are misleading due to the different scales of different vital rates (e.g., fecundity vs. survival) (167). One solution to the scaling issue is elasticity, defined as the *proportional* change in λ related to a *proportional* change in vital rate. More recently, Link and Doherty (168) introduced methods for a variance stabilizing transformation to deal with scaling issues.

Hamilton and Moller (96) examined sensitivity of population growth rate of Sooty Shearwaters to small changes in adult mortality, and found that the population trajectory was not particularly sensitive to this parameter, but was more sensitive to changes in juvenile mortality. This finding runs counter to the conventional understanding that population trajectories of long-lived species such as seabirds are most sensitive to changes in adult mortality rates. Indeed, Russell presents evidence from several studies supporting the latter argument, including a model of the sensitivity of λ to variations in adult survival and reproductive success in Wandering Albatrosses.

Buckley and Downer (1) conducted perturbation analyses on several idealized seabird species by taking into account the expected range of variation in each parameter, and came to the conclusion that subadult survival—but not adult survival or first-year survival—was one of the most important parameters determining long-term population growth and persistence. Seather and Bakke (169) examined 49 bird species (including 0 seabird species) and found that covariance of vital rates influenced the contribution of a vital rate to λ , a consideration that is often overlooked.

An important question to consider is whether or not a prescription that perturbation analysis indicates would have a large effect on λ and actually provides a practical and realistic response. The answer to this depends on technical, economic, and political feasibility that must be considered both separately and jointly. Nichols and Hines (170) suggested a metric whereby elasticities of vital rates could be considered relative to costs of management actions, and provided an equation for calculating proportional change in λ per dollar spent.

Prognosis aims to predict a population's fate via population viability analyses (PVA). PVA uses stochastic models with fluctuating population size and varying vital rates to predict population size, and probability of population persistence for a defined time horizon under certain specific conditions (171). PVAs are inherently risky as they attempt to forecast the future fate of the population, but can be valuable so long as they are understood to be projections that are conditional on the population model(s) at hand.

If managers and policymakers could be educated to understand the probability projections from models representing different management regimes, PVAs could become a more useful conservation tool. Whereas PVAs have become more and more commonly applied to birds and mammals recently (9, 155, 172-175), there apparently have been few developed for seabirds. We know of only three examples: that of Hamilton and Moller (96) for Sooty Shearwaters and that of Sydeman et al. (133) for Ashy Storm-petrels (*Oceanodroma homochroa*) and Xantus's Murrelets (*Synthliboramphus hypoleucus*).

Population dynamic and metapopulation models serve an important role in planning and evaluating conservation programs. Evaluation of management actions should include quantifying the possible benefits of active and passive conservation efforts, as well as measuring the costs of not implementing conservation efforts. Population modeling permits different conservation scenarios to be evaluated using a common yardstick.

Population models provide a good framework for exposing areas where we have insufficient information as well as allow us to evaluate the significance of these sources of uncertainty.

In one case, for example, a small gap in knowledge may have a big influence on the prognosis for a population and influence the evaluation of alternative restoration programs; in another case, ignorance of parameter values may be greater, but the impact on the future course of the population may be small.

An example of the second case is provided by results of a metapopulation model of Southern California Spotted Owl population dynamics (156). Dispersal among fifteen populations, thought to form a single metapopulation, was not known, but the available evidence indicated very low rates of dispersal. Specifically, observations of two color-banded populations 10 km apart indicated no exchange of individuals over a five year period. Therefore LaHaye et al. (156) carried out metapopulation simulations in which dispersal was moderate (4% between neighboring populations), low (2%), very low (1%), or none (0%). It turned out that predictions of their model were insensitive to the presumed level of dispersal. Thus dispersal was clearly a parameter with insufficient information (and one that might be picked upon should the metapopulation model become implicated in a litigation effort), yet not one that had an important consequence for model predictions.

Population models (and models in general) require one to be explicit about assumptions. These assumptions, and the sensitivity of population model predictions to them, can and **should** be evaluated directly. For example, a model may assume the presence or absence of density dependence, either negative or positive, and this would need to be considered when assessing the appropriateness of the model. A different type of assumption may relate to the efficacy of conservation action. Following an oil spill, for example, little is known about the subsequent fate of "rehabilitated" birds despite good estimates regarding the number of oiled birds treated and released (176). One can create a model to compare predictions regarding impact and subsequent recovery from a spill assuming that (1) some or all rehabilitated birds die within a specified time period, (2) a fraction of rehabilitated birds survive but never successfully breed, (3) a fraction of rehabilitated birds survive, and their breeding is impaired only for the immediate breeding season, or (4) some combination of (1), (2), and (3).

Select examples of population models

To illustrate the general points made above, we conclude by considering a few recent seabird models that have, in our view, produced valuable insights and serve as examples of potential avenues of investigation.

First, Hamilton and Moller (96) conducted a PVA of Sooty Shearwaters. They determined that predator control was the key ingredient to assure long-term persistence of Sooty Shearwater populations, and that control of adult predation was much more effective than control of chick predation. However, one of their other conclusions also bears repeating: “Less reliance should be placed on the predictions of population trends or extinction probabilities than on the model’s guidance to the relative efficacy of management actions.” This is a view with which we concur.

Shannon and Crawford (177) used modeling to investigate population dynamics of African Penguins (*Spheniscus demersus*) at Dassen Island, South Africa in relation to egg harvesting and oil pollution. The authors were able to estimate the extent of commercial egg harvesting on the population during the early 20th century, back-calculate pre-egg-harvesting population size, and determined that there was no sustainable egg harvest plan; even harvesting 1% of annual egg production negatively affected population growth rate. Simulations projected the 50-year population under 7 different chronic and catastrophic oiling scenarios, both with and without rehabilitation.

Cuthbert et al. (178) developed stochastic population models of Hutton’s Shearwaters (*Puffinus huttoni*), an endemic, endangered seabird from New Zealand that may be negatively impacted by introduced mammalian predators. Data were available from the species of interest to estimate adult survival and fecundity, but juvenile survival and age of first breeding were taken from similar species. Sensitivity analyses indicated that breeding parameters, the previous focus of research, had little influence on λ , and that further research was needed to 1) obtain more precise estimates of adult survival, and 2) obtain data on juvenile and adult mortality sources. This exercise enabled managers to prioritize research needs and focus management efforts where they would be most productive.

Another example of the utility of a population model in developing and evaluating conservation plans and programs is provided by a population model developed by Ainley et al. (in press) for the Newell’s Shearwater on Kauai.

The Kauai population appears to be declining, which is of concern since the vast majority of Newell’s Shearwaters breed on this island (Ainley et al., in press). A principal objective of the study was to evaluate the impact of different mortality sources of anthropogenic origin. These included “fallout” of newly fledged juveniles, attracted to lights on the island; collisions with power lines, resulting in mortality of adults and subadults; and mortality of adults and subadults during the breeding season, due to introduced predators. In addition, in the past decade a mitigation program had been instituted: juveniles which had “fallen out” were routinely picked up and subsequently released. While this program (Save Our Shearwaters, SOS) did not eliminate “fallout” mortality, it undoubtedly reduced mortality.

The authors evaluated the contribution of each anthropogenic source of mortality to the overall rate of population decline. Model results demonstrated the greatest impact was mortality due to introduced predators; of least impact was residual mortality due to fallout, i.e., fledgling mortality occurring despite the presence of the SOS program. Power line collisions were of intermediate importance. However, fallout mortality would be of much greater importance were the SOS program to cease.

With these results in hand, one can discuss costs and benefits of different restoration programs. The most desirable program combines high benefit with low cost. Thus, burying of power lines (at least in key flyway areas) may be more feasible (and less costly) than attempting to eradicate introduced predators on Kauai, even though the latter has greater overall effect on population trends.

4.13 MODELING EFFORTS FOR CALIFORNIA CURRENT SYSTEM SPECIES

Nur et al. (60) created age-structured models with environmental and demographic stochasticity for three species of California Current System seabirds: Common Murre, Brandt's Cormorant, and Western Gull. The models were integrated with a toxic spill module that predicted mortality given season, size, and drift direction of an oil spill. Density dependence was included in the Western Gull model, but not in the models for the other two species. Food availability could be manipulated directly, or as a function of sea surface temperature and consequences observed. Four simulations were run under different scenarios: status quo, oil spill, reduced prey availability, and El Niño.

Sydeman et al. (133) presented results of PVA for two California Current system endemic species: the Ashy Storm-Petrel and the Xantus's Murrelet. They demonstrated that predation was likely a key component determining population persistence or likely extinction. In the case of the Ashy Storm-Petrel, predation by Western Gulls (which in recent years had become especially numerous in proximity to Ashy Storm-Petrel breeding sites) appeared to be sufficient to account for the entire observed population decline in the past two decades. Given current demographic parameters, the population faced a high (45%) probability of being reduced to less than 500 breeders within 50 years.

For the Xantus's Murrelet, the most important demographic process accounting for the observed population decline of 3-5% per year was apparently low reproductive success, mainly due to mouse predation. Reduction of mouse predation on eggs by 50% had the potential to reverse the population decline.

In addition, adult Xantus's Murrelets suffered from predation by Barn Owls (*Tyto alba*), but even complete elimination of Barn Owl predation was insufficient to arrest the population decline. Furthermore, Sydeman et al. (179) recommended that the Xantus's Murrelet population be considered "threatened" since there was at least a 30% (and up to 80%) probability that the largest known colony would be reduced to less than 500 breeders within 20 years.

Parrish et al. (180) studied the demography of Common Murres at Tatoosh Island, Washington from 1991-1999, a period of ~3% annual decline. Age-specific vital rates drawn from the literature were used to develop a number of plausible population models that were compared to the observed population decline. Models included effects of climate, direct predation by Bald Eagles on adults, and indirect reductions in fecundity due to eagle-facilitated gull and crow predation on unguarded murre eggs. Direct and indirect eagle pressure on the Tatoosh Island murre population were implicated in the population decline, but emigration was not quantified.

4.14 RESEARCH AND MONITORING RECOMMENDATIONS

1. Include assessments of adult survival as an essential component of all seabird monitoring programs in the CCS.
2. Study sources of adult, nestling and egg mortality for all seabird species.
3. Conduct research to determine which demographic parameters are most sensitive to temporal environmental variability. This will facilitate the development of predictive population models.
4. As possible, add measurements of demographic parameters to long-term seabird monitoring programs.
5. Conduct research into how demographic parameters co-vary through time to aid in the development of predictive models.
6. Investigate spatial variation of species demographic parameters for metapopulation modeling efforts.

4.15 CONSERVATION AND MANAGEMENT RECOMMENDATIONS

1. Identify and quantify sources of mortality for seabird species of concern.
2. Increase the use of modeling in decision making and as a practical conservation tool in general.
3. Train new experts (i.e. graduate students) in quantitative population biology and the use of population dynamics modeling for seabird conservation.

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The California Current Marine Bird Conservation Plan

Chapter 5

Climate and Food: “Bottom-Up” Control of Seabird Population Parameters
and Population Dynamics



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Version 1.0

**Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum**

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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CHAPTER 5. CLIMATE AND FOOD: “BOTTOM-UP” CONTROL OF SEABIRD POPULATION PARAMETERS AND POPULATION DYNAMICS

“Bottom-up” control of seabird populations includes those factors that influence the prey that are consumed by seabirds, namely zooplankton, squid, and fish. Climate, which alters the ocean characteristics responsible for cascading effects up the food chain, is the principal mechanism for bottom-up control of seabird population parameters and dynamics.

In this chapter we begin by exploring climate variability in the CCS, including a description of large-scale oceanographic and atmospheric processes, operating at short and long timescales, which affect ocean habitats of seabirds and how seabirds respond to marine climate variability.

After this discussion of climate, we describe the consequences of food limitation on seabirds, and the usefulness of seabird prey consumption models for determining the amount of prey required to sustain seabird populations, which can, in turn, be valuable for fisheries management and seabird conservation.

Seabirds are important predators in marine ecosystems, consuming large proportions of the biomass in the CCS. Briggs and Chu (1) estimated that off California alone, 1.8 million (midsummer) to 7.0 million (fall) seabirds are present, and consume on average 44,000 tonnes of plankton and 149,000 tonnes of fish and squid each year (4-7% of production).

The results of prey consumption models are highly valuable for practical conservation and management of both predator and prey species. Prey consumption models can be useful in a variety of manners, including: (1) incorporation of models into fisheries management plans to establish ecologically sensitive fishery quotas (a true multi-species approach), which incorporate local or regional prey consumption of predator species; (2) as baseline data in the event of development and management of future fisheries; (3) to strengthen arguments against opening certain fisheries that may deplete the prey base needed to sustain certain predator populations; and (4) to enhance available information and provide more “realistic” information for estimating natural mortality of fish populations to incorporate in stock assessments.

From a seabird management perspective, prey consumption models may be used to: (1) examine the impacts of fisheries on seabird populations, for example the evaluation of the effects of fishing down the food web; (2) assess potential impacts and competition between seabirds and fisheries, such as targeting the same fish, which may lead to seabird bycatch and reduction of the availability of seabird prey; and (3) to characterize the effects of both interannual and interdecadal variability and trends in ocean climate in the CCS, and how this variability may affect both seabird and prey populations in terms of food web dynamics and ecosystem productivity.

5.1 CLIMATE VARIABILITY ON MULTIPLE TIMESCALES

Naturally occurring climate cycles in the world’s oceans and atmosphere strongly influence the CCS and central North Pacific Ocean (NPO) ecosystems, and therefore the ocean habitats that seabirds depend on for their survival. Within the CCS ecosystem, seabirds respond to El Niño (the periodic, every 4-7 years, warming of the ocean), La Niña (ocean cooling associated with the El Niño-Southern Oscillation cycle), and lower-frequency ocean warming and cooling due to polarity reversals of the Pacific Decadal Oscillation (PDO).

Large-Scale Ocean/Climate Processes: El Niño, La Niña, the Southern Oscillation, and Currents

El Niño and La Niña are linked via changes in global pressure systems of the tropical Pacific Ocean. In the early 1970s, it was recognized that these events were part of an ocean-wide fluctuation in the atmosphere, called the “Southern Oscillation.”

In this oscillation, the usual pressure gradient from a region of high pressure in the western tropical Pacific Ocean to a region of low pressure in the Australia-Asian Pacific becomes higher or lower than average. Lower than average pressure gradients favor El Niño, whereas the higher than average situation promotes La Niña.

Typically, the pressure differences are measured as the difference in barometric pressure of Tahiti versus Darwin, Australia. This pressure difference is referred to as the Southern Oscillation Index (SOI), and has been used to study and predict El Niño/La Niña events. The connection of El Niño with the Southern Oscillation has led to the acronyms ENSO and LNSO, a convenient means to encapsulate this phenomenon. Figure 5.1d shows the SOI between 1987 and 2002.

La Niña is the inverse of El Niño and has occurred almost as frequently as El Niño over the past 3 decades. During La Niña, sea level in the eastern North Pacific Ocean decreases, thermocline depths become shallow resulting in a less stratified ocean, and ocean mixing of nutrients becomes more efficient. Upwelling results in mixing of cold, nutrient-rich water in the euphotic zone with positive effects on food web development.

Other changes that may be related to, or independent of, the ENSO cycle include a strengthening/weakening of the major currents, such as the California and North and South Equatorial currents. The latitudinal and longitudinal transport of nutrients and organisms by currents across ocean basins and within and between water masses may strongly influence the productivity of the ocean habitats of seabirds, but further research is required to understand the interactions of varying large-scale physical oceanographic processes with food web dynamics.

The Pacific Decadal Oscillation (PDO)

In the North Pacific Ocean, one of the “low frequency” marine climate shifts has been referred to as the Pacific Decadal Oscillation (PDO) (2-5). According to Mantua et al. (5), the PDO is “an El Niño-like phenomenon operating on timescales of decades.” In particular, a mid-1970s intensification of the Aleutian Low Pressure System (ALPS) has been related to long-term ocean warming in the CCS.

Under these barometric conditions, southwesterly winds and subtropical storms increase along much of the West Coast of North America. As a result, there is an increase in the transport of warm, equatorial water from the south through a strengthening of the California undercurrent and a weakening of the south-flowing, subarctic California Current.

Similar to El Niño effects, intensification of the ALPS causes thermocline deepening, increased ocean stratification, and a cessation of effectual upwelling (6-8). In short, intensification of the ALPS leads to warming of the North Pacific Ocean. Polarity reversals of the PDO occurred in 1900-1901, 1925-1926, 1949-1950, 1976-1977, and possibly 1998-1999, suggesting a 50-60 year periodicity to this cycle of climate variability (half cycles representing “cold” periods and “warm” periods last 20-30 years). Studies on effects of PDO on marine birds are few, but have documented some similar ecological effects as El Niño/La Niña in the Pacific Ocean.

5.2 SEABIRD RESPONSE TO CLIMATE VARIABILITY

Long-term population studies have clearly demonstrated the deleterious effects that El Niño can have on breeding seabirds, some of which are the reduction of breeding probabilities, reproductive performance, and survival.

Conversely, many of the same long-term studies have demonstrated the equally important and positive effects of La Niña events. Strong La Niña years may result in exceptional production of cohorts which sustain seabird populations for decades. Studies of the Pacific Decadal Oscillation (PDO) and similar low-frequency climate variations (e.g., intensification of the Aleutian Low Pressure System) are few, but have documented some similar effects to El Niño in the California Current.

Ocean Climate and Seabird Prey

Diet composition of Farallon alcid nestlings is related to various indices of ocean climate variability in the CCS: sea-surface temperature (SST, collected on the Farallones), the upwelling index (UI, average of values at 36°N and 39°N), the Pacific Decadal Oscillation (PDO), and the Southern Oscillation Index (SOI).

For each species, we examine the potential effects of these ocean climate indices on the proportion (by mass for Cassin’s and Rhinoceros Auklets, by number for Common Murre and Pigeon Guillemot) of primary prey species or groups in the diet (methods described in section 5.6).

Seasonal ocean climate indices showed substantial variability through time (Fig. 5.1). Generally, for the total range of years in which we present data (1987-2002), the Gulf of the Farallones was characterized by relatively cool conditions until 1992, when conditions became warmer (higher SST especially in winter, negative SOI, positive PDO). Following the ENSO year of 1998, cooler conditions prevailed for the remaining years.

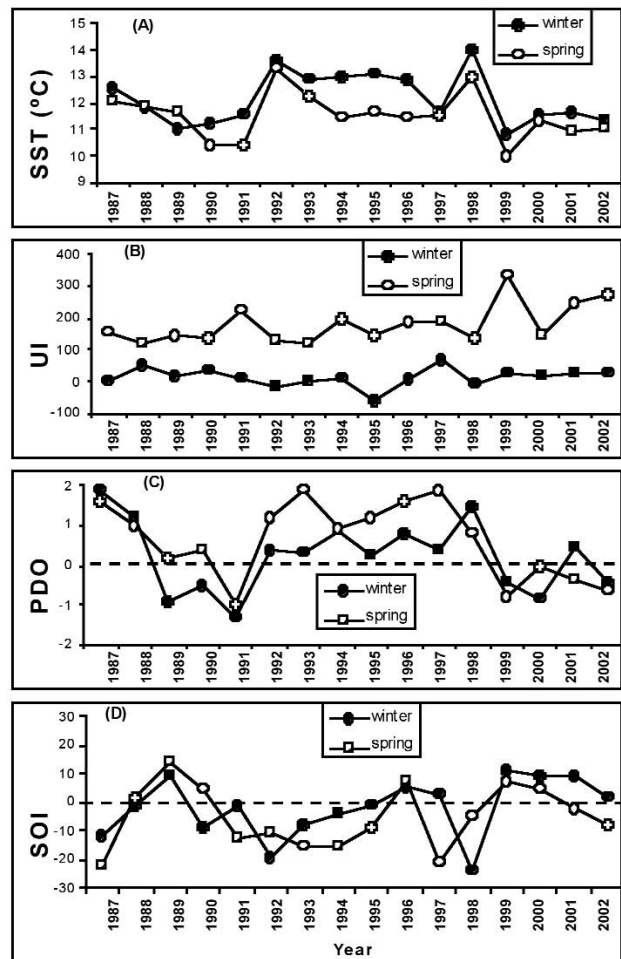


Figure 5.1 - Annual seasonal (winter and spring) mean values of (A) Farallon sea-surface temperature (SST), (B) the Upwelling Index (UI), (C) the Pacific Decadal Oscillation (PDO), and (D) the Southern Oscillation Index (SOI). We used seasonal mean values (winter = January-March, spring = April-June) of each climate index.

The results of the correlations between diet composition and ocean climate indices are presented in Table 5.1. These results indicate that the proportion of euphausiids in the diet of Cassin’s Auklet nestlings was negatively correlated with the spring PDO: when the value of PDO is low in spring (cool conditions), there is a greater proportion of euphausiids in the diet.

Interestingly, the correlations between the proportion of euphausiids in the diet and winter PDO and SOI values show the opposite results, suggesting that when winter conditions are relatively warm, there is a greater proportion of euphausiids in the diet. For Rhinoceros Auklets,

both northern anchovy and sablefish were correlated significantly with the spring SOI: the proportion of anchovy increased with increasing spring SOI values (cool conditions) and sablefish increased with decreasing spring SOI values (warm conditions). For Pigeon Guillemots, an increased proportion of Sculpin spp. was correlated significantly with increasing spring SST, decreasing spring and winter UI, and low winter SOI values (warm conditions).

In contrast to the trends observed for anchovy in Rhinoceros Auklet diet, the proportion of anchovy in Common Murre diet is greater when winter SST and the spring PDO are high (warm conditions).

Table 5.1 – Results of Spearman-rank correlations (r_s -values) for each primary prey species/group consumed by alcid nestlings versus mean winter (January-March) and spring (April-June) values of sea-surface temperature (SST), the upwelling index (UI; average of values at 36°N and 39°N), the Pacific Decadal Oscillation (PDO), and the Southern Oscillation Index (SOI). Sample sizes for tests are in parentheses. Significant values ($p \leq 0.05$) are shaded in light grey and significant values ($p \leq 0.1$) are shaded in dark grey.

$p \leq 0.05$

$p \leq 0.10$

SEABIRD, PREY	Winter SST	Spring SST	Winter UI	Spring UI	Winter PDO	Spring PDO	Winter SOI	Spring SOI
Cassin’s Auklet Euphausiids (n=9)	-0.10	-0.27	0.02	0.33	0.22	-0.62	-0.28	0.12
Rhinoceros Auklet N. Anchovy (n=16)	-0.11	-0.09	-0.14	-0.19	-0.37	0.05	0.22	0.46
Rhinoceros Auklet Sablefish (n=16)	0.07	0.14	-0.06	-0.04	-0.06	0.05	-0.19	-0.44
Rhinoceros Auklet Rockfish (n=16)	-0.01	-0.02	0.08	0.21	0.24	0.01	-0.09	-0.36
Rhinoceros Auklet Salmon (n=16)	-0.12	-0.07	0.09	-0.16	-0.24	0.13	-0.11	-0.23
Rhinoceros Auklet Pacific Saury (n=16)	-0.05	-0.19	0.11	0.37	0.15	-0.12	0.25	0.12
Pigeon Guillemot Rockfish (n=11)	-0.04	-0.06	0.22	0.21	0.41	0.17	-0.07	-0.22
Pigeon Guillemot Sculpin (n=11)	0.77	0.48	-0.82	-0.56	0.10	0.15	-0.71	-0.35
Common Murre N. Anchovy (n=16)	0.52	0.26	-0.42	-0.32	0.04	0.54	-0.22	-0.16
Common Murre Rockfish (n=16)	-0.28	0.03	0.29	0.03	0.01	0.01	-0.01	-0.24

These results demonstrate that certain prey species/groups may be sensitive to perturbations in ocean climate conditions in the CCS, especially during warm-water or ENSO events.

If these prey species typically comprise a substantial portion of either adult or nestling diet, a reduction in abundance of these species may ultimately result in (1) a delay in the timing of breeding or cessation of reproductive efforts, (2) reduced rates of nestling growth and development, (3) reduced reproductive success, and (4) reduced adult survival.

Indeed, reductions in Farallon seabird productivity, breeding propensity, and survival probability are all associated with negative SOI values (warm-water episodes; PRBO unpublished data), further illustrating the effects of ocean climate variability on seabird population processes.

Life History and Reproductive Consequences of the ENSO Cycle

Declines and increases in the zooplankton, squid, and fish populations that compose the food webs of most seabirds in the Pacific Ocean can be linked directly to a variety of physical oceanographic changes, which occur during ENSO/LNSO events.

These changes include a rise in sea level, a deepening of the thermocline, and a cessation of effectual ocean mixing. Under these conditions, while upwelling may or may not remain a dominant physical force (9), deepening of the thermocline results in mixing of warm, nutrient-poor water that has little positive effects on food web development.

As a consequence of poor nutrient input, there are changes in characteristics of phytoplankton and zooplankton communities. For example, larger diatoms are often replaced by smaller dinoflagellates, which, in turn, support smaller zooplankton. Eventually, poor nutrient levels cascade up the food web, with effects on seabird time and energy budgets.

During El Niño events, biological productivity in the euphotic zone declines markedly (10), with consequent negative effects on food web development, and ultimately, survival and reproduction of seabirds (11, 12). Since 1970, El Niño events have affected ecosystem productivity (i.e., food web development) in 1972-1973, 1976, 1982-1983, 1986, 1991-1992, and 1997-1998.

The El Niño of 1982-1983 dramatically focused attention on the effects of large-scale changes in circulation patterns of the tropical Pacific Ocean on biological communities worldwide (13).

In particular, oceanic and atmospheric effects from this event penetrated higher latitudes along the West Coast of North America, raising sea surface temperatures and causing mass mortality of many temperate region fish, marine birds, and mammal species (14). Seabird responses have varied by species in relation to the intensity and timing of each El Niño.

El Niño has been linked to the population dynamics of seabirds in the Central Pacific Ocean (15), and Eastern North Pacific Ocean (PRBO unpublished data) suggesting an important natural mechanism for understanding seabird population regulation. Life history and demographic parameters affected include the timing of egg-laying, proportion of adults breeding, offspring developmental patterns, reproductive performance, adult, subadult, and juvenile mortality rates, foraging habits, and diet (16).

Boekelheide (17) conducted a 13-year study of the Farallon Islands seabird community, and demonstrated several effects associated with El Niño, such as substantial delays in the timing of breeding and breeding effort (numbers attempting to reproduce) for many species (alcids and cormorants). More recently, Sydeman (18) studied the oceanographic relationships of timing of egg-laying in Common Murres, and demonstrated later breeding in years of warmer ocean temperatures associated with a series of El Niño events while controlling for confounding variables. However, the mechanism to later timing of breeding is not well understood.

Whether the reduction in prey associated with El Niño limits the condition of birds, thereby preventing earlier egg-laying, or whether birds delay reproduction to match the chick-rearing period with later blooms in prey species is an important question open for future research.

Seabirds in California often experience reproductive failure during the severe ENSO events. Ainley et al. (11) and Sydeman et al. (19) in extending earlier observations of the Farallon Island seabird community, showed that the response of various seabird species to El Niño and other warm-water anomalies depends on life history characteristics.

Species that foraged in nearshore habitats and those with more aggressive reproductive strategies (i.e., laying > 1 egg per clutch) often showed the greatest variability and decline in reproductive response. In studying reproductive performance (young fledged pair⁻¹ year⁻¹) of the Farallon seabird community, Brandt's (*Phalacrocorax penicillatus*) and Pelagic (*P. pelagicus*) cormorants and Pigeon Guillemots (*Cepphus columba*) were the species apparently most sensitive to interannual climate variability, i.e., El Niño/La Niña events associated with the ENSO cycle. These species also were exceptionally successful during La Niña years.

In Oregon, Hodder and Graybill (20) demonstrated reductions in reproductive success for cormorants and Common Murres (*Uria aalge*) and an increase in mortality for adults in Oregon during the 1982-1983 El Niño. Bayer et al. (21), who studied deposition rates of adult and juvenile murres on beaches in Oregon, reported larger than normal numbers of dead hatching-year birds on beaches in 1982, but not 1983.

In Washington, Wilson (22) showed that colony attendance of murres during the 1983 El Niño was 87% lower than in the previous year. Starvation appears to be the likely cause of elevated mortality, but direct relationships between prey availability and seabird reproductive success in relation to ENSO events have been infrequently developed. This remains an important area for future climate-seabird interaction research.

The El Niño of 1997-1998 was predicted well in advance of its arrival; hence, a number of investigations were designed specifically to investigate effects of this event. Sydeman et al. (pers. communication) assessed these effects on 12 geographically and temporally extensive time-series databases of 3 marine bird species from southern California through the Bering Sea, and found strong indications of reduced ecosystem productivity and effects on marine birds throughout the CCS and into the southern Gulf of Alaska (to ~56° N). The results showed ocean warming affected ecosystem productivity and seabirds in southern California in 1997, while populations in northern California were affected more in 1998. Notably, in central California in 1998, there was less of an effect of El Niño conditions on the planktivorous Cassin's Auklet (*Ptychoramphus aleuticus*) and omnivorous Common Murre, than the obligate piscivore, Rhinoceros Auklet (*Cerorhinca monocerata*) (23). This result led Sydeman and colleagues to propose that cessation of El Niño relatively early (in May) 1998, followed by moderate upwelling, allowed the planktivorous auklet and murre to take advantage of late season zooplankton blooms.

In northern California, Common Murres attended the Castle Rock colony throughout the 1998 breeding season, but experienced nearly complete reproductive failure, and Tufted Puffin numbers were the lowest on record (D. Jaques and C. Strong, pers. communication).

In southern British Columbia, the mean frequency of occupied detections for Marbled Murrelets, a possible measure of near-nest flight behaviors, was negatively correlated with nearshore ocean temperatures over a 7-year period including the 1998 El Niño when temperatures were the warmest (A. Burger, pers. communication). Also in British Columbia, the reproductive effort of breeding Cassin's Auklet on Triangle and Frederick Islands was significantly reduced and timing of breeding was delayed for those that tried (D. Bertram et al., pers. communication). Interestingly, nestling growth and breeding success were also reduced on Triangle Island (50° N), but not on Frederick Island (54° N). Breeding of Ancient Murrelets on Limestone Island began relatively early, but was spread over a much longer period than usual. In addition, 50% of the monitored burrows were deserted during incubation, far more than had been observed in any previous year (T. Gaston, pers. communication).

Effects of the 2003 El Niño Event on Seabirds Breeding on the Farallon Islands

Generally, the 2003 El Niño event showed all the classic signs of an El Niño for the seabirds on the Farallon Islands, but with much reduced effects. El Niño conditions during the winter of 2002/2003 resulted in reduced productivity for the seabirds during the spring/summer breeding season. The effects on individual species, however, were varied.

Brandt's Cormorant and Rhinoceros Auklet productivity was down from the 2002 season and well below the long-term mean for these species. Pigeon Guillemot and Common Murre productivity was also down from 2002, but still at or above their long-term mean reproductive success. However, Pelagic Cormorant and Cassin's Auklet productivity, although down from 2002, was still very high. The observed decline in Cassin's Auklet productivity is driven solely by a reduction in the number of second broods attempted and successfully fledged, although productivity among first broods was higher than in the 2002 breeding season.

In addition to generally lower productivity, 2003 was characterized by delayed breeding relative to the previous two seasons, moderately lower growth rates among chicks, a high rate of nest abandonment among Brandt’s Cormorants, and a reduction in the proportion of rockfish in chick diet (although still close to 50% of the diet for murres and guillemots). The rate of chick provisioning was also lower for murres and guillemots.

Finally, large numbers of emaciated sea lions were observed around the island during 2003, probably due to a lack of sufficient food available during the winter and spring months. These individuals then had a direct impact on seabirds by crawling into the colonies, causing disturbance to nesting seabirds, scavenging the carcasses of dead birds, and in one case, actively preying upon murre chicks.

By all accounts the first El Niño of the current “cold-water regime” was much more moderate in its effects than previous events, possibly because of the very high productivity (and presumably excellent feeding conditions) of most species in the past 4 years. Productivity, while reduced, was much higher in 2003 than in 1998, 1992, or 1983 (Table 5.2), particularly among those species thought to be most sensitive to oceanographic changes, such as Pelagic Cormorants, Pigeon Guillemots, and Brandt’s Cormorants.

The exceptionally high productivity among Pelagic Cormorants is most unusual for an El Niño event, as is the fact that Brandt’s Cormorants had low productivity while Pelagics did well. Cassin’s Auklets, though largely unsuccessful, still attempted second broods, which did not occur in previous events. The mean seasonal SST for 2003 (12.07° C), though higher than the past few years, was considerably lower than in previous El Niño years.

Table 5.2 – Comparison of seabird productivity on the Farallon Islands during the last six “El Niño” events. (COMU = Common Murre, BRCO = Brandt’s Cormorant, PECO = Pelagic Cormorant, PIGU = Pigeon Guillemot, CAAU = Cassin’s Auklet, RHAU = Rhinoceros Auklet, WEGU = Western Gull).

YEAR	COMU	BRCO	PECO	PIGU	CAAU	RHAU	WEGU
1978*	0.67	0	0	0.2	0.7	na	1.04
1983	0.04	0	0	0	0.24	na	0.63
1986	0.73	1.33	0.1	0.02	0.74	0.55	1.28
1992	0.08	0	0	0.31	0.25	0.73	0.51
1998	0.39	0.42	0.06	0.05	0.79	0.13	0.52
2003	0.72	1.01	2.21	0.92	0.9	0.43	0.81
Mean Prod.**	0.75	1.45	0.92	0.83	0.72	0.56	1.09

* 1978 was a warm water year, but not a tropical El Niño.

** Mean productivity represents the 32-year average productivity for each species.

Survival of Adults and Population Consequences of ENSO

El Niño has been linked to the population dynamics of seabirds in the central North Pacific Ocean (15), suggesting an important natural mechanism for understanding seabird population regulation.

In the CCS, evidence of population-level consequences of ENSO events depends on the species under investigation. In Washington, Wilson (22) showed that colony attendance of murres during the 1983 El Niño was 87% lower than abundance in the previous year, but suggested anthropogenic factors were responsible for continuing low numbers of murres attending colonies after 1983. Sydeman (24) found no change in the survival of adult, color-banded murres on the Farallon Islands in relation to the weak 1986 ENSO event.

However, Hodder and Graybill (20) documented an increase in mortality for murres and cormorants in Oregon during the 1983 event, and in relation to the 1997-1998 El Niño, deposition rates of murres (numbers/mile/week) on beaches on the outer coast of Washington were higher in 1997 than in both 1996 and 1998 (T. Good and C. Thompson, unpublished data).

For other species, mortality of breeding age adults is clearly elevated during El Niño. For example, Boekelheide and Ainley (25) and Nur and Sydeman (26) demonstrated considerable declines in survival and recruitment of Brandt’s Cormorants during warm-water anomalies in the CCS. Massey et al. (27) showed a decline in the return rates of older, rather than younger, breeding Least Terns in southern California.

Thus, while El Niño has been shown to have considerable effects on the demographic processes of seabirds, long-term population-level consequences are less convincing. In the only modeling exercise published to date on this issue, MacCall (28) investigated the effects of repeated El Niño events and chronic reproductive failures on CCS seabirds; indeed in this case, population declines were inevitable.

Seabird Responses to La Niña Events

Since 1970, La Niña events have affected CCS ecosystem productivity in 1971, 1974-1975, 1985, 1989, and 1999-2001. Other changes may include a strengthening of the California Current itself, and greater transport of nutrients and organisms from subarctic regions.

Seabird Responses to the Pacific Decadal Oscillation

Natural cycles that occur on timescales of decades or centuries, such as the PDO, add to the difficulty in interpreting the effects of ENSO/LNSO on seabird communities, species, and populations (29).

Biological communities have responded to PDO-related low frequency ocean warming in the Pacific Ocean. For example, zooplankton biomass in the Southern California Bight has declined significantly over the past 40 years (30, 31), and compositional changes in rocky-intertidal communities in central California have been documented (32). However, there has been little study on the direct effects of variability in the PDO on seabird populations in the Pacific. The results of Sydeman et al. (19), the only published work to date to explicitly examine patterns of response in seabirds to changes to the PDO, were equivocal. While some Farallon Island and Channel Island species showed long-term declines in productivity, others did not, and there was no obvious “step-wise” change in reproductive performance after the 1976-1977 PDO shift. Instead, Sydeman et al. suggested that a “regime shift” occurred in 1989-1990, which explained a reduction in the use of juvenile rockfish and declines in seabird productivity starting in the late 1980s (Figure 5.2).

The concept of a regime shift in 1989-1990 has now been strongly supported by many publications (33), but this ecosystem change, unlike shifts in 1976-1977 and earlier, was most pronounced in the biological time series rather than temperature and other environmental measurements. The concept of “regime shifts” and consequences for fish populations have been long discussed (reviewed by Chavez et al. 2003).

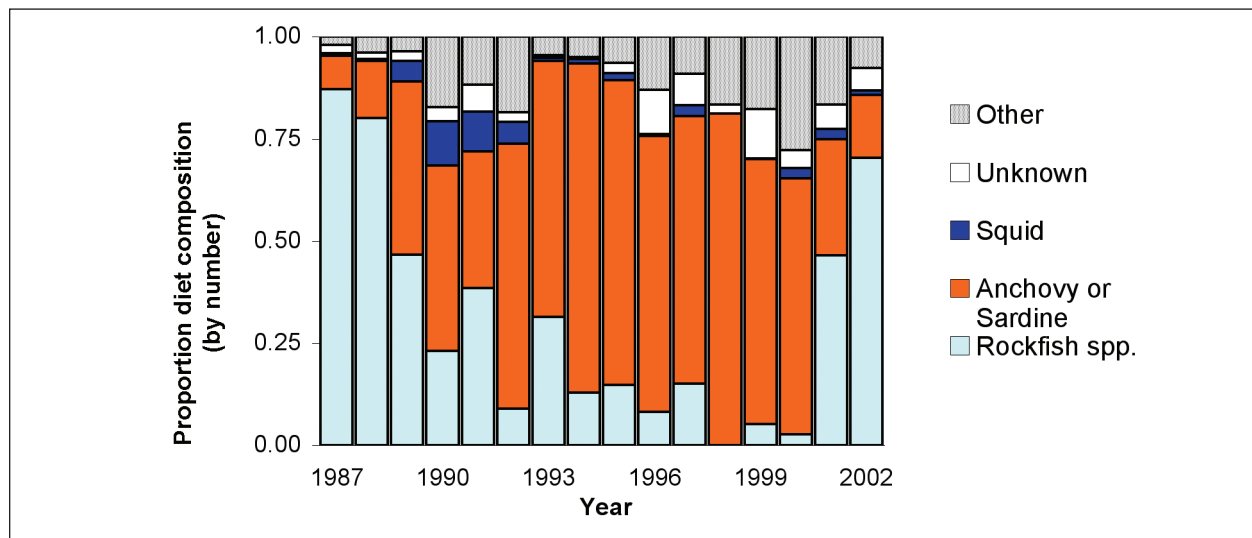


Figure 5.2 – Proportion diet composition (by number) of Common Murre nestlings on SEFI, 1987-2002.

In British Columbia, there have been considerable inter-decadal changes in the timing of breeding for 4 species of alcid breeding at Triangle Island (16). Chick growth of both Tufted Puffins and Rhinoceros Auklets has declined since the mid-1970s, and Tufted Puffins experienced reproductive failure from 1994-1998 (J. Ryder and D. Bertram, unpublished data).

Concurrently, there has been an overall decline in the proportion of sandlance in the nestling diet of both species. However, in the absence of sandlance, auklets switched to alternative prey, whereas puffins did not; for this species, breeding failure thus coincided with the timing of substantial decline of sandlance from nestling diet (D. Bertram et al. unpublished data).

At sea, changes in seabird communities and populations in the CCS may be related to variability in the PDO, although results are unclear. Veit et al. (34), in studying the seabird community off southern California, reported that overall seabird abundance decreased by 40% between 1987-1994, mostly due to the 90% decline in the dominant cold-water species, the Sooty Shearwater (*Puffinus griseus*).

Hyrenbach and Veit (35) have extended these observations, and remarked that since 1994, total seabird abundance and Sooty Shearwater numbers have remained consistently lower than during 1987-1994, suggesting that long-term changes to the ecosystem persist. In central California, Ainley et al. (85) and Oedekoven et al. (36) demonstrated interannual and long-term avifaunal changes, and declines in many cold-water, locally breeding species, including Common Murres and Cassin's Auklets.

The most parsimonious explanation for changes in seabirds at sea in southern and north-central California in the late 1980s is probably a response to ecosystem change at that time (~1989-1990), rather than a lagged response to the 1976-1977 regime shift. Wahl and Tweit (37) studied decadal trends in seabird populations off the coast of Washington, and demonstrated a decline in cold-water species and a concomitant increase in warm-water species over the past 3 decades.

Finally, in recent reports on the state of the California Current developed as part of the California Cooperative Oceanic Fisheries Investigation (38-40), combined colony and at-sea datasets have been used to investigate seabird response to a purported shift in the PDO in 1998-1999. Colony data from the Farallon Islands clearly demonstrates an increase in productivity for 6 species of seabirds after 1998. Moreover, Schwing et al. (40) demonstrate not only an increase in mean reproductive performance after 1998, but also a decrease in variance.

In contrast, the overall abundance of seabirds at sea in southern California has not changed simultaneously; numbers remain low when compared with the seabird communities of the late 1980s. However, in both 1999 and 2001, cold-water, subarctic species comprised a greater proportion of the avifauna.

Future surveys will reveal if this represents a consistent long-term change in seabird community composition or an intermittent change associated with cold-water intrusions during these years.

5.3 CONSEQUENCES OF GLOBAL WARMING

Despite controversies regarding the causes of climate change, the earth is getting warmer. Recent climate models from the U.K. Hadley Centre (41) combined with models of past climate indicate that mean global surface air temperatures have already increased 1°C in the past century. Under the models’ mid-range estimates, temperatures are expected to increase by 3°C within the next 100 years if “greenhouse gases” such as carbon dioxide and methane continue to grow at present rates. Rising global temperatures can affect marine life, including seabirds, in many ways, both directly and indirectly.

Because of their high status in the food web, seabird species are likely to be some of the most sensitive to human-induced climate change (42). Reductions in marine productivity associated with higher ocean temperatures directly impact seabird foraging, causing serious negative consequences for seabird reproduction and survival. In the California Current, both high frequency (El Niño) and low frequency (PDO) warm-water events have negative effects on seabird breeding. Seabirds breed later, lay fewer eggs, and fledge fewer chicks during El Niño events (19, 43).

Reduced prey availability causes changes in marine distribution as birds have to search wider areas to feed (44). As well, extreme El Niño warm-water events are associated with dramatically increased adult mortality due to starvation (19, 43). If global warming affects the frequency and duration of both high and low frequency warm-water anomalies in the California Current, there could be dramatic impacts on seabird populations.

Global warming may also have direct affects on marine bird populations. Sea level rise, increased precipitation, and increased storm activity – all predicted outcomes of increased warming, could destroy nests or eliminate breeding habitat altogether (45). Species that rely on low elevation islands (i.e. terns) for breeding would be greatly affected by these sorts of impacts.

5.4 FOOD AS A FACTOR LIMITING POPULATION GROWTH

The factors influencing the population dynamics of seabird colonies are of extreme interest to biologists and marine resource managers. Various natural mechanisms for regulating population dynamics have been proposed, ranging from predation to habitat availability to competition for resources such as nest sites and food. Studies have shown that among these, seabird populations track fluctuations in food availability more closely than other ecological factors (46) and that food is often an important factor regulating the growth or recovery of populations (47, 48).

Food resources are highly variable both spatially and temporally, and many factors may limit the amount of food available to seabirds in any given year. Among these are natural variability in oceanographic conditions (such as El Niño), which can negatively affect prey resources (19, 50, 51); competition with fisheries (51, 52); and density dependent intraspecific competition (47, 53).

Density dependent regulation of populations is predicated on the idea that there is an upper limit (the carrying capacity) of a population that is the maximum number of individuals that the most limited resource of an area can support (54). So as the population increases, more food is required, until the population size reaches a balance with the amount of food available. Studies have suggested that as seabird colonies increase in size, there is an increase in intraspecific competition and a reduction in the amount of food available close to the colony, thereby limiting the further growth of that colony (47, 55).

Food availability (or lack thereof) can limit population growth through two important mechanisms. The first is through limiting reproductive output of a colony during the breeding season. Food availability is closely linked to seabird reproductive success (56, 57) so that when food resources are limited, a seabird’s ability to successfully raise young is hampered, and productivity declines (19, 22, 58), resulting in slower or even negative population growth.

Food availability can also affect seabird populations during the non-breeding season through reduced adult survival (20, 26) as well as the decreased survival and recruitment of immature birds (56). For example, reductions in food availability during El Niño events in the 1980s resulted in large-scale adult mortality of murrelets and cormorants in the CCS (20, 59).

In order to determine if population growth will be limited by food availability, researchers will need to acquire: 1) accurate estimations of seabird populations both on colony and at sea; 2) energetic requirements of CCS seabird populations (see section 5.2);

3) information on the abundance and distribution of prey resources around breeding colonies and winter foraging areas; 4) foraging range of CCS marine birds; and 5) information on competition for resources with other species (fish and marine mammals) and fisheries.

5.5 PREY DEPLETION IN FISHERIES

Fishing activities can have both direct (see Chapter 6) and indirect effects on seabirds. Even though indirect effects are known to occur (and there are many studies that attempt to demonstrate that prey depletion in fisheries has a detrimental effect on seabirds) it is very difficult to provide a direct link between cause and effect (60). Even when it is documented that seabirds are affected by a reduction in prey, it is difficult to prove that this reduction is a direct result of fisheries (61, 62).

Prey depletion refers to the decrease in seabird prey as a result of fishery activity. In some ecosystems it has been estimated that seabirds consume between 20 to 30% of the annual pelagic production of fish (63, 64), which can place them in direct competition with fisheries.

Seabirds can be affected by a direct depletion of their food by fisheries, when seabirds and fisheries target the same species and age classes. Similarly, if fisheries target adults of the fish population, forage for seabirds may be affected if the spawning population is significantly reduced. The seabird species that are most vulnerable to these types of indirect effects are those that have a restricted foraging range or that are specialized in a certain feeding method or prey (63).

In the CCS, there are currently 22 fisheries that target the same species that seabirds consume (Table 5.3), and therefore may be a potential source of conflict by reducing seabird prey biomass. As stated above, it is difficult to provide evidence for detrimental effects on seabirds as a result of prey depletion from these fisheries. However, seabird prey consumption models can provide a starting point for examining potential overlap between seabird prey requirements and fisheries catch (see section 5.6). This type of information is extremely valuable for setting fisheries management limits.

In certain cases, a positive effect of fisheries on seabirds may occur when the fishery targets predatory fish, which may in turn decrease predation pressure on smaller fish. This can result in an increase in seabird forage, such is the case for seabirds in the North Sea (65).

However, in certain cases, the removal of large predatory fish may also cause a decrease in the availability of prey to seabirds. In certain habitats such as in the tropics, some predatory fish (such as tuna) are essential for driving smaller seabird prey to the surface, where non-diving or shallow-diving seabirds can access them (66, 67). Therefore, by removing these predatory fish, seabird access to smaller fish may decrease, resulting in more limited feeding opportunities. Whether the effect of predatory fish removal is positive or negative for seabirds, it has been recently estimated that 90% of large predators have been removed from global oceans, which will undoubtedly cause ecosystem-level repercussions yet to be determined (68).

Fisheries managers need to consider all possible conflicts and overlaps between seabird forage fish and fisheries that target the same fish. It is also important to understand natural prey fluctuations, which undoubtedly affects both seabirds and fishery catches.

When environmental perturbations such as an El Niño are coupled with poor fisheries management, dire situations can occur, such as the 1971-72 Peruvian anchovy collapse, which is thought to have been a result of a strong El Niño event coupled with over-fishing (69).

Seabird researchers need to be aware of these possible indirect conflicts with fisheries and provide assistance and information to fisheries managers, if deemed necessary. It is also of extreme importance for seabird researchers and fisheries managers alike to stay informed of potential emerging fisheries.

Table 5.3 – Fisheries that operate in the CCS and have the potential of reducing prey for seabirds.

FISHERY	TARGET SPECIES
WA Puget Sound Region salmon drift gillnet	salmon
CA squid purse seine	squid, loligo
WA/OR gillnet	herring, smelt, shad, sturgeon, bottom fish, mullet, perch, rockfish
WA/OR lower Columbia River salmon drift gillnet	salmon
CA anchovy, mackerel, tuna	anchovy, mackerel, tuna
CA herring purse seine	herring (roe and fresh herring)
CA sardine purse seine	sardine
CA/OR/WA salmon troll	salmon
WA groundfish, bottomfish jig	groundfish and bottomfish
CA/OR/WA sablefish pot	sablefish
WA Grays Harbor salmon drift gillnet	salmon
WA salmon purse seine	salmon
WA salmon reef net	salmon
WA Willapa Bay salmon drift gillnet	salmon
WA/OR herring, smelt, squid purse seine or lampara	herring, smelt, squid
WA/OR North Pacific halibut longline/set line	halibut
WA/OR smelt, herring dip net	smelt, herring
CA/OR/WA groundfish trawl	hake, flatfish, sablefish, lingcod, rockfish
CA/OR/WA groundfish, bottomfish longline/set line	groundfish, bottomfish
WA (all species) beach seine or drag seine	various species
WA groundfish, bottomfish jig	groundfish and bottomfish
Baja California sardine/anchovy	sardine/anchovy

5.6 SEABIRD PREY CONSUMPTION MODELS

The main goal of the prey consumption models we present here is to estimate the minimum amount of biomass of individual prey species or group of species consumed by dependent alcid nestlings (Common Murre, Pigeon Guillemot, Rhinoceros Auklet, and Cassin’s Auklet) on Southeast Farallon Island (SEFI), California.

We chose to construct prey consumption models rather than bioenergetics models, as there is little physiological data available regarding the energy *requirements* of these seabird species at this location.

Species-Specific Models:

1. Cassin’s Auklet

Cassin’s Auklet responds to interannual variability in ocean climate by alternating diet between *Thysanoessa spinifera* and *Euphausia pacifica*, although both are consumed in all years (19, 87). Euphausiid crustaceans comprised between 60% and 85% (by mass) of nestling auklet diet annually (Fig. 5.3). In fact, although *E. pacifica* is substantially more abundant (>100 times) than *T. spinifera* in the region (70), the two species comprise relatively equal proportions of auklet diet. Additionally, two subtropical euphausiid species, *Nyctiphanes simplex* and *Nematocelis difficilis*, are consumed occasionally by Farallon auklets during ocean warming events such as El Niño (19, 71, 72). In years when the overall abundance of euphausiids is relatively low in the diet, auklets supplement nestling diet primarily with amphipods, decapods, copepods, mysids (Class Crustacea), and larval fish.

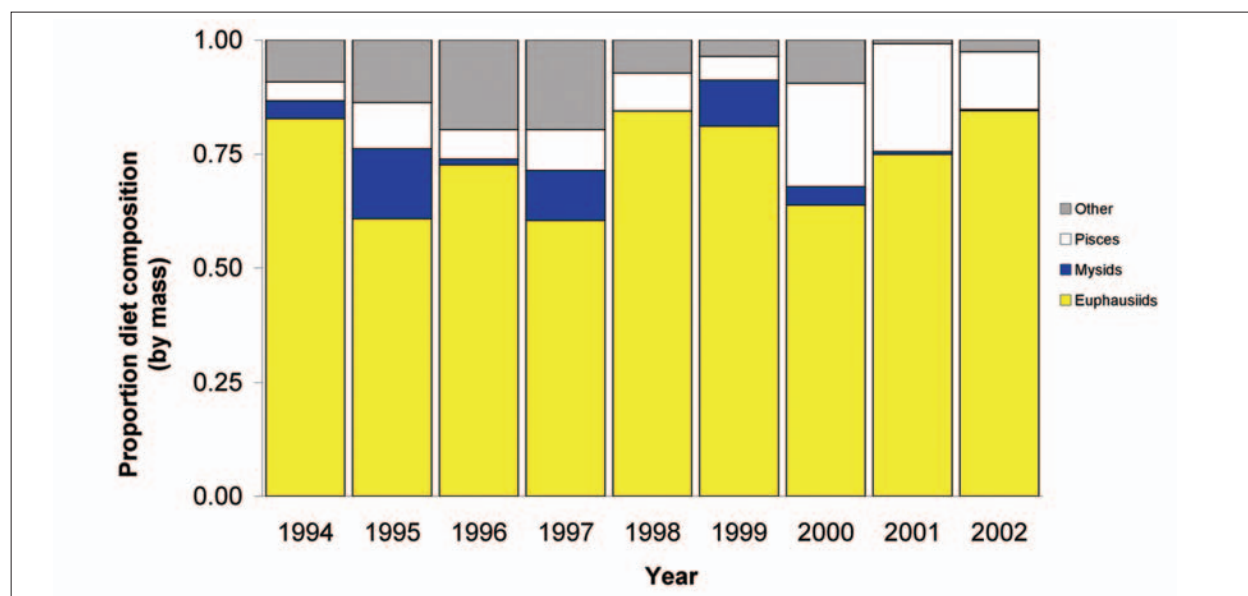


Figure 5.3 – Proportion diet composition (by mass) of Cassin’s Auklet nestlings on SEFI, 1994-2002. “Other” includes Nematodes, Cirripeds, Molluscs, Isopods, larval Pisces and unidentified organic matter.

The biomass of prey consumed by Cassin’s Auklet nestlings varied interannually (Fig. 5.4), ranging from 3.0 metric tons in 1998 to 15.6 metric tons in 1994. Prey consumption was relatively low during the 1997/1998 ENSO event, reflecting poor reproductive success in 1997 (55%, the lowest in this series), a reduced breeding population estimate and reduced parental food delivery amounts in 1998 (both the lowest in this series). The annual estimate of nestling food mass delivered per chick per day (assuming a constant annual rate of parental food delivery; Fig. 5.5) was also lowest during the 1998 ENSO year.

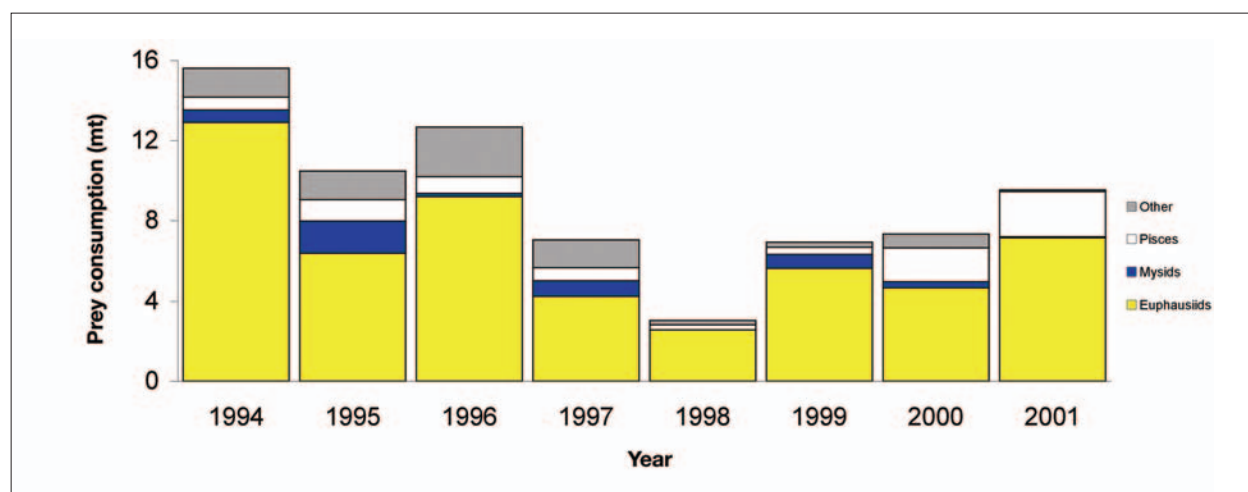


Figure 5.4 – Cassin's Auklet nestling prey consumption in metric tons, 1994-2002.

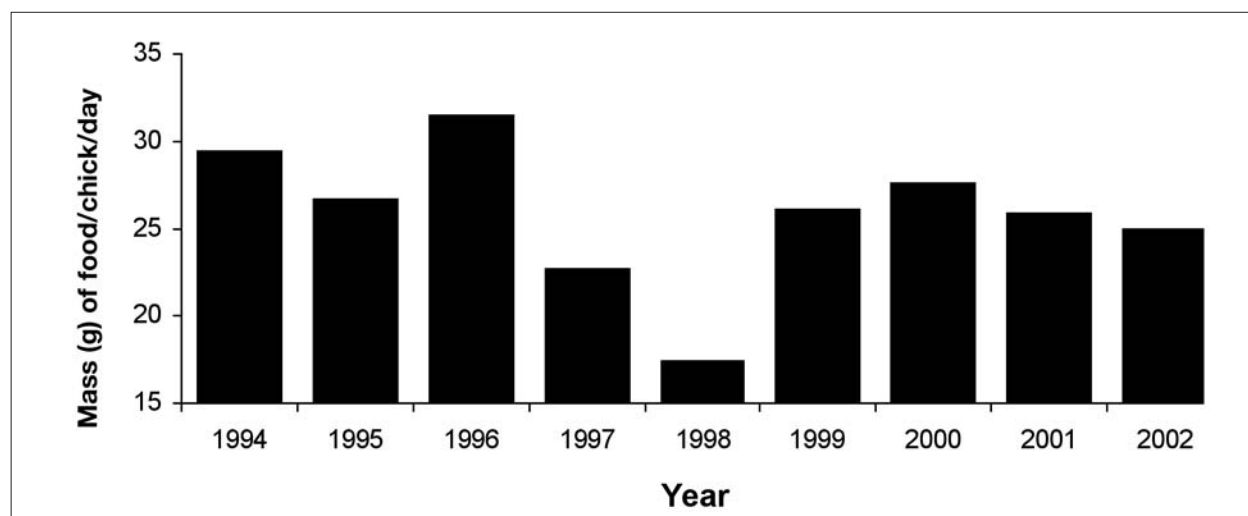


Figure 5.5 - Mass (g) of food delivered per Cassin's Auklet nestling per day.

2. Rhinoceros Auklet

Although the diet of Rhinoceros Auklet nestlings is more diverse than for Cassin’s Auklet, our results show that there are between one and three primary prey species or groups utilized in each year, and that these vary on an interannual basis (Fig. 5.6).

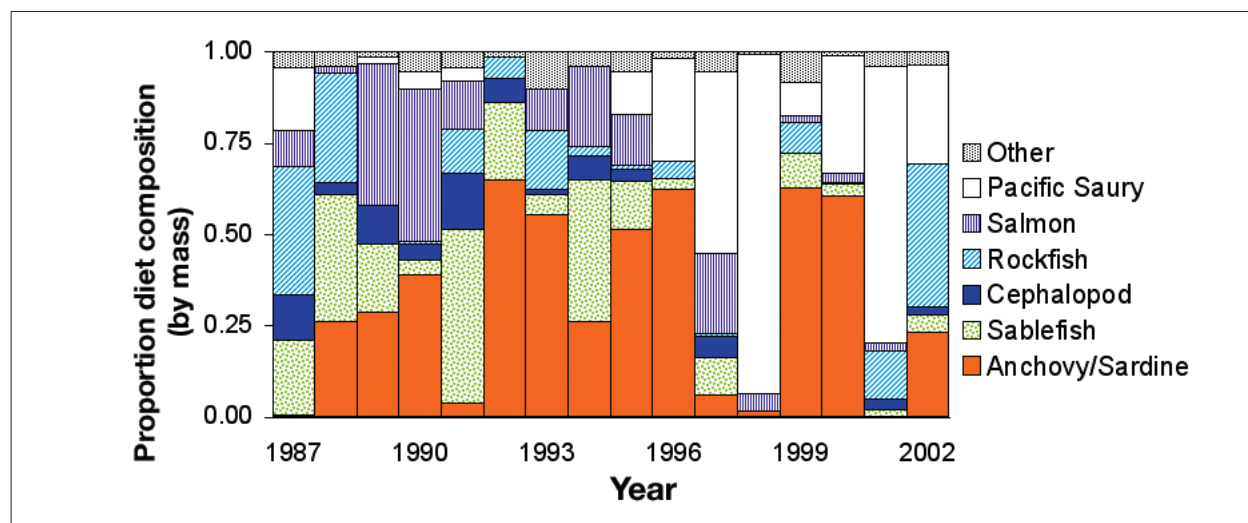


Figure 5.6 – Proportion diet composition (by mass) of Rhinoceros Auklet nestlings on SEFI, 1987-2002. “Other” category includes: Slender Barracudina, Mackerel, Sardine/Herring unidentified, Stickleback, Plainfin Midshipman, Smelt, Pacific Hake, Butterfish, Sculpin spp., Greenling spp., Lamprey, and Lanternfishes.

Salmon spp., Northern Anchovy, Sablefish, Rockfish spp., and Pacific Saury together comprised the major diet items, in varying proportions in all years, ranging from 70-98% of diet composition by mass. Northern Anchovy was one of the two most consistently present species in the diet, appearing in all years in varying amounts (0.5-62%), except in 2001. Anchovy were present in low amounts (less than 4%) in 1987, 1991, 1997, and 1998. This variability corresponds to the ENSO events in 1986 and 1997/1998 and possibly with a climatic regime shift in 1989/1990.

Sablefish were present in varying amounts (2-47%) in all years except 1998 and in low amounts (less than 6%) in 1990, 1993, 1996, and 2000-2002.

Pacific Saury comprised 17% of diet by mass in 1987, then disappeared or was present in low amounts (less than 5%) until 1995, when it reappeared in the diet in relatively large amounts (9-92%) for the remainder of the time series.

The proportion of Salmon spp. (mostly unidentified salmon spp. and King Salmon) in the diet (when present) ranged from 2% in 1988 to 42% in 1990. Salmon was absent or in low amounts (less than 6%) in 1988, 1992, and 1998-2002.

The proportion of Rockfish [various species, including Shortbelly (*S. jordani*), Widow (*S. entomelas*), Yellowtail (*S. flavidus*), Blue (*S. mystinus*), Square spot (*S. hopkinsi*), Striped tail (*S. saxicola*), Black (*S. melanops*), Halfbanded (*S. semicinctis*), Bank (*S. rufus*), Boccacio (*S. paucispinis*), Speckled (*S. ovalis*), and Dark-blotched Rockfish (*S. pinniger*)] in the diet (when present) ranged from 0.5% in 1990 to 39% in 2002. Rockfish were absent or in low amounts (less than 9%) in 1989, 1990, 1992, and 1994-2000.

The biomass of prey consumed by Rhinoceros Auklet nestlings varied interannually (Fig. 5.7), ranging from 0.52 metric tons in 1988 to 0.036 metric tons in 1998. Prey consumption was relatively low during the 1998 ENSO event, reflecting poor reproductive success (13%, the lowest in this series) and reduced parental food delivery amounts. The annual estimates of nestling food mass delivered per chick per day were also lowest during the 1992 and 1998 ENSO years (Fig. 5.8).

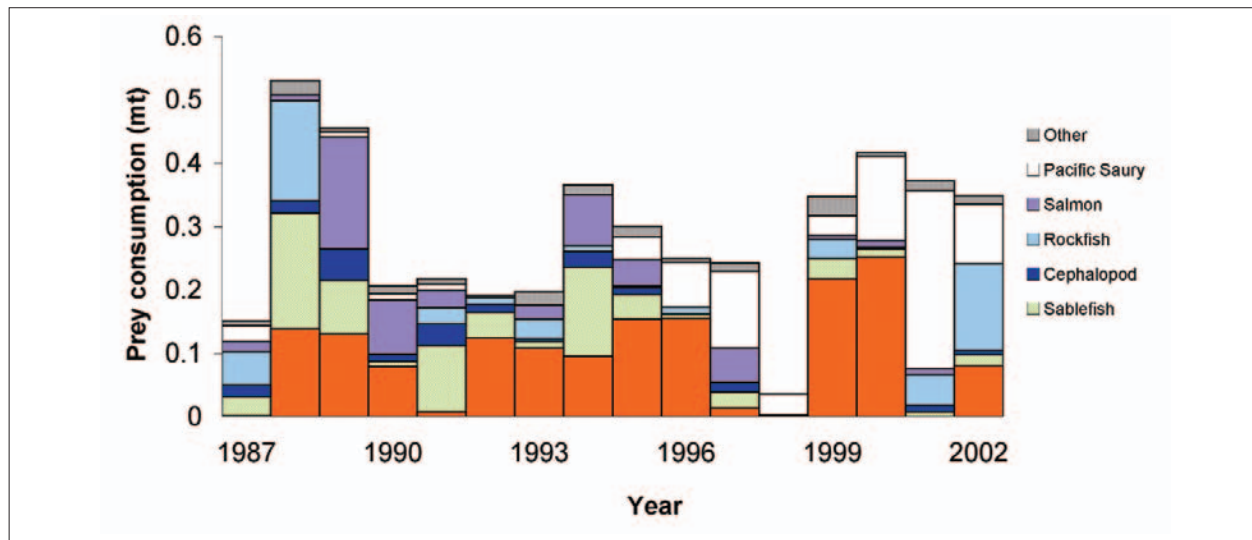


Figure 5.7 – Rhinoceros Auklet nestling prey consumption (in metric tons), 1987-2002.

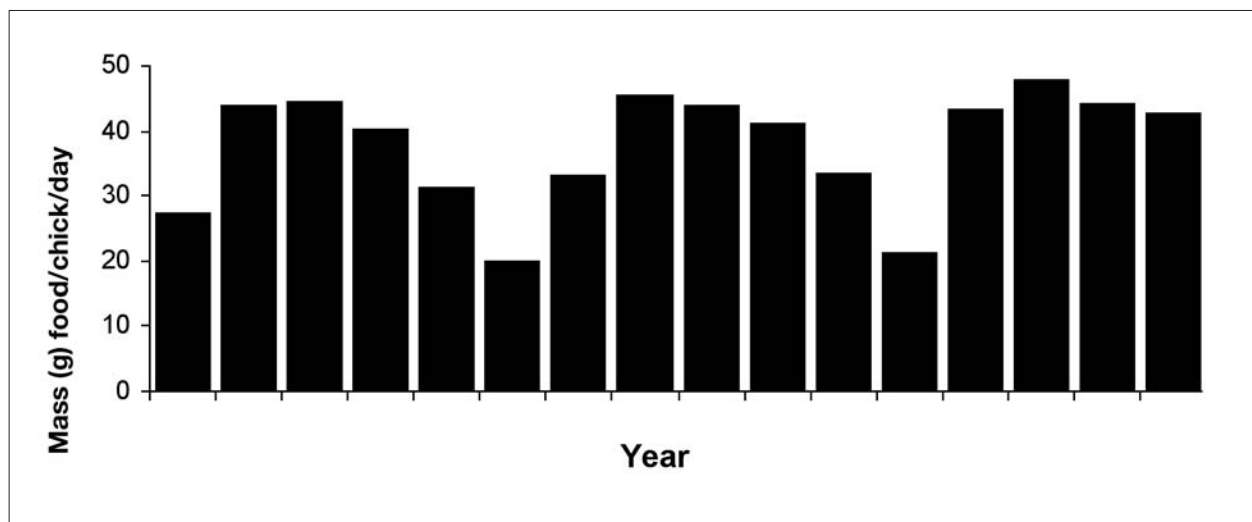


Figure 5.8 – Mass (g) of food delivered per Rhinoceros Auklet nestling per day.

3. Common Murre

Our results suggest that there are between one and two primary prey species or groups delivered to Common Murre nestlings in each year, and that these vary on an interannual basis (Fig. 5.9).

Northern Anchovy, Anchovy/Sardine, and Rockfish spp. together comprised the major diet items, in varying proportions in all years, ranging from 62-95% of diet composition by number. Northern Anchovy was present in all years in varying amounts, ranging from 1% in 2002 to 81% in 1994. Anchovy were present in low amounts (less than 8%) in 1987, 2001, and 2002. Anchovy/Sardine was present in 1995 and 1997-2002 in varying amounts, ranging from 2% in 1997 to 43% in 1998. Rockfish were present in all years except 1998. When present, rockfish varied from 87% in 1978 to 3% in 2000. Rockfish were absent or in low amounts (less than 9%) in 1992, 1996-1998, 1999, and 2000. The proportion of unknown prey items in the diet was relatively low in all years, ranging from 0.3% in 1994 to 12% in 1999.

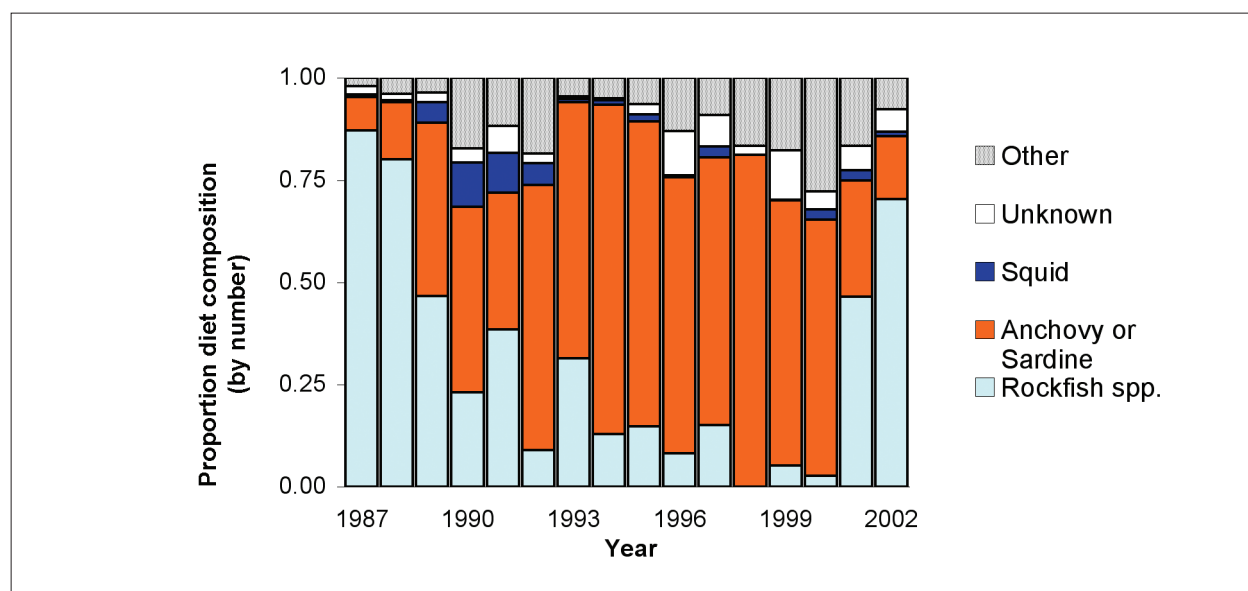


Figure 5.9 – Proportion diet composition (by number) of Common Murre nestlings on SEFI, 1987 – 2002.

The biomass of known prey items (prey included in model, but not representing all diet items) consumed by Common Murre nestlings varied interannually (Fig. 5.10), ranging from 1.02 metric tons in 1992 to 25.0 metric tons in 2002. The proportion of prey items in the diet (by number) included in the model varied from 70% in 2000 to 97% in 1987. Prey consumption was relatively low during the 1992 and 1998 ENSO events (8% in 1992 and 39% in 1998, the lowest in this series), reflecting poor reproductive success in 1992 and reduced parental food delivery amounts. However, the annual estimate of nestling food mass delivered per chick per day was high during the 1992 ENSO year (second highest in this series, Fig. 5.11).

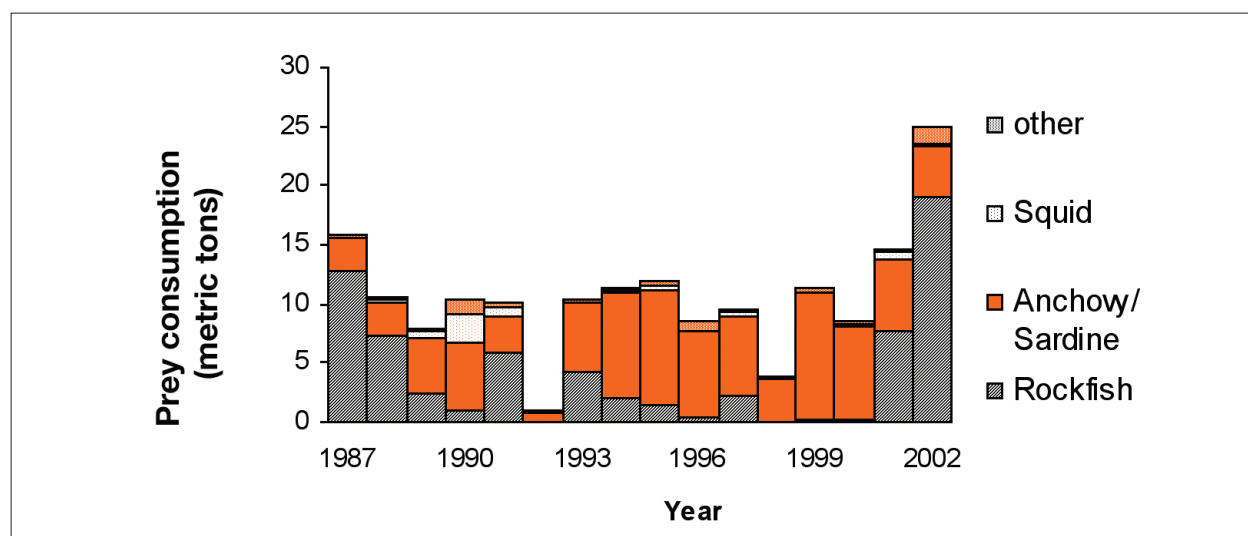


Figure 5.10 – Common Murre nestling prey consumption (in metric tons), 1987-2002.

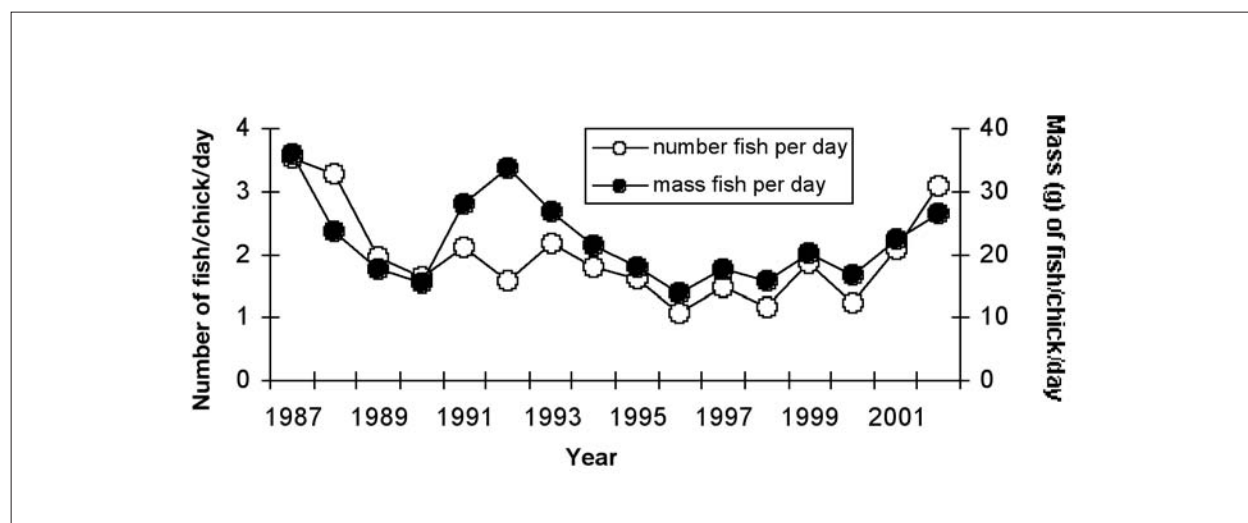


Figure 5.11 – Number of prey items and estimated mass (g) of food delivered per Common Murre nestling per day.

4. Pigeon Guillemot

Sculpin spp. and Rockfish spp. together comprised the majority of known diet items delivered to nestlings, in varying proportions in all years, ranging from 24-83% of diet composition by number (Fig. 5.12). Rockfish were present in all years in varying amounts, ranging from 56% in 1993 to 0.5% in 2000. Sculpin were also present in all years in varying amounts, ranging from 41% in 1995 to 19% in 1999.

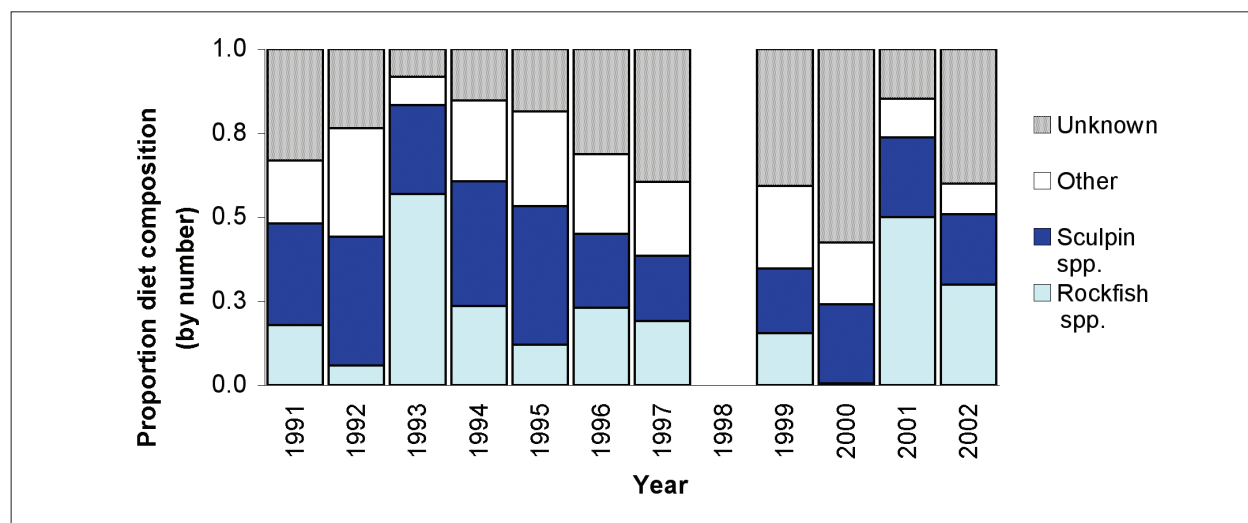


Figure 5.12 – Proportion diet composition (by number) of Pigeon Guillemot nestlings on SEFI, 1991-2002. “Other” includes Flatfish spp., Cuskeel, Gunnel/Prickleback, Kelpfish, Greenling, Shrimp, Crab, Red Brotula, Worm (polychaete), Blenny, Señorita, Octopus, Squid Sandlance, Anchovy, Anchovy/Sardine, Butterfish, Sablefish, and Pacific Saury.

The biomass of known prey items (prey included in model, but not representing all diet items) consumed by Pigeon Guillemot nestlings varied interannually (Fig. 5.13), ranging from 0.72 metric tons in 1995 to 0.032 metric tons in 1999. However, the proportion of prey items in the diet (by number) included in the model was relatively low, and varied from 83% in 1993 to 24% in 2000. Prey consumption was relatively low (less than 0.17 metric tons) for all years except 1991, 1995, 2001, and 2002, when it was greater than 0.4 metric tons. The annual estimate of nestling food mass delivered per nest site per day was high during the 1992 ENSO year (second highest in this series, Fig. 5.14).

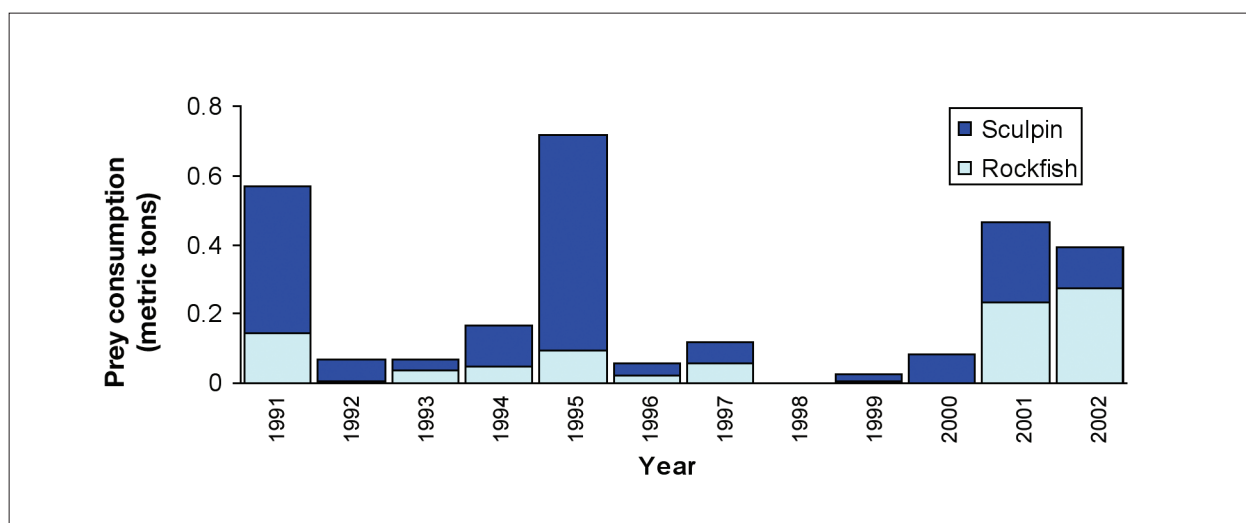


Figure 5.13 – Pigeon Guillemot nestling prey consumption (in metric tons), 1991-2002.

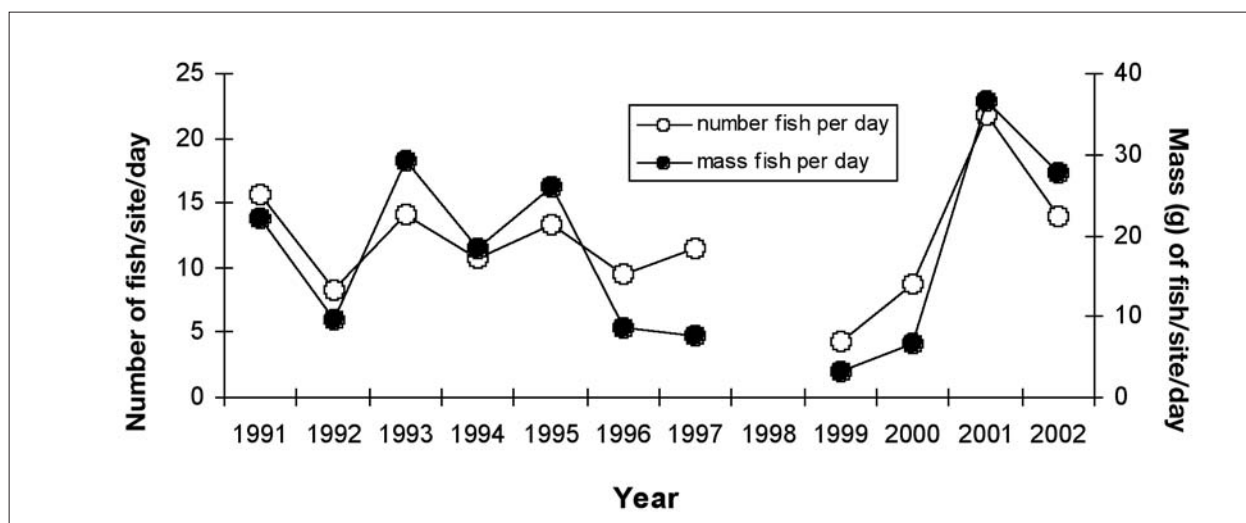


Figure 5.14 – Number of prey items and estimated mass (g) of food delivered per Pigeon Guillemot nest site per day.

Conclusions – Prey Consumption Models

Changes in annual diet composition (and thus prey consumption) of SEFI alcids are coincident (for some species) with interannual changes in local or basin-wide ocean climate conditions.

For example, the proportion of Rockfish spp. in the diet showed substantial interannual variability, ranging from 0-39% in Rhinoceros Auklet diet (Fig. 5.6) and 0-87% in Common Murre diet (Fig. 5.9). During the ENSO year of 1992 rockfish were present in very low amounts in the diet of both species and were totally absent in the ENSO year of 1998. Rockfish abundance in Pigeon Guillemot diet, however, did not display these trends (Fig. 5.12). This result must be taken with caution, however, as the proportion of known prey items in guillemot diet was consistently low (less than 61% by number for each year with the exception of 83% in 1992, but where there were only 34 prey items observed in that year).

In contrast, the primary prey utilized (euphausiids) by planktivorous Cassin’s Auklet nestlings shows relatively little interannual variability, ranging from 60-85% of the diet (Fig. 5.3), and remained relatively high during the 1997-98 ENSO event. Our results also suggest that the rockfish abundance in the diet varied, to some degree, with regime shifts in the North Pacific ocean in 1989-1990 and 1998-1999. The abundance of rockfish in Rhinoceros Auklet and Common Murre diet was relatively high prior to the 1989-90 regime shift, followed by a reduction throughout most of the 1990s. In 2001/2002, rockfish began to appear in the diet of both species in relatively high numbers, suggesting a slow recovery of this long-lived species, possibly in response to the 1998-99 regime shift to cooler conditions.

The models we present are good examples of estimation of prey consumption at a local scale. Development of prey consumption models for seabirds throughout the entire CCS would be extremely valuable for ecosystem-level predator and prey species management and for assessing effects of climate variability and change.

In order to make better predictions regarding the effects of ocean climate and prey variability on seabird populations throughout the CCS, it is necessary to obtain detailed seabird diet data from all significant seabird breeding colonies in the eco-region. To expand these analyses to include the entire CCS, cooperation between researchers is essential.

The models presented suggest substantial interannual and inter-decadal variability in diet composition and prey consumption, and also indicate that these trends are likely reflective of variability in ocean climate conditions (and possibly prey availability) in the CCS.

Seabirds are useful sampling devices of the marine environment and several investigators have reported that aspects of their biology, including diet characteristics, likely reflect relative prey availability (57, 73-75) as well as characterization of ocean climate conditions (16, 76) (Abraham and Sydeman in press). This is considered in greater detail in chapter 8.

5.7 Intra-annual Variations in Diet Composition

The diet composition and prey consumption models outlined above describe variations in the diet of marine birds both over years (interannual) and over decades (inter-decadal).

Diet can also vary at smaller temporal scales, such as within a year (intra-annual). Smaller timescales allow a glimpse of more subtle patterns of prey consumption that might be missed when examining the big picture. These short-term changes in prey resources can be important to the reproductive success and survival of seabirds, may increase our understanding of the life cycles and population dynamics of their prey species, and can contribute to our understanding of long-term trends in prey resources.

The diet of many seabird species changes between winter and the breeding season due to annual cycles of prey abundance. In many species this includes a change in the trophic level of their prey, meaning that they are eating “higher up on the food chain” during part of the year. For example, Common Murres in central California feed primarily on small fish during the spring and summer, while in the winter they also depend on krill (71, 72).

The prey of marine birds also changes within seasons. During the breeding season, when adults are often bringing prey items into the colonies for their chicks on a daily basis, these changes can be tracked closely. Seasonal changes in the prey fed to chicks have been shown for many seabird species in the CCS from British Columbia to the Gulf of Mexico (77, 78).

On Triangle Island in Southern BC, Cassin’s Auklets switched from copepods to fishes during the course of the season in several years. In other years, however, fishes were not an important part of the diet at any time during the chick-rearing period (79). When rockfish are present in the diets of Rhinoceros Auklets on Año Nuevo Island, in central California, they are typically only an important prey item early in the season (PRBO, unpublished data).

Changes are also seen in other areas of the North Pacific such as the Sea of Japan and the Gulf of Alaska (80, 81). In some cases, these seasonal diet changes may represent the appearance or disappearance of higher quality prey thereby altering the total caloric or nutrient intake of chicks (80, 82).

On the Farallon Islands, Common Murres primarily feed their chicks small forage fish. As shown in Fig. 5.10, the most common prey items that murres feed their chicks are juvenile rockfish, anchovies, and sardines, though the relative importance of these prey groups varies between years and decades. Common Murre diet tracks changes in rockfish populations very closely, as shown by the correlation between the percentage of rockfish taken by murres and the abundance of rockfish estimated by the National Marine Fisheries Service. This within-season relationship is therefore of particular interest as a proxy for rockfish population changes.

When we look at within-season changes in nestling diet, we can characterize the short-term changes in rockfish population dynamics. There are several important questions related to this pattern: Does the proportion of rockfish increase, decrease, or remain steady during the season? And do these within-season patterns differ between years?

Results indicate that the proportion of rockfish in the diet often decreased during a season, sometimes by as much as 50%. These decreases suggest that rockfish become more difficult to catch (i.e. scarcer) later in the summer, possibly because at this time of year juvenile rockfish reach the age or size when they shift to benthic (ocean floor) habitats instead of schooling within the water column. In some years, however, there was no within-season change in rockfish found in chick diet. The timing between the rockfish and murre breeding seasons may be more “matched” in these years, or the population of rockfish may have been larger, with more individuals available even late in the season.

Patterns of rockfish use by murres tend to remain the same for several consecutive years, which may suggest that the changes in patterns may be related to climate regime changes that affect rockfish populations. During our 30-year study period we found that seasonal rockfish use was steady during the 1970s (Fig. 5.15a), decreased within each season in the 1980s (Fig. 5.15b) and early 1990s, and was again steady in the late 1990s – though by this time total quantities of rockfish were very low to begin with (Figure 5.15c).

The decreasing seasonal patterns in the 1980s and early 1990s show several periods of multi-year declines that led to the near absence of rockfish in the late 1990s (Fig. 5.16). In annual diet summaries a major decrease in rockfish consumption was shown after the 1989 and late 1990s regime changes, but surprisingly no diet changes were evident before 1989 despite a major regime shift in 1976-77.

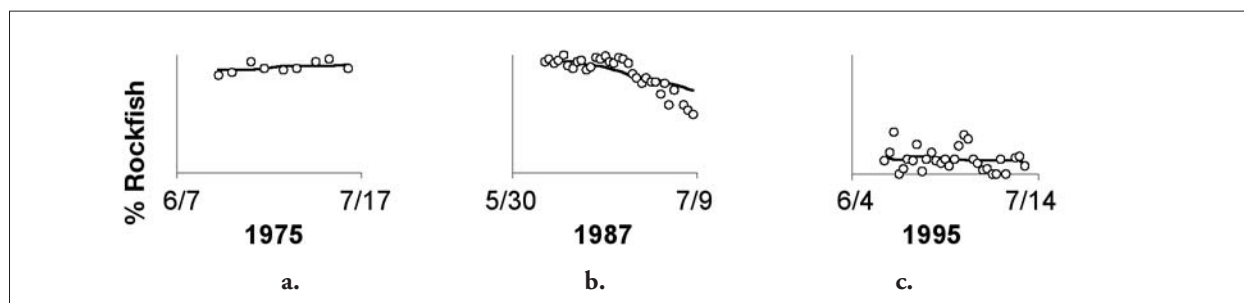


Figure 5.15 – Examples of seasonal changes in rockfish abundance in Common Murre chick diet from 3 years with contrasting patterns: (a) stable and high abundance of rockfish (1975), (b) rockfish decreasing during the season (1987), and (c) stable and low rockfish abundance (1995). Dates are standardized to the height of the breeding season in each year.

The seasonal patterns show that changes to rockfish populations were in fact starting in the 1980s, well before the changes became apparent in the annual diet summaries. The affects were subtle and slow, probably due to the long lifespan of rockfish. By looking at these intra-annual patterns over long time periods, we get a clearer picture of what is happening with rockfish over decades in response to climate regime changes.

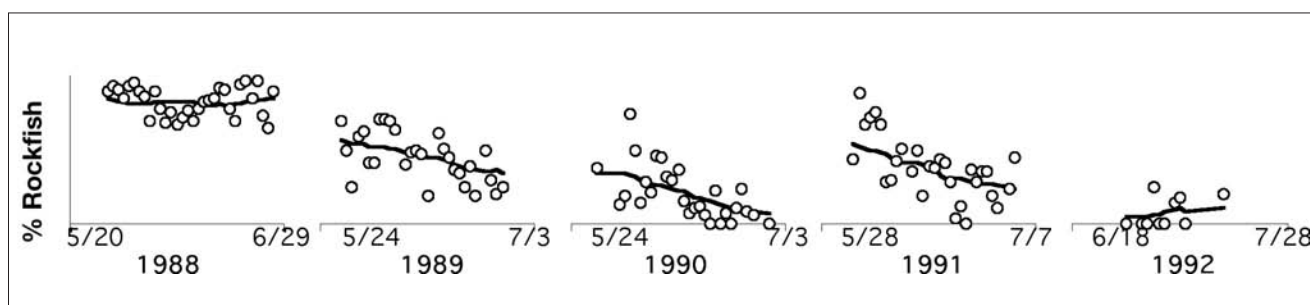


Figure 5.16 – Percent of rockfish in Common Murre chick diet during 5 breeding seasons. Example of multi-year seasonal decreases in rockfish abundance.

Intra-annual changes in prey availability may be important to seabirds that depend on particular prey species during breeding when energy needs are high, or during the winter when food sources may be particularly scarce. Decreases in food availability, or even switching to lower quality prey, can significantly reduce the energy seabirds are getting from their food, or force them to expend more energy finding food. These energy losses can negatively impact chick development and reproductive success (83, 84), and may also impact juvenile and adult survival.

Short-term patterns in prey use can also help give clues about the life cycles of some prey species. Studying fish and plankton populations directly is both difficult and expensive so the population dynamics of many of these species are poorly understood. Decreases in certain prey items can indicate movement of these species either horizontally, out of the foraging range of birds, or vertically, to depths the birds cannot reach. These seasonal changes in prey may also be indicators of the peaks in prey populations.

When seasonal patterns are compared across years, we can learn about changes in prey population over time. As seen in the example of rockfish in the diet of Common Murres on the Farallon Islands, seasonal diet patterns can help us understand the long-term (interannual and inter-decadal) patterns in the diet.

The results from the observations of murre diet presented in this section provided a time series and a level of detail that is unlikely to be found in any direct fish population monitoring program. The importance of short-term patterns in interpreting the effects of long-term patterns highlights the value of considering multiple timescales when looking at the biological effects of climate change, as well as the value of using marine birds as indicators of local ecosystems.

Research and Monitoring Recommendations

1. Investigate prey consumption by seabirds (at short and long timescales) in the CCS to assess seabird prey requirements, seabird-based prey mortality, potential conflicts with current or future fisheries, and the consequences of removal of predatory fish to ecosystem structure and functioning.
2. Continued monitoring of the effects of climate change on diet shifts and population dynamics.
3. Evaluate erosion rates for burrow nesters based on weather.
4. Develop programs that enable regional comparisons of diet.
5. Establish standardized methodologies for use in monitoring diet and prey consumption, including defining which reproductive, diet, and climate parameters are essential to monitor.

Conservation and Management Recommendations

1. Integrate seabird prey requirements into fishery management plans.
2. Investigate seabird prey requirements prior to opening new fisheries.

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The California Current Marine Bird Conservation Plan Chapter 6

Predators, Competitors, Disease, and Human Interactions:
“Top-Down” Control of Seabird Population Parameters and Population Dynamics



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*Predators, Competitors, Disease, and Human Interactions:
“Top-Down” Control of Seabird Population Parameters
and Population Dynamics*

Version 1.0

Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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CHAPTER 6: PREDATORS, COMPETITORS, DISEASE, AND HUMAN INTERACTIONS: “TOP-DOWN” CONTROL OF SEABIRD POPULATION PARAMETERS AND POPULATION DYNAMICS

Marine birds in the Pacific are faced with many threats, on land and at sea, natural as well as anthropogenic in nature.

Natural threats include: ecological factors that limit population growth, large-scale climate change, disease, parasites, and marine biotoxins.

The most serious anthropogenic threats include loss or degradation of habitat, human disturbance, introduced species, oil and other marine pollution, contaminants, and fisheries interactions. Fisheries can impact seabirds, both directly and indirectly. Direct effects include entanglement in gear or hooking, leading to injury and/or drowning. Indirect effects may be caused by a reduction in seabird prey stocks, or by fisheries targeting adult/reproductive fish that might reduce the spawning population and cause a reduction in the juvenile fish that seabirds prey upon.

Other indirect effects may include disturbance to seabirds at colonies, oil contamination from vessels, and the introduction of debris into the marine environment.

In this section we discuss several “top-down” effects on seabird populations of the CCS, including predation, competition, disease, and fisheries.

6.1 PREDATORS

Predation at Sea

Predation on marine birds at sea is less commonly observed than land-based predation, as the wide distribution of birds at sea makes it difficult to make these rare observations. Inter-avian predation is not well described at sea, likely because predators, primarily large larids or raptors, have more difficulty capturing prey like small alcids on the ocean than on land. At sea, alcids can avoid gulls by diving, and are much more susceptible to predation on land where they are less maneuverable.

At sea, predation on North Pacific seabirds by marine mammals has been well described. For pinnipeds, documented records of predation include those of Northern Fur Seals on Rhinoceros Auklets, Marbled Murrelets, and Black-footed Albatross; Stellar-Sea Lions on Glaucous-winged Gulls; and California Sea Lions on Common Murres (see references in Long and Gilbert (1)). However, these observations are uncommon and seabird prey is often assumed to compose a minor portion of pinniped diet. Similar patterns for Killer (Orca) Whales have been observed, with observations of subadults rarely feeding on alcids. Quantitative diet analyses of Orcas in British Columbia and Washington suggest that seabirds are not a significant prey resource for this species (2).

Predation on Land

Direct predation of adult seabirds at their breeding colonies in the California Current has been widely documented. Raptors, primarily Peregrine Falcons and to a lesser extent Bald Eagles and owls, are often observed preying on auks as they leave and arrive at several colonies, including Triangle Island (Centre for Wildlife Ecology, Simon Fraser University, unpublished data), Tatoosh Island (3, 4), Southeast Farallon Island (SEFI), and Ano Nuevo Island (PRBO unpublished data).

For Rhinoceros Auklets on Tatoosh Island and Ano Nuevo Island, Peregrine Falcon predation has been shown to have population level effects on the entire colony (3) (PRBO unpublished data). Predation of small auklets and storm petrels by larger gulls has also been well documented. On SEFI Western Gulls often prey on Cassin’s Auklets and Ashy Storm-Petrels, and increases in gull numbers have mirrored decreases in these prey species throughout the last 3 decades (5). Burrowing Owls have also been observed to prey on Ashy Storm-Petrels on SEFI (5).

Predation on seabird eggs and chicks at breeding colonies is conducted by a large suite of predators, namely gulls, corvids, and rodents. In addition to preying on adult birds, large gulls will often take eggs and chicks of surface nesting seabirds (6-8).

Spear (6) found that many of the Western Gulls observed taking Common Murre and Brandt’s Cormorants on SEFI were specializing in this prey resource.

Corvids, primarily Common Ravens, are also major predators of seabird eggs at certain coastal sites. Raven predation on some murre and cormorant colonies in central California has been shown to reduce productivity (8)(PRBO unpublished data). As corvid populations in the western United States have increased dramatically in recent decades (46), it is possible that predation pressure on seabird eggs by corvids may increase in the future.

Native rodents, specifically deer mice (*Peromyscus sp.*), have been observed to prey on the eggs of crevice nesting seabird eggs of Rhinoceros Auklets, Xantus’s Murrelets, and Ancient Murrelets at breeding colonies in the California Current (9-11). Blight (9) noted high egg predation by deer mice during egg neglect of parents during a year of low ocean productivity.

Large introduced mammals, rats and cats, have caused major damage to seabird colonies through predation on eggs, chicks, and adult crevice nesting seabirds. The issue of predation by introduced species is detailed in the Introduced Species section of this document (Chapter 7, section 7.3).

In addition to direct predation, indirect predation effects through disturbance events or interactions between suites of predators can also have great effects on seabirds at their breeding colonies in the California Current. On Tatoosh Island, for example, disturbance of breeding Common Murres by Bald Eagles has caused increased levels of egg and chick predation by large gulls (4). At coastal Common Murre colonies in central California, disturbance of breeding birds by Brown Pelicans has facilitated egg predation by Common Ravens and gulls (8, 12).

6.2 COMPETITORS

Seabirds often forage in multi-species feeding associations. These associations, or feeding flocks, create visual cues for food finding and make more prey accessible due to the differentiation of feeding methods (13). Specifically, pursuit divers often initiate these aggregations and allow them to persist by driving prey to the surface (14, 15).

However, while different individuals and species can facilitate foraging for each other, they also compete for food. Intra-specific food competition can have direct effects on seabird population dynamics and has been suggested to have greater influence than interspecific food competition (16). Lewis et al. (47) showed how Northern Gannets at large colonies in the U.K. must forage longer to find food than birds at small colonies. In addition, marine mammals in the California Current consume similar prey to seabirds in significant quantities (48).

Seabirds in the California Current also compete for nest sites. Cavity nesting alcids from the Farallon Islands compete for burrow and crevice sites, with larger species usurping nest sites, pithing eggs, and killing young of smaller Cassin’s Auklets (17). As Common Murre populations expand in large colonies like those on the Farallon Islands, they outcompete Brandt’s Cormorants and exclude them from nesting at high densities within murre colonies (PRBO unpublished data).

In addition, marine mammals, particularly California Sea Lions, can exclude gulls, cormorants, and oystercatchers from breeding when their haulout areas expand (18).

6.3 DISEASE AND TOXINS

Viral, bacterial, algal, and fungal diseases impact seabirds. The incidence of disease outbreaks may increase in the next decade, given the many stressors plaguing the physiologic functions and organ systems that maintain homeostasis and health in seabirds.

The causative agents of diseases are found naturally in the environment, but disease typically has not been prevalent thus far due to the balance and co-evolution between potential pathogens and their hosts (49-50). However, as perturbations occur with increasing frequency in the marine ecosystems inhabited by seabirds, disease-associated morbidity and mortality will likely become more prevalent as the “host-pathogen” balance sways in favor of the pathogens.

Changes in ecological health are beginning to result in the emergence of new infectious diseases affecting seabirds (e.g. West Nile Virus), the reemergence of historical diseases such as exotic Newcastle's disease, changes in the geographic range of disease distributions in Hawaiian avifauna (e.g., malaria), and pathogens altering their mechanisms of infecting seabirds, such as in botulism transmission in pelicans.

Source: (<http://pacific.fws.gov/salton/saltn96.htm>).

Because large segments of seabird populations congregate in small geographic zones annually for breeding or foraging purposes, they are at great risk of rapid and extensive disease transmission. This, coupled with the fact that many seabird species are typically wide ranging, suggests that seabirds may serve the role of sentinel species, the proverbial “canaries in the coal mine.” The aforementioned characteristics make it likely that seabirds indicate the health and condition of the marine ecosystems.

The seabird sentinel species concept can be useful for providing an “early warning” system for emerging diseases and to monitor the course of disease-related activities requiring prevention, remediation, or control. Diseases that have historically impacted seabird populations in CA, OR, WA, AK, HI, and the Pacific Islands include: 1) bacterial diseases Salmonella, Chlamydia, Erysipelas, and Avian Cholera; 2) viral diseases Avian pox, Exotic New Castle disease, and Avian influenza; 3) fungal disease Aspergillosis; 4) parasitic disease Eustrongylidosis; and 5) biotoxins Domoic acid or Amnesic shellfish poisoning, Saxitoxin or Paralytic shellfish poisoning, and the Avian botulism toxin.

Large-scale mortality of hundreds to thousands of seabirds has historically occurred in the CCS region. According to information provided by the National Wildlife Health Center (NWHC), USGS, in Madison, WI, major mortality incidents have been caused by aspergillosis, botulism, and avian cholera, resulting in 2,360 seabird deaths in CA, OR, WA, AK, HI, and the Pacific islands between 1980 and 1989. This number more than tripled to 7,908 between 1990 and 1999. Although not of great concern to populations of seabirds numbering in the tens of thousands or more, the number of cases seen by the NWHC is certainly a small percentage of the actual number of birds that die in the wild. Furthermore, the recent trend towards increased documented mortality due to disease may be cause for concern and indicative of environmental problems.

In a given decade, multiple mortality events occur and relatively few birds are recovered, because many die at sea, sink, or are scavenged if they wash ashore. Of those birds recovered, few are sent to the NWHC for diagnosis; of those sent to the lab, some are not fresh enough to conduct proper disease testing. In fact, over 10,000 birds analyzed at NWHC from 1980-1994 had no diagnosis; this was due, in part, to the condition of the received carcasses. Collectively, these factors systematically bias the number of reported deaths. This suggests that the numbers of seabird disease-associated deaths may actually be orders of magnitude larger than what is reported by the NWHC.

Another gap in information regarding disease-induced seabird mortality may be related to the manner in which much of seabird mortality data are collected, namely beached bird survey programs.

Many survey programs exist (i.e. Gulf of the Farallones National Marine Sanctuary Beach Watch Program, Monterey Bay Beachcombers, and Coastal Observation and Seabird Survey Team in Washington State), each of which documents seabird mortality along regularly surveyed stretches of coast. However, because these projects record low-level, typically background mortality rates, they do not routinely result in the same investigative response or public awareness as do large-scale die-off incidents. Thousands of dead seabirds are documented annually in beached bird surveys. Unfortunately, the cause of mortality for many of these birds is undetermined.

Additionally, in many cases mortality recorded in these surveys is not included in morbidity or mortality reports provided by the NWHC whenever they did not conduct diagnostic testing of the carcasses. Despite the best efforts of volunteers and trained beached bird survey staff, diagnoses remain undetermined for most beach-cast birds because many carcasses are decomposed or scavenged by the time they are observed on beaches.

Another common limiting factor in diagnosing diseases of seabirds is the lack of appropriate diagnostic techniques. While testing techniques have improved significantly in the past 20 years, some pathologies, such as that for domoic acid toxicosis, remain difficult to ascertain.

Finally, some morbidity or mortality incidents are handled by state or local agencies and biologists. If these agencies possess sufficient internal diagnostic capacity, they typically do not send samples to the NWHC. In these cases, diagnostic testing has been conducted and results are not added to the database maintained by USGS because the mortality incident was handled locally.

Despite data gaps that exist in documenting the extent of disease-associated seabird mortality in the United States, one fact remains indisputable; in the past 10 years, seabird disease-associated mortality has increased. Anthropogenic activities are undoubtedly playing a role in this increase in disease emergence amongst seabird populations.

While bacterial and viral diseases have been historically documented as sources of mass mortality of seabirds, biotoxins have only recently been recognized as a significant problem.

Biotoxins pose a great threat to seabirds when high levels produced during algal blooms accumulate in seabird prey (fish). Many scientists believe that biotoxins are becoming more prevalent as agricultural runoff, pollution, and nutrient loading create ecological conditions favoring algal blooms. Increased frequency and intensity of algal blooms can, in turn, lead to more biotoxin mortality incidents (21). The first documented Domoic acid (DA) associated mortality in California seabirds was in 1991 and killed hundreds to thousands of birds, primarily brown pelicans and Brandt’s cormorants (22). A variety of other algal blooms have occurred along the California coastline, most recently in 2002, including another DA toxicosis incident in which an estimated 1,000 California brown pelicans died in southern California and Mexico (F. Gress, pers. comm.).

A unique outbreak of botulism at the Salton Sea, California, has killed thousands of brown and white pelicans over the past four years. Typically, botulism outbreaks require that birds ingest biotoxins found in maggots that have eaten infected carcasses (51). In this recent outbreak, however, normal disease transmission did not occur. Instead, pelicans became infected while eating live fish (*Tilapia sp.*). This is the first recorded instance of botulism occurring through this transmission mode.

This disease outbreak raises the question of whether environmental changes such as increased pollution or salinity levels at the Salton Sea have enabled a pathogen to evolve a new mode of transmission and infection; alternatively, it is possible that the host susceptibility to this disease has changed due to a compromised immune status in pelicans.

As more ecological perturbations occur in the marine environment, alterations in disease expression and changing relationships between hosts and infectious organisms are likely to occur. Such changes could be expressed in three ways: 1) diseases could spread to new species that are immunologically naïve, thereby establishing new host species; 2) diseases that currently coexist at low background levels in species could increase in pathogenicity in conjunction with declines in immunocompetence associated with increased environmental stressors; and 3) diseases that are geographically restricted could spread into different regions, thereby broadening their distribution. All of these situations have the potential to result in disease outbreaks and large-scale seabird mortality.

Another group of diseases of particular concern are the vector borne diseases, specifically arboviruses (diseases transmitted by mosquitoes or other arthropods). Theoretically, seabirds would be expected to be relatively safe from arboviruses since standing water sources required for mosquito reproduction are usually less common near seabird colonies, especially on off-shore rocks and islands where seabirds tend to nest. However, the prevalence of avian malaria and avian pox demonstrate that seabirds are susceptible to mosquito-borne diseases. Since it is unlikely that seabirds have much, if any, exposure to West Nile virus (WNV) to date, their immune systems are likely naïve, making them very susceptible to this newly emerging disease.

Mosquitoes do occur on many of the nearshore islands on which seabirds nest, and it is also possible that mainland mosquitoes could be transported to large offshore breeding colonies via storms or wind. Seabird responses when they become exposed to WNV are currently unknown; they may be immunocompetent, develop titers, and survive or, alternatively, succumb to this disease. To date, the most severely impacted species have been corvids and raptors although some marine species including pelicans, skimmers, herons, cormorants, and gulls have recently been shown to be susceptible to WNV (<http://www.promedmail.org>) raising concern for other species.

As WNV becomes established on the West Coast, mortality of some terrestrial avian species is almost certain, but the disease could also affect other colonial nesting seabirds. Inland nesting seabirds such as Marbled Murrelets (*Brachyramphus marmoratus*) may be at risk due to the high mosquito densities in terrestrial habitats.

Disease outbreaks in seabirds are most common and most devastating during the breeding season when high densities of birds at colonies facilitate pathogen transmission. Seabird diseases are transmitted through a variety of routes including fecal-oral, aerosol-inhalation, inoculation through trauma, bites, or scratches, and via vectors (i.e. arboviruses, tick-borne diseases).

Direct seabird morbidity or mortality secondarily through scavenging sick or freshly dead carcasses can also play a role in disease transmission. For those species of seabirds that congregate in closely associated groups or forage in flocks, the likelihood of disease transmission among individuals increases. This is exacerbated during the breeding season when adults can easily infect chicks.

Post-breeding dispersal movements of seabirds provide another mode by which diseases could be transported hundreds if not thousands of kilometers from their place of origin, thus potentially exposing large numbers of individuals from many different species. Diseases pose the greatest threat to small isolated populations of seabirds where the spread of a single disease at one colony could lead quite easily to a local island extinction and potential loss of genetic diversity.

The lack of available information about diseases and the immune status in free-ranging populations of seabirds emphasizes the need for collecting more baseline health information. Serological surveys for diseases in free-ranging seabird populations could greatly enhance our understanding of diseases that currently pose risks to populations and those diseases that birds have previously acquired immunity against.

The NWHC maintains an excellent national database of disease outbreaks and die-off incidents but dead birds are not always made available to the NWHC lab for diagnostics, thereby creating gaps in information. A single comprehensive national seabird disease morbidity and mortality database could incorporate information from local, regional, and national (already being conducted by NWHC) investigations and enhance efforts to better understand and document chronic seabird disease-associated mortality through collaborative efforts with beached bird survey groups.

Establishing better regional monitoring programs, coordinating epidemiological disease outbreak investigations, and initiating a seabird stranding network similar to the NMFS marine mammal stranding network would greatly assist seabird disease surveillance and documentation of emerging seabird pathogens that result in morbidity and mortality. Ultimately, this valuable information will assist resource managers in making important management decisions in an effort to balance seabird resources and other interests.

6.4 FISHERIES EFFECTS ON SEABIRDS

The California Current System (CCS), as a highly productive marine ecosystem, has a high abundance and diversity of marine mammals, sea turtles, seabirds, and fishers. This has resulted in encounters and conflicts between certain fisheries and marine wildlife, in some cases causing mortality of numerous marine animals, including seabirds.

Fisheries have existed for centuries, although only within the last few decades has there been growing awareness of the impact of fisheries on seabird populations. Direct injury or mortality by fishing activities is one of the most serious threats currently faced by seabirds that breed and feed within the CCS, and there is a high potential that this problem will intensify in the future as the demand for seafood increases with a growing human population.

Not only is it crucial to identify the existing problem areas and seek solutions to these conflicts, but it is also necessary to keep informed of developing or future fisheries that might impact seabirds, both directly as well as indirectly (see Chapters 5 and 7 for a description of indirect impacts on seabirds).

Seabirds that breed and feed in the CCS region are affected by commercial fisheries by several factors, including: (1) entanglement in deployed or discarded fishing gear, (2) competition for the same fish or invertebrate species (discussed in Chapter 5), and (3) changes in ecosystem structure produced by commercial fisheries activities due to biomass removal or habitat degradation (23).

Fisheries target a diverse group of species and use a variety of vessels and gear including pots, throw and dip nets, and harpoons that catch fish at a small scale. Purse seines, trawls, longlines, and drift gillnets target larger fish and at a correspondingly larger scale. Seabirds are killed incidentally in all oceans of the world in almost all gear types used by fisheries. Fishing activity within the U.S. portion of the CCS occurs within state waters (from the coastline to 3 miles from shore), and within federal waters (3-200 nautical miles offshore). Several fisheries also operate beyond the 200-nautical mile Exclusive Economic Zone (EEZ) and target highly migratory species such as tuna, swordfish, sharks, and billfish.

Direct seabird mortality, caused by entanglement in gear or hooking (leading to injury and/or drowning), can seriously jeopardize seabird populations. A select few fisheries pose a serious threat to certain seabird species (Table 6.1). Only eight of these 17 fisheries have ongoing observer programs.

Fisheries that pose the greatest risk for direct seabird mortality in the CCS region include those using set and drift gillnets, and pelagic and demersal longlines.

Table 6.1 – Fisheries that operate in the CCS that have documented seabird bycatch and presence (Y)/absence (N) of an observer program associated with each fishery (the years in operation are in parentheses).

FISHERY	SEABIRD SPECIES DOCUMENTED	OBSERVER PROGRAM
CA angel shark/halibut set gillnet	COMU, CORM SP, LOON SP, GREBE SP, ALCID SP	Y (1990-1994)
CA other species, large mesh set gillnet	CORM SPP.	Y (1983-1989)
WA Puget Sound Region salmon drift gillnet	COMU, RHAU, PIGU, MAMU	Y (1990-1994)
CA/OR thresher shark/swordfish drift gillnet	NOFU, unidentified spp.	Y (1990-present)
U.S. West Coast (CA/OR/WA) pelagic longline	BFAL	Y
CA/OR/WA commercial passenger fishing vessel	BRPE, LETE, MAMU, cormorant spp.	Y (short-term programs)
CA/OR/WA groundfish trawl		Y (2001-present)
Baja California sardine/anchovy seine net	BVSH, XAMU, CRMU	N
Baja California lobster and crab trap	BRAC, PECO, DCCO	N
Baja California gillnet for finfish and shrimp	BRAC, PECO, DCCO, XAMU, CRMU, CAAU, BVSH	N
Baja California longline	MAFR, BRPE, DCCO, BRAC, PECO, LAAL	N
Canada Halibut/Sablefish longline	BFAL, NOFU	Y (1999-present)
BC - Longline (ZN)	BFAL	Y (1999-present)
BC - Trawl - Midwater	STSH	Y (started 02/03)
BC - Schedule II Dogfish	gull spp.	Y (started 1999)
Vancouver salmon test fishery	COMU	
BC - Gillnet	PALO, COLO, SOSH, PECO, BRCO, COMU, RHAU, MAMU, PIGU, CAAU	Y (1995 - present)

Species abbreviations: **ALCID SPP**, alcid species; **BFAL**, Black-footed Albatross; **BRCO**, Brandt’s Cormorant; **BRPE**, Brown Pelican; **BVSH**, Black-vented Shearwater; **CAAU**, Cassin’s Auklet; **COLO**, Common Loon; **COMU**, Common Murre; **CORM SPP**, cormorant species; **CRMU**, Craveri’s Murrelet; **DCCO**, Double-crested Cormorant; **GREBE SPP**, grebe species; **GULL SPP**, gull species; **LAAL**, Laysan Albatross; **LETE**, Least Tern; **LOON SPP**, loon species; **MAFR**, Magnificent Frigatebird; **MAMU**, Marbled Murrelet; **NOFU**, Northern Fulmar; **PALO**, Pacific Loon; **PECO**, Pelagic Cormorant; **PIGU**, Pigeon Guillemot; **RHAU**, Rhinoceros Auklet; **SOSH**, Sooty Shearwater; **STSH**, Short-tailed Shearwater; **XAMU**, Xantus’s Murrelet.

Although there are few fisheries that account for most of the seabird mortality, these can severely impact the health of some seabird populations. Additionally, there are 12 other fisheries that have a high potential of seabird mortality because of the type of gear used and the location of the fishery (Table 6.2), and few of these have ongoing observer programs.

Table 6.2 – Fisheries that operate in the CCS that have potential seabird bycatch.

FISHERY	TARGET SPECIES	OBSERVER PROGRAM
WA/OR lower Columbia River salmon drift gillnet	salmon	Y (1980s, 1990-93)
CA emerging tuna with surface drift net	tuna	Y (1999)
WA Willapa Bay salmon drift gillnet	salmon	Y (1980s, 1990-93)
WA Grays Harbor salmon drift gillnet	salmon	Y (1980s, 1990-93)
WA/OR gillnet	various species	N
OR blue shark surface longline	blue shark	N
OR swordfish surface longline	swordfish	N
WA/OR North Pacific halibut longline/set line	halibut	N
CA/OR/WA groundfish, bottomfish longline/set line	groundfish, bottomfish	N
CA shark/bonito longline/set line	shark, bonito	N
CA/OR/WA salmon troll	salmon	N
CA longline	pelagics	N

Another direct effect is seabird mortality or injury from lost or discarded nets or other fishing gear. Lost nets, such as drift gillnets, can travel long distances, affecting birds over vast regions.

Monofilament poses a serious threat to seabirds. This material is difficult to see, and is almost indestructible. Many birds are often seen on beaches with monofilament around their legs, wings, or head. Even though this may not cause immediate mortality, severe injuries may develop from the monofilament cutting into the flesh and becoming infected, and may impede with foraging or other behavior (mating).

Hooks are often associated with the monofilament. Fishermen in both commercial and recreational hook and line fisheries frequently cut the line after a bird has taken the bait and hooked itself, leaving the hook in the bird with trailing monofilament line. Hooks can become embedded in the mouth or in body parts. This type of injury usually results in the death of the bird affected.

In California, Brown Pelicans are one of the primary species affected. During 2002, at least 150 pelicans were affected by hooks or line entanglement at the Santa Cruz City Pier, resulting in the death of many of these rescued birds (24).

Gillnets and Seine Nets

Both set and drift gillnets pose a serious threat to seabirds (Fig. 6.1), the use of which has resulted in the incidental catch of numerous seabirds of various species. The majority of the seabirds affected are diving and surface-seizing species, of the family Alcidae (25), although cormorants are also commonly caught (26).

One seabird species that has been severely impacted by fishing activities in central California is the Common Murre (*Uria aalge*). Populations of this species declined 53% between 1980 and 1986, due to oil spill and gillnet mortalities (27); populations continued to have high gillnet mortality in the 1990s (26, 28).

One of the most serious cases of seabird mortality associated with a specific fishery occurred with the North Pacific high seas drift gillnet fishery. It is estimated that more than 500,000 seabirds were killed by this fishery in 1990 (29, 30). Although the species most affected by this fishery were the Sooty Shearwater (*Puffinus griseus*) and the Short-tailed Shearwater (*P. tenuirostris*), up to 23 species have been taken in the Japanese salmon drift gillnet fishery (31), including large numbers of Black-footed Albatross (*Phoebastria nigripes*) and Laysan Albatross (*Diomedea immutabilis*) (30). The Japanese squid driftnet fishery reported a bycatch of almost 10,000 Black-footed and Laysan Albatross in 1990 alone (52). As a result of this, the use of drift gillnets was banned in 1992 (29, 32, 33).

FISHERY								
open ocean			coastal			near shore		
	PELAGIC LONGLINE (O)	TROLL (O,C)	DEMERSAL LONGLINE (C)	TRAP (C)	TRAWL (C)	PURSE SEINE (C)	GILLNET DRIFT (C)	SET (NS)
BYCATCH	++	-	+	+	-	-	++	++
OFFAL	(+)	(+)	++	(+)	++	+	-	-
	++ big effect		+ effect	(+) possible effect			- no effect	

Fig. 6.1 – Seabird interactions with different types of fishing gear (from Parrish et al. 2002).

Longlines

Longlining, which targets mainly tuna and swordfish, is a more cost-effective method of catching large fish, but many seabirds are also caught in the process (34, 35). Longline fishing has increased rapidly in the Pacific because of the ban on high seas drift netting in the early 1990s and an increasing demand for tuna, swordfish, and shark. As a result of increased fishing pressure on pelagic species, such as tuna, billfish, and oceanic sharks, the Pacific Fisheries Management Council has banned pelagic longline fishing within the U.S. EEZ zone. However, longlining outside of the EEZ still poses a significant threat for seabirds within the CCS region.

Longline fisheries affect between 40 and 60 species of seabirds globally, most of which are procellariiformes, and particularly albatross (34). Albatross are surface-feeding birds, and bycatch occurs most often when birds are feeding actively in the vicinity of longline vessels, especially those targeting swordfish. Fishing for this species requires the use of bait that is set at more shallow depths (between 5-60 m), resulting in a line that is more buoyant than that for tuna, with slower sinking rates (35).

California and Washington

Large mesh gillnets (both set and drift gillnets greater than 3.5 inches [8.9 cm]) are known to incidentally take seabirds (26, 28). In California, the angel shark/halibut set gillnet (8.5 in mesh) has documented seabird bycatch for at least 7 species, including alcids, cormorants, and loons (28) (Table 6.1). The thresher shark/swordfish drift gillnet fishery has documented bycatch of Northern Fulmar (*Fulmarus glacialis*), although these numbers have been relatively small (26).

Between 1979-1987, the set gillnet fisheries caused the mortality of at least 75,000 Common Murres and undocumented numbers of cormorants, Pigeon Guillemots, and non-nesting grebes, loons, and Sooty Shearwaters in nearshore areas of Monterey Bay, Gulf of the Farallones, and Bodega Bay, before regulations moved the fishery offshore and instituted area closures (36, 37). In 1997, the Central California set gillnet fishery was re-examined when local monitoring efforts detected an estimated 1,000 to 3,000 stranded Common Murres annually south of Monterey Bay (28). Gillnet efforts had increased substantially between 1994-1998 and had shifted inshore in the bay (28), prompting new gillnet fisheries closures in 2000 (California Fish and Game Code Section 8664.5). In the Southern California Bight, gillnetting has killed smaller numbers of seabirds, particularly cormorants, between 1983-1994 (38).

In the drift gillnet salmon fisheries in Washington, Common Murres were the most abundant alcid killed, although other species included Rhinoceros Auklet (*Cerorhinca monocerata*), Pigeon Guillemot (*Cepphus columba*), and the federal and state listed Marbled Murrelet (*Brachyramphus marmoratus*) (39), (Table 6.1).

In the coastal drift gillnet fishery of Washington, Melvin et al. (25) demonstrated that there was a significant reduction in seabird bycatch (up to 70-75%), of mainly Common Murres and Rhinoceros Auklets, when visual (visible mesh panels) and acoustic alerts (pingers) were used in this fishery.

Regulatory difficulties exist with the fishery in the shared waters of Canada, Washington, and the Treaty Tribes because of these three governing entities. Within Washington, both state and tribal governments manage the fishery. Each of these governments enforces different regulations, with tribal regulations being less strict than those of the state. The tribal government does not enforce a length limit for gillnets and set nets from shore (29). Furthermore, the Washington Treaty Tribes argue that they are not bound by the Migratory Bird Treaty Act, and are therefore “allowed” bycatch in their fisheries.

Largely due to the high mortality resulting from swordfish longline fishing in Hawaii, this fishery has been closed, since December 27, 1999¹. As a result of this closure, a recently emerging fishery of concern, particularly for albatross mortality, is the U.S. West Coast Pelagic Longline Fishery which occurs outside the 200 nm EEZ (K. Rivera, pers. comm.).

This California-based longline fishery, mostly composed of Vietnamese vessels, will be managed under the Highly Migratory Species Fisheries Management Plan. The vessels that operate within this fishery will be required to have High Seas Compliance Act permits from the National Marine Fisheries Service, as well as a state license if operating out of California (40). Current regulations do not require observers aboard these vessels.

An emerging fishery that may pose a risk for seabirds in the CCS is the California tuna fishery, where surface drift nets are being used (6-7 in mesh size; Table 6.2). This fishery, which began in 1999, uses nets that were formerly used for catching sea bass and were set at the bottom. The current fishery uses these nets at the surface, where the potential for seabird bycatch is very high (41).

Baja California

Seabird mortality in gillnets is not well documented in Baja California (Q. García, pers. comm.). However, the species that have been recorded killed in gillnets off the Baja California peninsula include Brandt's and Double-crested Cormorants, Brown Pelicans, Common Loons (*Gavia immer*), Pacific Loons (*Gavia pacifica*), and Western Grebes (*Aechmophorus occidentalis*) (37). As diving species, Black-vented Shearwaters, Xantus's Murrelets, Craveri's Murrelets, and Cassin's Auklets are at high risk (42).

In Baja California gillnets are legal fishing gear and are used for a variety of small-schooling fish species including: mullet, sea bass, sierra mackerel, corvina, and shrimp inside coastal lagoons. The average net length used by fishermen in the region is 60 to 100 m. Because most of these fish species are unregulated and the catch is used primarily for local consumption, there is little data on the numbers of gillnets or fishing effort for the Baja California peninsula, and therefore no information on seabird bycatch. However, this type of nets does result in bycatch of large numbers of alcids off the western U.S. and it is highly probable that there is considerable bycatch of seabirds off Baja California.

Long gillnets are used to catch sharks, tuna, and billfish in waters more than 50 nautical miles from shore. These nets can be up to 2,000 m long and 36 m high with a minimum mesh size allowed of 457 mm. This fishery takes place year-round, mostly around the Revillagigedo Archipelago. No records of mortality rates of seabirds on offshore gillnet fishing gear are available. If bycatch occurs, it is most likely to affect albatrosses, shearwaters, pelicans, frigatebirds, and cormorants. Since the mid-1980s, a coastal gillnet fishery has developed and expanded along the western coast of Baja California with potential impacts on diving species (29, 42).

The Mexican tuna fishery fleet, which uses seine nets, is the most important tuna fleet in the Eastern Tropical Pacific. Tuna is the second most important fishery in Mexico, in terms of weight landed after the sardine fishery, and the second in the value of the weight landed, after the shrimp. This fishery takes place in offshore waters inside the EEZ of Mexico. Vessels are sophisticated technologically and have capacities ranging from 150 to 1,300 metric tons. This fishery has long been known to have high levels of marine mammal bycatch. However, there is no estimate of the seabird bycatch, although it is believed to be small.

In Baja California, pelagic sharks, tuna, and sailfish are caught using longlines. The maximum length allowed is 85,000 m, with 1,500 hooks per line; in practice, longlines in this region are usually shorter with fewer hooks, frequently set at depths of 100m. The size of the pelagic long liner fleet size operating off the Baja California Peninsula is small, 15 boats in 1996. However, because of the length of the longlines and the large number of hooks deployed by each vessel, even a small fleet can cause significant seabird mortality. In this region, the fishery poses a danger to albatrosses, pelicans, cormorants, and frigatebirds, primarily during the hook baiting and deployment phase. This fishery takes place all year, mostly around the Revillagigedo Archipelago and off the southern Gulf of California. No data on actual seabird bycatch numbers are available for this fishery.

Canada

The two species that are most commonly found in gillnets in British Columbia are Common Murres and Rhinoceros Auklets (43). Other species also found in gillnets include loons (both Pacific and Common), Sooty Shearwaters, Pelagic and Brandt's Cormorants, Pigeon Guillemots, Marbled Murrelets, and Cassin's Auklets. The DFO manages a salmon test fishery off Vancouver Island, which is carried out in September and October every year since 1995. This test fishery regularly kills Common Murres in its seine and gillnets (43).

In British Columbia, longline fishing for halibut and sablefish has a high documented bycatch of Blackfooted Albatross, and the second highest rate for this species in the Pacific Halibut fishery (44).

6.5 RESEARCH AND MONITORING RECOMMENDATIONS

Bycatch and other Fisheries Interactions:

1. Foster communication with agencies involved in fisheries management to keep informed of potential or emerging fisheries that may affect seabird bycatch in the CCS.
2. Use population dynamics models to estimate and evaluate the potential impacts of fisheries bycatch on seabird populations.
3. Identify current or potential impacts of aquaculture (e.g., salmon farming) on seabirds, including change in predator-prey interactions and competition.
4. Identify the spatial and temporal overlap between seabird foraging “hotspots” and fisheries in the CCS.
5. Collate and distribute information regarding seabird species that are affected by fisheries bycatch.
6. Investigate how international fisheries affect seabirds of the CCS.
7. Model population decline of seabird species (e.g., Sooty Shearwaters, Black footed Albatross) in relation to both bycatch and climate/ecosystem change.
8. Identify areas of high boat traffic that have potential or actual conflicts with seabirds at-sea.
9. Continue, or begin, population monitoring programs of seabird species that are impacted or have the potential for being impacted by fisheries.
10. Conduct studies on foraging ranges and diet of seabirds (e.g., Short-tailed, Black-footed, and Laysan albatross) which are often victims of bycatch.
11. Assess each fishery in U.S. Pacific waters for seabird bycatch. Design mitigation measures that are fisheries- and species-specific to minimize or eliminate bycatch.

Disease, Parasites, and Biotoxins:

1. Identify the main seabird diseases, parasites, and biotoxins responsible for seabird mortality events and model their effects on seabird population dynamics.
2. Conduct surveys for diseases present in adult seabirds, fledglings and juveniles to evaluate how diseases are affecting different age classes of seabirds.
3. Develop a standardized collection protocol for unusual mortality events for both live and dead birds.
4. Develop a seabird stranding network (similar to the Marine Mammal Stranding Network) to facilitate pathological and toxicological sampling.
5. Develop collaborations with the USGS – Wildlife Health Laboratory and local agency and university partners to facilitate necropsies and pathological examinations during seabird mortality events.
6. Coordinate dispersal of dead seabirds for research and specimen archival.
7. Establish an archival freezer for future use studies of seabird genetics, pathology, parasitology, etc.
8. Determine whether parasite loads, disease prevalence, or pathogen prevalence is greater in habitats that are more fragmented, more disturbed, and/or more polluted.
9. Evaluate breeding success in relation to contaminants and potential pathogens.
10. Evaluate environmental conditions associated with harmful algal blooms (HABs) and determine whether agricultural run-off and coastal development is contributing to this problem.
11. Conduct research on HABs and the physiological and pathological effects on seabirds.
12. Determine prevalence of West Nile Virus in seabirds and evaluate potential mortality from spread of this disease.
13. Test for prevalence of the following diseases in seabirds in the CCS: New Castle’s, St. Louis, Western Encephalitis viruses.

6.6 Conservation and Management Recommendations

6.6 CONSERVATION AND MANAGEMENT RECOMMENDATIONS

Fishing Interactions and Marine Ecosystem Protection

1. Managers need to be aware of emerging fisheries that could potentially impact seabird bycatch and take action before they become a problem.
2. Examine krill fishing moratoriums in California National Marine Sanctuaries (NMS) and work to establish a CCS-wide ban on krill fishing.
3. Ban fishing for forage species around important seabird breeding colonies and foraging areas.
4. Despite the obvious value of Observer Programs and the necessity of these programs for documenting impacts of fisheries on seabirds and other marine animals, there are few Observer Programs for Pacific fisheries. Fisheries that have a high potential for seabird bycatch need to be identified, and funding secured for observer coverage for these fisheries.
5. Resolution is needed for conflict between tribal gillnet fishing in Washington State and seabird bycatch.
6. Work with appropriate agencies to develop solutions for studying and lessening, as needed, interactions between seabirds and aquaculture.
7. Establish a network of Marine Protected Areas for seabird foraging “hotspots” in the CCS.

Disease, Parasites, Marine biotoxins:

1. Establish a national and international database of seabird morbidity and mortality events of both natural and anthropogenic causes.

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The California Current Marine Bird Conservation Plan

Chapter 7

Other Human-Seabird Interactions



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The California Current Marine Bird Conservation Plan Chapter 7

Other Human-Seabird Interactions

Version 1.0

**Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum**

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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CHAPTER 7: OTHER HUMAN-SEABIRD INTERACTIONS

As discussed in the previous chapter, fisheries are one human-seabird interaction that can have significant direct effects on seabird populations. There are also additional interactions that can have population-level consequences for seabirds in the CCS and, thus, need to be addressed. These include habitat alteration, both terrestrial and marine, species interactions, various pollutants, and direct human disturbance.

Oil pollution is a globally recognized issue; exposure to even small amounts can coat seabird feathers or be ingested, thereby compromising health or killing individuals outright. Garbage is ubiquitous, occurring throughout the world's oceans and coastlines. Plastics are especially problematic as they are often mistaken for food and fed to chicks, which in severe cases can cause starvation.

Human disturbance includes impacts such as the disruption of feeding flocks and injury of seabirds on the water by fishing vessels. Fishing vessels that approach too closely to breeding birds on their nests may cause them to flush, thereby leaving the eggs and/or chicks exposed to predation.

In this chapter, we highlight various human-seabird interactions, including loss of nesting or roosting habitat, modification of marine habitat, the impact of introduced and "overabundant" species on seabird populations, effects of pollution (organochlorine, metal, oil, and plastic), and direct human disturbance of seabirds.

Loss of Nesting or Roosting Habitat

Loss of nesting or roosting habitat is a common problem faced by seabirds in the CCS. With the increase in the world's human population, there has been corresponding encroachment into seabird habitats. Other reasons for habitat degradation include habitat alteration, vegetation succession, sea level rise (from global warming), erosion, and periodic inundations.

Despite the protection of many important seabird habitats, historic loss and degradation of coastal habitat in the CCS region has been significant. In many areas of the CCS region, there has been a long history of human presence. For example, the Channel Islands, off the coast of southern California, have a long history of human habitation and support populations of native mammalian predators (e.g., mice, fox) in addition to introduced plants and animals that have greatly altered the natural habitats (see section 7.3).

Larger islands, such as Santa Catalina and San Clemente islands in the Channel Islands and Whidbey and Camano islands in Puget Sound (Washington), are more likely to be inhabited, or to have been inhabited in the past, by humans (some for thousands of years) and, thus, to support both native and introduced predators. Most of these larger islands have been significantly altered through development for residential, agricultural, commercial, or military purposes. Consequently, few of these large islands support large numbers of breeding seabirds.

Present sites of high seabird concentrations, such as the Farallon Islands and the Channel Islands in California, once had human settlements which decimated several species (1), although some populations subsequently have recovered.

Coastal development and logging of old growth forests have impacted seabirds along the west coast of North America; in particular, logging in the 1800s removed over 90% of Marbled Murrelet habitat (2). This loss of habitat resulted in the listing of this segment of the population as threatened under the Endangered Species Act.

However, not all species are equally vulnerable to habitat loss. Species such as Common Murres (*Uria aalge*), Pigeon Guillemots (*Cephus columba*), and Pelagic Cormorants (*Phalacrocorax pelagicus*) nest on steep cliffs and headlands, areas which are difficult for predators and humans to access; thus, levels of disturbance and predation are typically lower.

Wetland and estuary habitats, despite providing critical nesting and feeding opportunities to numerous species, both resident and migratory, are the most severely impacted by humans. Most of these impacts have been the result of conversion of these habitats for development and discharges of pollutants through agricultural practices and runoff. It is estimated that there has been a loss of approximately 54% of wetland habitat in the United States (87), impacting certain seabirds such as Caspian Terns (*Sterna caspia*), a species which seems to prefer to nest on isolated and sparsely vegetated islands (3).

Euro-Americans have significantly degraded low islands found in bays and estuaries through channelization, construction of hydroelectric dams, dredging, increased boat traffic and disturbance. On the other hand, islands created or enhanced by deposition of dredge spoils now provide some of the most important habitat for coastal seabirds. Many of the species that historically nested in coastal estuaries and marshes now nest on artificial habitats such as dredge-spoil islands and salt pond dikes. Several of these species are federally listed under the Endangered Species Act (California Least Tern), Birds of Conservation Concern (Gull-billed, Caspian, and Elegant Terns), and state threatened/endangered species lists.

With a growing human population, the loss of nesting or roosting habitat will likely become a more pressing issue in the future. It is therefore of great importance to protect those areas that are identified as important nesting and roosting habitat, if they are not already protected. With challenges such as these, it is essential to implement proactive conservation actions for long-term preservation of marine birds in the CCS.

7.2 MODIFICATION OF HABITAT

There are numerous indirect effects of fisheries on seabird populations in the CCS, including the reduction of seabird prey (discussed in Chapter 5), disturbance of seabirds at sea and at colonies (discussed in section 7.9), oil contamination from fishery vessels (discussed in section 7.7), and the introduction of debris into the marine environment (discussed in section 7.9).

Another indirect effect is the impact to the marine ecosystem caused by fisheries; the Gulf of California shrimp fishery is a good example. Among the problems associated with this particular fishery is the modification of marine habitats. Such habitat alteration can, in turn, change ecosystem structure by both removing large amounts of biomass and modifying the ocean floor.

Typically, the shrimp fishery uses medium-sized boats equipped with otter-trawl nets that are dragged over shallow soft-bottom areas. This dragging action, or trawling, has been widely recognized as one of the fishing methods with the most impacts on marine ecosystems.

There are two basic sources of these impacts. The first is related to the type of nets used in the shrimp fishery. These nets have very low selectivity and thus capture large quantities of non-target organisms in a ratio that has been estimated at 10:1 (10 kg of bycatch per kg of shrimp) and consists of up to 200 different species (88). For the shrimp fishing in the upper Gulf of California, Nava-Romo found that the diversity of the bycatch decreased as the fishing season progressed. Some species became more prevalent in the catch, and the size of individuals and total biomass captured decreased. In general, seabird bycatch is not a problem associated with shrimp trawl operations.

As mentioned above, the second way that marine habitats are impacted by this fishery is through alteration of benthic habitat (89). It has been calculated that in some heavily fished areas, each square meter of bottom is trawled between four to seven times per year (88). The impact of shrimp trawlers in heavily fished areas can be substantial in changing the biodiversity, complexity, and structure of communities in the ocean floor (89). These changes can have a ripple effect through the ecosystem, potentially producing changes in the composition of species that form the prey base for migrating or breeding seabird populations, especially those that rely on coastal prey species. No studies have been conducted to investigate these effects.

Shrimping is the most economically important fishery in Mexico and the third largest by catch volume. In 1997, the total catch in Mexico was 66,500 metric tons, of which 70% was harvested from the Pacific Ocean.

The shrimping areas off the west coast of the Baja California peninsula are located over the continental shelf off Bahía Magdalena and inside Bahía Vizcaíno. The rest of the habitat is too deep for the operation of the otter-trawl nets. Most boats in the fishing fleet, which numbers nearly 1,000 boats, use two nets, from 25 to 35 m wide.

In Washington, Oregon, and California, the shrimp fishery operates between April and October, with a fleet size of approximately 300 vessels.

In B.C., a prawn and shrimp fishery operates in nearshore waters. However, the trawling is mid-water, and therefore does not impact the ocean floor; also, bycatch of non-target species has been reduced to essentially zero because of a special net design.

7.3 INTRODUCED SPECIES

There has been a long history of both accidental or purposeful introduction of animal and plant species to areas that support seabird colonies. During the past 200 years in the Channel Islands, 15 herbivore species have been introduced. Rabbits were transported to four island groups by fishermen as pets and for hunting as recently as the 1990s (4).

Such introductions have resulted in both direct and indirect impacts on seabirds of the CCS, including decreases in population numbers and extinctions. In the CCS, 20 non-native vertebrates and 100+ plant species have been introduced to islands with breeding seabirds (Table 7.1 and 7.2). Non-native animals impact seabirds through predation, habitat alteration, and/or competition for food or habitat. Non-native plants may impact seabird populations by displacing native plants used by seabirds as nesting material or by covering the habitat of burrowing seabird species with a tough root system.

Non-native predators of seabird adults and nestlings include cats (*Felis catus*), black rats (*Rattus rattus*), brown rats (*Rattus norvegicus*), and dogs (*Canis familiaris*). Introduced vertebrate species may also significantly impact seabird colonies through habitat alteration.

On the Mexican islands, introduced cats are responsible for the extirpation of Cassin's Auklets (*Ptychoramphus aleuticus*) from four islands and for the extinction of the Guadalupe Storm-Petrel (*Oceanodroma macrodactyla*) (5, 6). Existing feral cat populations undoubtedly continue to reduce the breeding populations of small-bodied alcids and procellariiforms on Guadalupe Island (5, 6). Cats have been documented depredating large Magnificent Frigatebird (*Fregata magnificens*) and Brown Pelican (*Pelecanus occidentalis*) chicks and displacing Western Gulls (*Larus occidentalis*) from nests to depredate eggs and chicks on Santa Margarita Island (7) and Laysan Albatrosses (*Phoebastria immutabilis*) on Guadalupe Island (B. Keitt pers. comm.). Thus, cats are also capable of impacting large-bodied species.

A large feral dog population on Cedros Island is known to depredate the endemic mule deer and rabbit (8) and may be a significant predator of ground-nesting seabirds.

Introduced pigs (*Sus scrofa*) and ungulates (Family Artiodactyla and Perisodactyla) may damage seabird nesting habitat by trampling breeding burrows, consuming native vegetation, and increasing erosion (4). European rabbits (*Oryctolagus cuniculus*) browse foliar cover and compete with burrow-nesting seabirds for limited nest sites, ejecting eggs, chicks, and adults from nests (1). When rabbits are introduced along with exotic predators such as cats, they may impact seabird populations by sustaining predator populations when seabirds are not attending the colony (5).

Introduced mammals have had impacts on a range of other islands in the CCS. A combination of cat predation and burrow damage from goats (*Capra hircus*) caused the extinction of the Guadalupe Storm-Petrel on Guadalupe Island (5, 6). Cats were introduced to five of the Channel Islands, where they extirpated Cassin's Auklet (*Ptychoramphus aleuticus*) colonies from Santa Barbara Island and Leach's Storm-Petrel (*Oceanodroma leucorhoa*) from Coronado North (9, 10). Black rats significantly reduced the population of Xantus's Murrelet (*Synthliboramphus hypoleucus*) from Anacapa Island (11).

Seabird populations can also be impacted by non-native plants, which compete with native plants and may disrupt ecological processes of native floral communities. Non-natives may outcompete native plants during average environmental conditions and dominate floral communities on small islands with little habitat variation. However, during extremes in climatic and/or disturbance events, non-native plants may not have the genotypic variation to survive. Non-native plants common to CCS islands include iceplant (*Mesembryanthum* spp.), mallow (*Malva* spp.), New Zealand spinach (*Tetragonia expansa*), and various grasses (i.e. *Hordeum* spp.).

Non-native plant populations on Año Nuevo Island in central California were established during human occupation in the early-mid 1900s and dominated the floral community until 1998. In 1998, an unusually dry summer and wet winter, coupled with unusual levels of trampling by pinnipeds and Brown Pelicans likely led to a simultaneous rapid increase in non-native plant mortality and decrease in native plant recruitment. Consequently, Año Nuevo is now virtually devoid of plants, resulting in increased erosion and susceptibility of Rhinoceros Auklet (*Cerorhinca monocerata*) and Cassin's Auklet burrows to collapse. Efforts are currently underway to revegetate the island with native plants.

Eradication of non-native species is an effective management strategy, although it is often a difficult and costly task. Island size, variation in insular habitats, and natural history of non-native species all influence the difficulty of eradication. Public reaction also affects the likelihood of a successful eradication. Large islands and those with high habitat diversity pose a greater difficulty for eradication than small islands or islands with less habitat variability. Non-native species with relatively high fecundity and small body size are more difficult to eradicate than species with low fecundity and/or large body size. Eradication efforts should take into account impacts on native flora and fauna and public reaction.

A number of successful eradications of introduced mammals have been achieved on islands within the CCS. Cats have been successfully eradicated from islands under 1,000 hectares (Tables 7.1 and 7.2), including two of the Channel Islands, Anacapa and Santa Barbara, but they remain on Santa Catalina, San Nicolas, and San Clemente. Black rats have been removed from Anacapa (284 ha) and San Roque (79 ha) islands (12) but are still present on San Miguel, San Clemente, and Santa Catalina in the Channel Islands. Brown rats are present only on Santa Catalina. In Mexico, black rats remain on Cedros Island, and are suspected, but not confirmed, on San Martín, Santa Margarita, and Santa Magdalena islands (5). Sheep have been eradicated from all of the Channel Islands (284-26,134 ha) and from Natividad Island (1029 ha). Pigs were eradicated from Santa Rosa and San Clemente islands (14), and eradication is in progress on Santa Catalina Island (15) and is planned for Santa Cruz Island (S. Ortega, pers. com).

Introduced herbivores have successfully been removed from a number of islands. Feral rabbits have been removed from most islands less than 850 hectares. In the Channel Islands, eradication efforts have eliminated non-native herbivores from all but two islands: Santa Rosa with two non-native ungulate species and Santa Catalina with five non-native ungulate species (17, 18). Eradication efforts have eliminated introduced herbivores from all but six of the Mexican island groups (12). Eradications are more difficult on larger islands, and as a consequence, Guadalupe is still beset by a large feral goat population and Cedros by four ungulate species (8, 16) (Table 7.1).

Table 7.1 – Accounts of introduced species on islands off of Baja, Mexico.

	Area (ha)	Human Use	Cat (<i>Felis catus</i>)	Black rat (<i>Rattus rattus</i>)	Brown rat (<i>Rattus norvegicus</i>)	House mouse (<i>Mus musculus</i>)	Dog (<i>Canis familiaris</i>)	Pig (<i>Sus scrofa</i>)	Rabbit (<i>Oryctolagus cuniculus</i>)	Sheep (<i>Ovis aries</i>)	Cattle (<i>Bos taurus</i>)	Donkey (<i>Equus asinus</i>)	Horse (<i>Equus caballus</i>)	Elk (<i>Cervus elaphus</i>)	Mule deer (<i>Odocoileus hemionus</i>)	Other herbivores	References
Mexican Islands																	
Los Coronados:																	(98,115-118)
*North Coronados	80	REC	E														
*Middle Coronados	32	REC															
*South Coronados	227	LH, MIL, REC, VIG	E				C					C					
Todos Santos:																	(98,115,116,119-121)
*North Todos Santos	61	LH, MIL, REC	E				C		E			C					
*South Todos Santos	127	FISH, LH	E				E		E								
							C										
San Martín	298	FISH, LH, REC	E	P					NE								(98, 116, 116, 119)
San Jerónimo	67	FISH, LH	E				C					E					(98,116, 116)
Guadalupe	26,470	FISH, LH, MIL	C			C	C		E			C	C		Mule		(98, 116, 116,122-126)
		FISH, IND, LH, MIL, REC, TOWN, VIG	C	C		C	C		C		C	C					(98, 122, 126)
San Benitos:																	(98, 116, 116, 122, 127,128)
*East San Benito	195	REC	NE						E								
*Middle San Benito	104	REC	NE						E								
*West San Benito	548	FISH, LH, REC, RES, VIG	NE						E			C					
		FISH, LH, IND, REC, RES, TOWN	E					C							Antelope squirrel		(98, 116, 116, 122, 129-131)
San Roque	79	VIG	E	E													(98, 116, 116)
Asunción	68	VIG	E														(98, 116, 116)
Santa Magdalena	30,330	FISH, REC, RES, TOWN	C	P	P	P	C										(131)
Santa Margarita	23,892	FISH, REC, RES, TOWN	C	P	P	P	C										(105, 131)
Creciente	2,494																(131)

For each island, area in hectares, current human use, and the status of introduced species are indicated. Under human use, **RES**, research activity; **REC**, recreation/tourism; **MIL**, military base and/or testing; **LH**, lighthouse; **FISH**, fishing camp; **TOWN**, permanent human habitation >250 residents; **IND**, industry; **VIG**, vigilante camp.

Under introduced species, **C**, current feral population (2002); **C boxed**, current domestic population (2002); **E**, feral population eradicated; **E boxed**, domestic population removed; **IP**, eradication in progress (2002); **P**, probable population, presence of non-native species suspected but not confirmed; **NE**, population naturally eradicated (i.e., population established, but died out naturally).

Table 7.2 – Accounts of introduced species on the Channel Islands, California.

	Area (ha)	Human Use	Cat (<i>Felis catus</i>)	Black rat (<i>Rattus rattus</i>)	Brown rat (<i>Rattus norvegicus</i>)	House mouse (<i>Mus musculus</i>)	Dog (<i>Canis familiaris</i>)	Pig (<i>Sus scrofa</i>)	Rabbit (<i>Oryctolagus cuniculus</i>)	Sheep (<i>Ovis aries</i>)	Cattle (<i>Bos taurus</i>)	Donkey (<i>Equus asinus</i>)	Horse (<i>Equus caballus</i>)	Elk (<i>Cervus elaphus</i>)	Mule deer (<i>Odocoileus hemionus</i>)	Other herbivores	References
Channel Islands																	
San Miguel	4,342	REC, RES		C						E		E					(98, 99)
Santa Rosa	22,565	REC, RES						E		E			E	C	C		(98, 100)
Santa Cruz	26,137	REC, RES						C		E	E		E				(98, 99, 101, 102)
Anacapa:		REC, RES															(98, 103-105)
*East Anacapa	45	REC, RES		IP					E	E							
*Middle Anacapa	60	RES		IP						E							
*West Anacapa	179	RES	E	IP						E							
Santa Barbara	328	REC, RES	E						E	E							(98, 104, 106-109)
Santa Catalina	20,363	REC, RES	C	C	C	C		IP		E	E					American bison, Asian black buck	(98, 99, 104, 110-112)
San Nicolas	6,234	MIL, RES	C							E			E				(98, 113)
San Clemente	15,555	MIL, RES	C	C		C		E		E	E					California vole, Harvest mouse	(98-100, 104, 114)
For each island, area in hectares, current human use, and the status of introduced species are indicated. Under human use, RES, research activity; REC, recreation/tourism; MIL, military base and/or testing; LH, lighthouse; FISH, fishing camp; TOWN, permanent human habitation >250 residents; IND, industry; VIG, vigilante camp. Under introduced species, C, current feral population (2002); C boxed, current domestic population (2002); E, feral population eradicated; E boxed, domestic population removed; IP, eradication in progress (2002); P, probable population, presence of non-native species suspected but not confirmed; NE, population naturally eradicated (i.e. population established, but died out naturally).																	

Ten herbivore species have been introduced to the Mexican islands, whose arid climate may have discouraged ranching ventures. Goats released on Guadalupe Island in the 1700s intensively trampled and browsed the nesting habitat of the Guadalupe Storm-Petrel in upland pine and cypress forests and contributed to its extinction (19, 20). Donkeys (*Equus asinus*) are still commonly used on various islands to transport diesel to lighthouses and are permitted to browse native vegetation (5).

Over many decades, introduced goats and donkeys on West San Benito Island collapsed the nesting burrows of storm-petrels, Cassin's Auklets, and Black-vented Shearwaters (*Puffinus opisthomelas*), either blocking entry to the nest or exposing individuals to Western Gull and Common Raven (*Corvus corax*) predators (B. Tershy and D. Croll, pers. comm.).

7.4 NUISANCE SPECIES: THE PROBLEM OF OVERABUNDANCE

As described in the Predators section of this plan (Section 6.1), gulls (*Larus* spp.) are common predators of adults, eggs, and young of other seabirds at colonies in the CCS. Furthermore, gulls may compete for breeding sites with other ground-nesting species (21). Gulls are extremely adaptable to changing environments and have exploited several artificial food resources created by humans, namely landfills and discards from commercial fishing.

As populations of several gull species in North America have increased in recent decades, management concerns have arisen regarding the impact of inflated gull populations on other seabird species. Large concentrations of gulls in urban areas have occasionally been associated with fresh water contamination, damage to buildings, and increasing hazards to aircraft (22). A fair body of scientific research has examined these issues, primarily with Atlantic and Great Lakes populations, though there are similar issues in the CCS.

Sanitary landfills frequently attract large numbers of feeding gulls, at least seasonally, and create concentrations of gulls in urban areas (22). It has been suggested that food gathered by gulls at landfills is "lower quality" than natural food sources (i.e. fish). Long-term studies of Western Gulls on Alcatraz Island showed that individuals foraging primarily on garbage had shorter breeding lifespans and lower reproductive success than those which fed primarily on fish (23). Belant et al. (22) suggested that breeding Herring Gulls (*Larus argentatus*) in the Great Lakes rarely fed in landfills when higher quality food was available, but that these areas were extremely important for post-fledging birds and non-breeders.

Recent changes in landfill practices to reduce garbage availability to gulls might be contributing to recent declines in Western Gull populations at the Farallon Islands (PRBO unpublished data).

Another unnatural source of food for seabirds comes from fisheries practices. Fisheries discards and offal provide a large quantity of food for seabirds, particularly gulls. Furness et al. (24) detailed how fisheries discards are important food resources for four species of British gulls, and positive correlations between fishery landings and gull population numbers have been shown for several species (25, 26).

Where gull populations have grown, their impact as predators on other species has often increased. A number of studies (27, 28) have documented the complete abandonment of traditional nesting areas by terns in response to the encroachment of breeding gulls.

Further evidence comes from culling programs in which removing gulls from breeding colonies has increased recruitment and breeding performance of other seabird species (29-31). However, continued culling of gulls may be required to ensure the positive effects for other species (30). Non-lethal control methods to exclude gulls from nesting with the use of “above-ground wires” have been successful in some areas (32), although similar efforts to exclude Western Gulls from study plots on the Farallon Islands were unsuccessful (33).

Management decisions regarding the use of gull control to reduce negative impacts should be based on solid scientific data since population reduction from culling of gulls can threaten populations without reducing negative impacts, as seen in some instances of airport-based “gull control” to reduce air strikes (34).

Populations of Double-crested Cormorants (*Phalacrocorax auritus*) have been increasing rapidly in many parts of the U.S. since the mid-1970s. This abundance has led to increased conflicts, both real and perceived, with various biological and socio-economic resources, including other birds, recreational fisheries, and hatchery and commercial aquaculture.

The Double-crested Cormorant population breeding in the California Current System is a small fraction of the North American population, comprising only ~4% (USFWS 2003). Within the CCS, Carter et al. (35) documented recent population increases in California and Oregon, and declines in British Columbia, Washington, and Baja California. In the past 20 years, the largest increases in the region have taken place in the Columbia River estuary, where East Sand Island supports the largest active colony along the West Coast, with 6,390 pairs (~1/4 of the region’s breeding population) in 2000 (35, 36).

The primary concern with population increases of Double-crested Cormorants and other piscivorous marine birds, primarily Caspian Terns, is that they eat large numbers of migrating juvenile salmonids.

In 2003, the U.S. Fish and Wildlife Service produced an environmental impact statement for Double-crested Cormorant management, recommending a take of 160,000 cormorants from 24 U.S. states. However, no Pacific states are currently part of this plan, which seeks to reduce exponential growth of Double-crested Cormorant populations and their impact on human activities in eastern states. Current management of large cormorant and tern colonies in the Columbia River ecosystem is confined to non-lethal methods to discourage breeding in certain areas.

7.5 ORGANOCHLORINE POLLUTION

Organochlorines (OCs) encompass a large array of compounds that are highly toxic and remarkably persistent once released into the environment. Some of the more common and serious compounds are summarized below.

A large body of research has been conducted on effects of OC contamination on seabirds. Seabirds in the CCS may be contaminated by OCs introduced into the marine system from agricultural runoff, industrial effluents (37) from pollutants associated with pelagic dumpsites (e.g., radioactive waste and chemical munitions dumpsite near the Farallon Islands), and from marine dredge spoils (38).

Organochlorines are lethal to adult birds at high concentrations. Fortunately, the levels of OCs in the U.S. have declined considerably since the ban of DDT and PCBs. The primary impact of DDT on marine birds is its negative effect on eggshell thickness. As concentrations become higher, eggshells become correspondingly thinner. This can lead to a dramatic drop in productivity, through failure to hatch chicks. Several studies have investigated the degree to which OCs affect seabirds in the CCS by comparing OC concentrations and eggshell thickness between different species and different sites, and at different times (i.e., before, during, and after DDT) (37, 39-41).

It is important to consider bioaccumulation when assessing the effect of OCs on seabirds. Bioaccumulation is the tendency for certain substances, in this case OCs, to become increasingly concentrated in organisms at higher trophic levels. For instance, piscivores will have higher levels than planktivores within the same ecosystem. Likewise predatory birds that feed at an even higher trophic level (e.g., consume piscivores) will consequently have higher concentrations than piscivores (42).

OC levels not only vary between species, but they also differ intraspecifically as well; this is primarily due to habitat location (40, 41) but can also be a result of varying diet (43). Speich et al. (40) found that eggshell thickness of Glaucous-winged Gulls (*Larus glaucescens*) differed (but not significantly) and that DDT and PCB concentrations varied significantly between different breeding grounds along the Washington coastline. Their findings suggest that colonies nearer urban-industrial areas have higher concentrations of OCs. Bustnes et al. (43) found that Glaucous Gulls (*Larus hyperboreus*) that fed regularly on eggs of murrelets (*Uria* spp.) had higher levels of OCs than those that fed primarily on fish, providing evidence of bioaccumulation.

The following are short descriptions of the most common organochlorines historically and/or currently found in the CCS:

DDT is a pesticide that was once widely used but was banned in the U.S. in 1972 because of damage to wildlife (www.epa.gov/history/topics/ddt/01.htm); however, Mexico continues to allow the use of DDT. Recently, however, Mexico has successfully reduced use of this persistent organic pollutant by 80% under a side agreement of the North American Free Trade Agreement (NAFTA) (<http://www.ecoisp.com/goodnews12.asp>). DDE, a chemical similar to DDT, is the metabolic byproduct of DDT. Bioaccumulation is a serious problem with DDE. DDE build up in the fatty tissue of seabirds can cause eggshell thinning, which may significantly decrease reproductive success.

Polychlorinated biphenyls (PCBs) are mixtures of synthetic organic chemicals that were widely used for both industrial and commercial applications; their non-flammability, chemical stability, high boiling point, and electrical insulating properties made them highly versatile compounds. More than 1.5 billion pounds of PCBs were manufactured in the United States prior to the cessation of production in 1977 (<http://www.epa.gov/opptintr/pcb>).

Chlordane is a pesticide that was used in the United States from 1948 to 1978. It bioaccumulates and is a persistent toxic pollutant (<http://www.epa.gov/opptintr/pbt/chlordane.htm>).

Aldrin and Dieldrin (a product of Aldrin) are both insecticides that are now banned in the U.S. Both are persistent, toxic pollutants that bioaccumulate (<http://www.epa.gov/pbt/aldrin.htm>).

A study on Southeast Farallon Island and Año Nuevo Island in 1993 (41) found a trend suggesting that eggshell thickness was negatively correlated with six different organochlorines. However, only oxychlordane showed a significant correlation. The same study also reported that shell thickness was significantly thicker in the 1990s than the 70s, although eggs remained thinner than historic records from before 1947. Henny et al. (39) also found that eggshell thinning in Oregon seabirds appeared to be more severe during the 1950s than in 1979.

The current general opinion is that OCs have been a significant problem in the past but levels have declined to concentrations that no longer pose a great risk to seabirds in the CCS. Nonetheless, OCs persist in the environment and in seabird tissues.

7.6 METAL POLLUTION

The primary metals of concern to seabirds in the CCS are lead, mercury, cadmium, and selenium. These metals are present in trace quantities in the earth's crust and thus throughout the marine environment, but at levels which are not toxic to seabirds.

At higher concentrations, however, all metals are toxic. Such elevated concentrations of metals can occur in the marine or onshore coastal environment from anthropogenic sources. Because seabirds usually feed at high trophic levels, they are susceptible to bioamplification of metals.

Following are descriptions of the metals of concern in the CCS, including documented effects on seabirds.

Lead. Potential sources of lead include waste from industrial sources, atmospheric lead from combustion of leaded gasoline, and lead paint. Sea ducks also occasionally ingest lead shot (44). Mortality from lead poisoning in seabirds is rare, but sublethal effects may be widespread. At high levels, lead causes neurological problems, including drooped wings, loss of appetite, lethargy, weakness, tremors, and impaired locomotion (91). On Midway Island, peeling lead paint on old military buildings has been found to cause lead poisoning in albatross chicks, sometimes leading to mortality. In the CCS, there are no reported incidents of lead poisoning in seabirds. Industrial lead sources probably pose the greatest threat of lead contact for seabirds in the CCS.

Mercury. Sources of mercury in the marine environment include runoff from terrestrial sources and atmospheric deposition, largely from coal-fired power plants (91). Although mercury occurs naturally in the earth's crust, considerably more mercury can enter the marine environment through contaminated watersheds. In the San Francisco Bay area, for example, runoff through mine tailings has led to significant contamination of marine sediments downstream from historic mines. Mercury poisoning can lead to reduced survival of embryos and chicks, behavioral effects, and other health-related issues. Sydeman and Jarman (45) studied trace metals in marine birds, mammals, and their prey in the central portion of the CCS, near the San Francisco Bay area. They found moderately elevated levels of mercury in eggs of Rhinoceros Auklet, Brandt's Cormorant (*Phalacrocorax penicillatus*), and Pigeon Guillemot.

Cadmium. Cadmium has been found in relatively high concentrations in marine organisms, and has been found to cause sublethal and behavioral effects at lower concentrations than other metals (91). Cadmium is a carcinogen and also causes behavioral and reproductive effects. Little information is available regarding effects of cadmium on seabirds, particularly in the CCS. Anthropogenic sources include smelters and the manufacture and disposal of batteries and paints.

Selenium. Selenium is an essential element for birds in small quantities, but in larger quantities can lead to deformities and mortality in aquatic birds. Selenium occurs naturally at low levels in the earth's crust, but can be concentrated in agricultural wastewater. High selenium in agricultural drainwater collected in California's Central Valley led to extreme embryonic deformities in several species of shorebirds and waterbirds (46).

Relatively little is known regarding the levels of these and other contaminants in seabirds within the CCS. Ohlendorf (92) posited that, based on available information, metal pollution is unlikely to lead to direct mortality in seabirds (with the exception of ingestion of lead paint chips at Midway, discussed above). Chronic metal contamination may, however, lead to sublethal effects, particularly reproductive failure (92). These sublethal effects have the potential to affect seabird populations in the CCS; thus, more research on this topic is warranted.

7.7 OIL POLLUTION

Oil pollution is one of the greatest threats to marine birds in the CCS, impacting birds in several different ways. Oil disrupts the waterproofing, and hence the insulation value, of birds' feathers, often leading to hypothermia in seabirds that have been oiled. Seabird mortality can also result from direct ingestion of oil, which occurs when birds preen oiled feathers. Even relatively small amounts of oil can lead to rapid mortality (i.e., a few days) through either of these pathways (47).

Oil spills in the CCS have occurred as a result of ship collisions and groundings, accidents while loading or unloading, and accidents at offshore oil rigs and pipelines.

Considerable oil also enters the marine environment through "non-point" sources, including runoff from terrestrial sources. Some oil can also enter the marine environment via natural seeps, most famously in the Southern California Bight. Seeps actually contribute the majority of oil in the marine environment in North America, and non-point sources also exceed the amount of oil from accidental spills (48).

Although these ongoing sources of oil represent a threat to seabirds, they contribute a small amount of oil over a long time period, as opposed to a large amount in a small time period typical of anthropogenic causes, and thus do not pose the same threat as large oil spills. Large spills can cover an extensive area of ocean with oil and persist for weeks or longer. Serious oil spills such as the Exxon Valdez spill in Alaska in 1989 can kill hundreds of thousands of seabirds (49).

In the CCS, there have been at least five major spills of over 1,000,000 gallons (Table 7.3). The 1969 spill from a Union Oil rig off Santa Barbara oiled hundreds of birds (probably thousands, although reliable estimates of mortality are unavailable), and helped to spur the environmental movement in the U.S. in the 1970s.

Between 1970 and the 1990s numerous federal and state regulations have been passed, including legislation requiring oil tankers to have double hulls. These regulations appear to have helped, as there has not been a spill of greater than 1,000,000 gallons in the CCS since 1984 (Table 7.3). It should be noted that although many of these spills in the CCS have heavily impacted seabirds, the largest spills here (a few million gallons) are considerably smaller than those that have occurred in other regions of the world.

Worldwide, there have been several spills of over 10 million gallons, including the *Exxon Valdez* spill in Alaska. The largest spill, the *Amoco Cadiz* spill off the coast of France in 1978, was approximately 60 million gallons. A spill of this scale in the CCS, where seabird densities at sea are among the highest in the world, would be truly devastating.

Although there have been no recent major spills, spill volume is not always directly proportionate to number of birds killed (50). As Table 7.3 shows, devastating impacts can result from moderate-size spills if they occur in areas of high seabird abundance.

Most oil spills in the CCS have occurred during winter months, probably as a result of severe weather. During this time both resident seabirds and wintering seabirds are found throughout the coastal waters. These visitor species include loons, grebes, and sea ducks, all of which have been heavily impacted by spills. Because Common Murres are the most abundant breeding species in the CCS and are resident year-round, they are usually the species most heavily impacted (in total numbers, if not proportion of population) during spills.

Areas most susceptible to population-level impacts from oil spills are those with the greatest densities of birds at sea, including the Puget Sound area, the Columbia River area, the Gulf of the Farallones and Monterey Bay (central CA), the Southern California Bight, and the Punta Eugenia area. Unfortunately, these are also areas of shipping traffic.

Location and timing of spills not only affect the total number of birds killed, but also affect which species are hardest hit. For example, although less than 2,400 birds were killed in the New Carissa spill in Oregon, 262 Marbled Murrelets were estimated to have been killed, a significant impact to their limited population in the CCS (51).

In addition to direct loss of individual birds during spills, populations can be negatively affected for years after a spill as a result of impacts to the entire marine ecosystem. In Prince William Sound, Alaska, populations of several species of seabird have failed to recover more than a decade after the *Exxon Valdez* spill. In addition, loss of breeding adult birds has cascading population-level effects; not only is an individual bird lost, but its potential offspring are also lost from the population. Rehabilitation of oiled birds may save individuals, but rehabilitated birds may be permanently affected and fail to breed, thereby contributing nothing to the population (52, 53).

Unfortunately, reliable estimates of damage to seabirds from several major oil spills in the CCS are unavailable (Table 7.3). Although most spills in the CCS receive considerable response, including analyses of both numbers of oiled birds recovered on beaches and of birds at risk at sea, a significant gap occurs off Baja California.

California has developed an efficient response program through the California Department of Fish and Game's Office of Spill Prevention and Response (OSPR); however, there is no mechanism for standardized scientific response to spills south of the border. In many areas, most notably in Mexico, there is also little in the way of ongoing research of baseline conditions.

Baseline data of seabird distribution at sea throughout the year could aid in developing damage assessment models, and ongoing monitoring of breeding colonies is important in determining long-term effects of spills on seabird populations in the CCS. In addition, ongoing monitoring of beaches for beach-cast birds can be useful for baseline mortality levels and detecting oil spill events (54, 55).

In B.C., one of the largest threats is illegal discharge of oil by ship operators, due to low fines and poor enforcement. However, a good system of aerial surveillance is now in place. The Canadian Coast Guard surveys the coast of B.C. for pollution and fisheries enforcement patrols between 65 and 70 days per year. In addition, the Department of National Defence also conducts pollution surveillance flights. Even though the spill reporting system in B.C. is good, it primarily reports and responds to large spills, disregarding the smaller spills (56), which can take a heavy toll on seabirds.

Although shipping traffic is less off Baja California than off southern California, there are no active programs to monitor and respond to oil spills off the Pacific coast of Baja; thus, spills usually go unreported. Pleasure craft use in this area is expected to rise dramatically in the next 12 years, in response to development of marina facilities. At Ensenada in 1997 there were 1240 arrivals and departures, more than double the number in 1993, and at Cabo San Lucas there were 1434 arrivals and departures, up from 1000 in 1993 (Fondo Nacional de Fomento al Turismo). Current plans to develop northwest Mexico with greater infrastructure for pleasure boats is expected to increase the current level of use more than eight-fold by 2014.

In addition, a large development project called the Escalera Nautica will create six new marinas and greatly expand one other along the Pacific coast of Baja California (Fig. 7.1). Considered as a whole, all of north-west Mexico will gain 23,000 new boat slips, of which 55% are marine and 45% are dry dock facilities. Total numbers of arrivals and departures are projected to reach 50,000 by 2014. The majority of this traffic will involve boats in the 30 to 55 foot size range.

It is unknown how the proposed Baja California Pacific Islands Biosphere Reserve will affect the threat of oil pollution in this region. It is highly unlikely that the creation of the reserve will lead to any changes in the current use of the waters surrounding the islands, and thus they will likely be at the same risk from an oil spill. However, in the case of an oil spill the reserve will provide the infrastructure to monitor and report the situation. Additionally, reserve status will hopefully provide increased awareness of these islands and make funds available for cleanup in the aftermath of a spill.

Table 7.3 – Significant oil spills (including various petroleum products) in the California Current System (Vancouver Island to Punta Baja, Mexico). Question marks indicate lack of data; in some cases no data exist, in others (e.g., recent spills in California), mortality estimates are in preparation.

Year	Month	Name	Location	Volume (x1000 gal.)	Estimated Seabird Mortality	Refs
1937	Mar.	Frank Buck	Central CA	3900	10000	(50)
1956	Sep.	Seagate	Washington	?	>3000	(50)
1957	Mar.	Tampico Maru	Baja CA, Mex.	2500	?	-
1964	Mar.	United Transportation Barge	Washington	1200	?	(132)
1969	Jan.	Santa Barbara Oil Well	Southern CA	4200	?	(133)
1971	Jan.	OR Standard/AZ Standard	Central CA	810	20000	(50, 133, 134)
1971	Apr.	United Transportation Barge	Washington	230	?	(132)
1972	Jan.	General M.C. Meiggs	Washington	2300	?	(132)
1976	Dec.	Sansinena	Southern CA	1260	?	(133)
1983	Nov.	Blue Magpie	Oregon	69	?	(134)
1984	Mar.	Mobiloil	Washington	165	?	(50, 133)
1984	Oct.	Puerto Rican	Central CA	1470	4815	(133, 134)
1984	Dec.	Whidbey Island	Washington	5	?	(133)
1984	Dec.	Unknown Puget Sound	Washington	>406	>1500	(50)
1985	Dec.	ARCO Anchorage	Washington	239	4000	(50, 133)
1986	Feb.	Apex Houston	Central CA	26	10577	(135)
1987	Sep.	Pacific Baroness	Southern CA	386	?	(133)
1988	Jan.	MCN-5	Washington	67	?	(50, 133)
1988	Dec.	Nestucca	Washington	231	56000	(50, 133)
1990	Feb.	American Trader	Southern CA	417	3400	(135)
1991	Jul.	Tenyo Maru	Washington	100	?	(132, 133)
1991	Feb.	Texaco	Washington	210	?	(132, 134)
1992	Aug.	Avila Beach	Central CA	17	?	(134)
1993	Dec.	McGrath	Southern CA	87 (on beach)	?	(135)
1994	Dec.	Crowley Barge	Washington	27	?	(132)
1996	Oct.	Cape Mohican	Central CA	40	593	(135)
1997	Nov.	Kure	Northern CA	2+	?	(135)
1997	Sep.	Torch/Platform Irene	Central CA	>12	700	(135)
1998	Sep.	Command	Central CA	3	1500	(135)
1999	Sep.	Dredge Stuyvesant	Northern CA	2	?	(135)
1999	Feb.	New Carissa	Oregon	70?	2358	(136)
1999	May	Chevron	Baja CA, Mex.	110?	?	-
<2003	Winter	Jacob Luckenbach	Central CA	?	>20000	(55, 135, 137)

7.8 PLASTIC POLLUTION

Few studies have been conducted on ecosystem-wide effects of plastic pollution, yet plastic pollution in the marine environment is ubiquitous and can cause significant seabird mortality. There are several ways that plastic can affect seabirds and the marine environment in which they live: through ingestion or entanglement; by absorption and concentration of toxins (including DDT, PCBs, and organochlorines from seawater) (57); and through alteration of ecosystem function by reducing the exchange of gases between sediment and seawater, changing the chemical makeup of the benthos (58). Drifting plastic is also a vector for alien species. Plastics encrusted with marine organisms may travel long distances, introducing alien species and adversely affecting native flora and fauna (58).

Plastic debris is concentrated by currents along the same fronts and convergences as seabird prey items, thereby facilitating ingestion. In many cases, plastic debris also resembles prey items. The 0.5 – 1.0 cm plastic pellets used as raw material for the plastics industry are often mistaken for prey items by seabirds and fish, and can be passed on to young through regurgitation (58). Sievert and Sileo (59) found large volumes of plastic pellets in Laysan and Black-footed albatross chicks.

Spear et al. (60) have shown that in seabirds, body condition and plastics ingestion have a strong negative correlation, meaning that body condition declines as the amount of plastic ingested increases. Plastic ingestion may lead to false feelings of satiation, reducing foraging effort and perhaps hindering digestive processes (58). Drift plastics can be used as substrate by encrusting prey organisms, which are then eaten by seabirds along with the plastic substrate. Ingestion of plastic which has concentrated toxins can lead to reproductive disorders, increased risk of disease, altered hormone levels, and death (58).

Entanglement of marine organisms in plastic debris is well documented for several species of pinnipeds and several species of sea turtles, but the evidence is mainly anecdotal for seabirds, fish, and other animals. Natural behaviors such as curiosity or a need to find protection or food can increase the likelihood of entanglement. Animals can also become entangled when they attempt to haul out on debris, or when pursuing prey already caught in debris. Entanglement can cause decreased mobility, injury (which may lead to death from wounds or through decreased foraging efficiency), and death.

Monofilament fishing line is cited as most likely the greatest danger for entanglement for seabirds. The long life of plastic means that even after the entangled organism is gone, the plastic is available again to entangle another.

Distribution of plastic debris in the marine environment is uneven and dependent on currents, eddies, and weather patterns. Plastic debris is generally buoyant, which facilitates its long-distance dispersal. Drift plastic in the open ocean tends to be concentrated across fronts, at convergences, or held in gyres. In nearshore areas, plastic debris accumulation is typically denser following storms, which provide an influx of terrestrial debris (61).

There is evidence that the abundance of plastic debris in the ocean has declined slightly since 1987, when plastic dumping at sea was banned (60). However, illegal dumping still takes place, and the international authority responsible for enforcement, Annex V of MARPOL, does not have resources for complete enforcement (58). With the continually increasing human population and a corresponding increase in plastic usage, the threat of increased plastic in the marine environment is likely. Thus, stricter measures need to be developed to prevent plastic from polluting the marine environment and negatively affecting seabirds.

7.9 HUMAN DISTURBANCE

As the importance of human disturbance impacts to seabirds has been more widely acknowledged during the past two decades, it has become a more popular topic in the published literature. Many studies, however, have failed to deliver information which is reliable or appropriate to the practical challenges faced by conservation managers (62).

Only in the last several years have studies started to tackle the complex and interrelated factors influencing disturbance effects (63, 64), and experimentally test seabird limits for disturbance (65). The continued growth of human populations and their increasing mobility, concurrent with decreasing available quality habitat for seabirds, effectively increases potential for human-seabird interactions. Therefore, it has become imperative to understand the consequences of disturbance on seabirds for effective conservation and management.

Human activities can affect seabirds' ability to feed, rest, and breed; consequently, seabird breeding colonies, roosting sites, and foraging areas are all sensitive to human disturbance. Seabird responses to disturbance can vary depending on species, breeding status, group or community size and structure, environmental conditions, and type, severity and proximity of the disturbance. Effects may be direct or indirect, clearly observable (e.g., alarm calling, flushing, predation) or difficult to detect (e.g., physiological changes, cumulative effects of disturbance), or may impact an individual or an entire population. Effects of repeated or long-term disturbance are especially difficult to study and quantify.

Therefore, in long-lived species such as seabirds, the cumulative effects that disturbance can have on the individual (survival, lifetime reproductive success) or population level remain unknown. Furthermore, additional factors such as modification of species interactions and environmental change can either mask or intensify the effects of human activity (63, 66, 67). Although difficult, it is important to consider these factors in concert with breeding and/or feeding biology when assessing the impacts of human disturbance on seabirds (63, 64).

Finally, some researchers have begun studies of disturbance effects based on stimulus-response experiments with the scientific understanding that these quantitative assessments are more useful than anecdotal observations of wildlife responses to human activities (65).

Disturbance to Seabird Colonies and Roost Sites

For roosting and successful breeding, many seabirds are dependent on islands free from both mammalian predators and high levels of human disturbance. Yet human use of and influence on the coastline and small islands appear to be increasing in many parts of the world, especially along the coasts of California and Baja California. Seabird responses to human disturbance at colonies or roost sites include alarm behaviors and temporary or permanent site abandonment; these effects can result in reduced nesting success or reproductive failure, or even death of adult birds due to predation (66, 68-70). Human disturbance to seabird colonies can result from recreational and commercial boating activities, aircraft overflights, ecotourism, and investigator disturbance.

Boats or aircraft that approach too closely to breeding seabirds on their nests may cause birds to flush, thereby leaving the eggs and/or chicks open to predation or overexposure to harsh elements. Recreational kayakers, jetskis (or personal watercraft), sailboats, fishing boats, and tourist helicopters or airplanes too close to breeding colonies on Alcatraz Island in San Francisco Bay are a common cause of disturbance to breeding Brandt's Cormorants, Pelagic Cormorants, and Western Gulls, resulting in stress responses of adults as well as some egg and chick loss (J. Thayer, pers. obs.).

Investigator disturbance in seabird colonies is known to reduce survival and growth rate of chicks of several species, thereby reducing overall breeding success (71, 72). Many researchers have altered methodologies to reduce disturbance in seabird colonies as much as possible, including erecting blinds from which to observe birds and reducing or eliminating the need to enter areas with colonially-nesting birds.

There are also several fisheries operating in the CCS that cause disturbance to seabird colonies (Table 7.4). The live rockfish fishery in central California, in which fishing activity is in close proximity to land, has been known to cause egg and chick loss at

Common Murre colonies, yet there are no regulations in place to prevent this from happening (M. Parker, pers. comm.). Negative effects of disturbance from bright lights used at night by the squid fishery are of great concern to seabirds that breed in the Channel Islands, California. This practice has resulted in nest abandonment and low reproductive success for Brown Pelicans (F. Gress, pers. comm.) and may have affected other species as well, including Xantus's Murrelets and Ashy Storm-Petrels (*Oceanodroma homochroa*) that breed on Santa Barbara Island.

The bright lights used in this fishery illuminate parts of the islands and make seabirds more vulnerable to predators such as gulls or owls. In addition, bright lights from boats can also attract birds to the lights and disorient seabirds as they fly to and from the islands, resulting in disruption of their foraging trips and/or collisions with the boat (70).

Table 7.4 - Fisheries that operate in the CCS that indirectly affect seabirds as a result of disturbance (ASSP = Ashy Storm-Petrel, BRPE = Brown Pelican, COMU = Common Murre, XAMU = Xantus's Murrelet).

FISHERY	SPECIES AFFECTED	DISTURBANCE
CA squid purse seine	BRPE, XAMU, ASSP	light disturbance
CA finfish live trap/hook-and-line	COMU	vessel proximity to nesting colonies

Disturbances do not always have visible negative effects. Slight stress reactions, for example, may not be noticeable to observers. Physiological studies have found that humans approaching Adélie Penguins (*Pygoscelis adeliae*) resulted in significant increases in penguin heart rates, even when no evidence of stress was behaviorally manifested (73, 74).

Regular or repeated disturbances can in some cases devastate seabird colonies, but in other instances not have much visible effect. Explanations for the latter may stem from habituation of seabirds that are regularly disturbed (75-77). Laysan Albatrosses that were frequently exposed to humans responded more slowly and less severely than those that had experienced very little prior human contact (77). The researchers caution, however, that although these experiments suggest that albatross can habituate to the presence of humans, human activity should be limited to confined areas rather than distributed throughout the colony (78).

A cautionary consideration is the potential that regularly disturbed colonies are likely to persist only if the advantages for seabirds to stay at a colony outweigh the disadvantages. For instance, prey availability near Alcatraz Island may be high or predictable, prompting cormorants to breed there, but environmental conditions negatively affecting feeding conditions may intensify the effects of disturbance felt by the birds, resulting in colony abandonment (J. Thayer, pers. obs.).

With habitat for seabirds decreasing and becoming further degraded, such examples of other advantages outweighing human disturbance to a colony may be increasingly rare.

Disturbance to Foraging Seabirds

There are both direct and indirect human threats to seabirds foraging at sea. Direct disturbances include boats disrupting seabird feeding flocks and injuring seabirds on the water, either through direct collision or entanglement in fishing gear. Indirect human threats can involve reduction of prey as a result of competition with fisheries for shared prey resources. While this section deals only with direct human threats to seabirds, please also see the fisheries-related sections in this document (in Chapters 5 and 6).

Flushing in response to boat traffic is frequently observed in many seabird species (68, 79-81, 93). Aside from direct injury, at-sea disturbance effects may be more severe during times of poor feeding conditions for seabirds, such as El Niño events or even seasonally during the winter when food is scarcer in the CCS. Belanger and Bedard (82) found that human activities resulting in flushing and alertness increased energy expenditure by Snow Geese (*Chen caerulescens*) and reduced their energy intake due to lower feeding rates. Extra energy expended during disturbances or missed feeding opportunities could act to reduce both reproductive success and survival of seabirds, potentially having negative population-level consequences.

Seabird response to disturbance can vary depending on a myriad of factors. Despite its close association with and known habituation to boating activities along the coast of Florida, the Brown Pelican exhibited one of the larger average flush distances of waterbirds studied by Rodgers and Schwikert (65), probably due to the fact that pelicans require more time to take flight. While larger species generally exhibited greater average flush distances to approaching watercraft, considerable variation in flush distances was detected both among individuals within the same species and among species (65). Ronconi and St. Clair (64) found that flushing behavior of Black Guillemots (*Cepphus grylle*) was related to the size, speed, and approach distance of boats as well as foraging distance from the colony, a variable which changes in both a diel (influenced by tides) and seasonal pattern.

Reducing or Mitigating Disturbance

Rigorous studies that carefully measure disturbance responses are the first step towards establishing effective measures to reduce disturbance. Alert distance (the distance between an animal and an approaching human at which point the animal begins to exhibit alert behaviors to the human) or flush distance have been proposed as indicators of tolerance for birds (82-85). The largest flush distances should be used when buffer zones are implemented for mixed-species groups of birds at foraging, roosting, or breeding sites (86).

Although management options may be specific to a particular type of disturbance or location where a study is conducted, the analytical approach used to identify appropriate buffer zones may be relevant to other locations and seabird species. Once recommendations are proposed, however, reducing or mitigating disturbance at fixed locations such as seabird colonies or roosting areas may be somewhat easier than managing disturbance to seabirds at sea where distributions often depend on ephemeral oceanographic processes that concentrate prey.

A 1999 review by Carney and Sydeman (94) provides a useful summary of literature on human disturbance to seabirds, although more research has subsequently been conducted. Other useful endeavors such as conference workshops and ongoing field projects have been undertaken by various government agencies around the world to identify and suggest solutions for seabird disturbance. Several important documents have resulted from these efforts, including Guidelines for Managing Visitation to Seabird Breeding Islands, developed for the Great Barrier Reef Marine Park Authority, Australia, and websites such as Canadian Arctic Profiles' Arctic Environmental Sailing Directions.

Source:

<http://collections.ic.gc.ca/arctic/envsens/environm.htm>

Australia's Great Barrier Reef guidelines contain information on the vulnerability of seabirds to disturbance, priorities to establish values for seabird breeding aggregations, the impacts of a range of human activities on breeding seabirds, and ways of mitigating these impacts.

Techniques for implementing the guidelines include developing codes of conduct/practice, island closure, signage, publicity, permits, ranger patrols, and scientific monitoring.

Canadian Arctic Profiles has made widely available maps of sensitive wildlife areas along the Canadian coast, integrating seven different components: sensitivity, vulnerability, relative density, harvesting, endangered species index value, travel routes, and season. These efforts can serve as models for products from workshops focusing on seabird disturbance in the CCS.

7.10 RESEARCH AND MONITORING RECOMMENDATIONS

1. Investigate and model short-term and long-term effects of oil spills (chronic and catastrophic) on seabird prey, habitats, and population dynamics.
3. When an oil spill occurs, model the mortality of all species affected to determine appropriate mitigation and restoration efforts.
4. Assess oil pollution threats along the coast and identify areas most at risk (based on frequency of vessel traffic, time of year, and seabird numbers and diversity, etc.).
5. Implement regular monitoring of contaminant levels in seabird eggs, feathers, and tissues and of the effects of contaminants on seabird demography (survival and fecundity). Use bycaught seabirds to monitor contaminant levels.
6. Evaluate sublethal effects of contaminants.
7. Determine whether environmental contaminants are affecting breeding hormone concentrations and reproductive success.
8. Identify sources of contaminants and garbage in marine systems.
9. Examine levels of ingestion of plastics and other garbage in live and dead seabirds; determine the magnitude of this problem at the population level.
10. Map all sunken vessels in the CCS, with information on oil quantity and type aboard each vessel, date of sinking, depth, etc.
11. Identify which seabird species and colonies are most at risk from freshwater runoff (non point contaminant sources), especially from urban and agricultural centers.
12. Create a database that contains the results of seabird contaminant analyses and distribute this information to agencies with mandates to maintain water quality.
13. Investigate more thoroughly the interactions between terrestrial and marine environments regarding contaminant introductions to the ocean.
14. Consider removing fuel/oil from large-volume sunken vessels near colonies or near important seabird foraging habitats.
15. Conduct float/sink dispersal studies on small seabirds (nearshore and near island) to evaluate beach deposition rates.
16. Further investigate and document the effects of human disturbance on seabirds.

7.11 CONSERVATION AND MANAGEMENT RECOMMENDATIONS

1. Ensure that all oil transportation vessels have a double hull.
2. Change routes of major oil transportation vessels and barges based on studies of main current and wind patterns (by season) and potential impacts on important seabird colonies. Conduct studies to identify the level of “threat” in case of major oil spill at important colonies and where changes need to be recommended.
3. Enforce current bilge pumping regulations and work with appropriate agencies to increase strictness of regulations.
4. Use California oil spill response and documentation protocols as a model and make them available to other states in the CCS that lack comparable response protocols.
5. Create a database that includes a list of sensitive seabird areas, sensitive times of year, and a list of contact people for each of these areas. This database should be made available in the case of oil spills or other contaminant emergencies.
6. Require bilge tank cleaning to occur further offshore than current regulations mandate.
7. Work with waste removal and sanitation departments to decrease exposure of seabirds to garbage.
8. Evaluate and monitor the effects of light-intensive fishing activities on offshore, nearshore, and island colonies.
9. Include fisheries effects in management plans. Priority topics to include are: bycatch; light effects on seabirds; and disturbance of seabird colonies or roost sites by fishing vessels.

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The California Current Marine Bird Conservation Plan

Chapter 8

Use of Seabirds as Ecological Indicators and Biological Samplers
of the California Current



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The California Current Marine Bird Conservation Plan Chapter 8

*Use of Seabirds as Ecological Indicators and Biological Samplers
of the California Current*

Version 1.0

**Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum**

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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CHAPTER 8: USE OF SEABIRDS AS ECOLOGICAL INDICATORS AND BIOLOGICAL SAMPLERS OF THE CALIFORNIA CURRENT

Higher trophic level predators, such as predatory fish, seabirds, and marine mammals, depend on the ocean for their survival and successful reproduction. As such, they may be indicators of ecosystem health, including such parameters as spatial and temporal variability in food web dynamics, climate variability and change, and the effects of several human activities, such as disturbance and fishing activities.

Seabirds, in particular, may be useful indicators because they are relatively easy to study. A number of commonly measured avian parameters are useful as bio-indicators (based on demonstrated or inferred links between food abundance and availability). These include: reproductive success, adult survival, adult mass, chick growth and fledging mass, egg size, clutch size, colony attendance, activity budget, and guano production (1-8).

In this chapter we review the various ways that seabirds can be used as ecological indicators and biological samplers to aid in understanding fish and zooplankton population dynamics, fishery stocks and pollutant levels.

8.1 USE OF SEABIRD INFORMATION FOR UNDERSTANDING ZOOPLANKTON STOCK DYNAMICS

Variability in ocean climate results in changes in marine food web structure and dynamics. Investigating oceanographic variability in relation to seabird parameters can provide insight into not only seabird population trends but also population dynamics of fish and zooplankton stocks. Several investigators have reported an association between seabird prey availability and/or diet composition and various reproductive parameters, such as breeding phenology, nestling growth, and reproductive performance (9-14).

These changes in prey availability can then be linked to ocean climate patterns. Within the California Current System (CCS), biological evidence suggests that zooplankton abundance and distribution vary significantly both spatially and temporally in response to ocean climate variability (15-20).

At Southeast Farallon Island (SEFI), in central California, Cassin's Auklets (*Ptychoramphus aleuticus*) respond to interannual variability in ocean climate by alternating diet between two euphausiid (krill) species, *Thysanoessa spinifera* and *Euphausia pacifica* (13), which together comprise about 80% of the prey items in their diet. The abundance and population fluctuations of these euphausiids is hypothesized to depend upon seasonal changes in the timing and intensity of upwelling and the corresponding variance in sea temperature and overall ocean productivity (19, 21-26).

In this section we describe a study (27) that examines the response of euphausiids to variability in upwelling intensity and circulation in coastal central California and the connection between euphausiid availability and auklet reproductive parameters (timing of breeding, nestling growth rate and productivity, and prey availability from 1973 through 2001).

Relationships between auklet timing of breeding, diet, growth and productivity.

The correlations between timing of breeding, diet, growth rate and productivity are presented in Table 8.1. Hatch date was negatively correlated with the proportion of *E. pacifica* in nestling diet; thus, when hatch date was delayed, the proportion of *E. pacifica* in the diet was low. Timing of breeding was also negatively related to the strength of the spring sea surface temperature (SST) transition (not shown).

SEFI auklets breed earlier in years when fall through spring SST is relatively cool and later when fall through spring SST is relatively warm, and delay breeding substantially in strong El Niño years. When the ocean is warm in spring in the Gulf of the Farallones, the initiation of effectual upwelling is delayed, presumably resulting in a delay in euphausiid abundance. In general, the Farallon population of Cassin's Auklets appears to respond adaptively to changes in ocean climate by delaying the initiation of breeding in warm years such that the critical period of growth coincides with adequate prey availability.

Meal mass did not show any significant associations, although it was positively correlated with both the proportion of *E. pacifica* in the diet and nestling growth rate. Nestling growth rate was positively correlated with auklet productivity. Although not statistically significant, growth rate also showed a positive relationship with the proportion of *T. spinifera* in the diet and a negative correlation with the proportion of *E. pacifica*. Productivity was positively related to the proportion of *T. spinifera* in the diet.

Although the trends are not significant, growth rates were higher and reproductive success lower when breeding was delayed. However, the trend of lower productivity with delayed breeding is driven primarily by the very poor reproductive success in the strong El Niño years of 1983 and 1992. Growth rate was correlated with productivity, and productivity was strongly correlated with the proportion of *T. spinifera* in the diet. Therefore, of the two primary prey species in the diet, *T. spinifera* seems to be most important in terms of growth and productivity, while *E. pacifica* may be more important in terms of timing of breeding.

Table 8.1 – Results of Spearman-rank correlations (r_s -values) between mean auklet hatch date, meal mass, growth rate, productivity and diet composition (1973-2001, not all years inclusive for some parameters). Significant values ($p \leq 0.05$) are shaded in light grey and significant values ($p \leq 0.1$) are shaded in dark grey. Sample sizes for tests are listed in parentheses.

 $p \leq 0.05$  $p \leq 0.10$

	Hatch date	Meal mass	Growth rate	Productivity	<i>T. spinifera</i>	<i>E. pacifica</i>	All euphausiids
Hatch date	-	-0.09 (16)	0.16 (16)	-0.22 (29)	0.16 (20)	-0.52 (20)	-0.12 (20)
Meal mass	-	-	0.33 (11)	0.13 (16)	-0.05 (16)	0.35 (16)	0.25 (16)
Growth rate	-	-	-	0.65 (16)	0.20 (12)	-0.13 (12)	0.22 (12)
Productivity	-	-	-	-	0.48 (20)	-0.28 (20)	0.13 (20)

Relationships between euphausiid abundance and auklet timing of breeding, diet, growth and productivity.

The correlations between euphausiid abundance in central California and timing of Cassin's Auklet breeding, diet, nestling growth and productivity are presented in Table 8.2. The spring abundance of *E. pacifica* in central California was positively correlated with meal mass, growth rate (although not significantly) and productivity. For *T. spinifera* the spring abundance was also positively correlated with growth rate (although not significantly) and productivity.

Only weak relationships existed between the spring abundance of both species and timing of breeding as well as the proportions of both species in the diet. However, the euphausiid abundance data were collected between March and May and auklet diet samples were generally collected between May and September. Therefore, it is possible that the abundance of euphausiids in central California by summer (during the period of chick-rearing) may have been substantially different than in spring.

Table 8.2 - Results of Spearman-rank correlations (r_s -values) between *T. spinifera* and *E. pacifica* abundance in central California (May - March) and auklet hatch date, diet composition, meal mass, growth rate and productivity (1973-2002, not all years inclusive for some parameters). Significant values ($p \leq 0.05$) are shaded in light grey and significant values ($p \leq 0.1$) are shaded in dark grey.

 $p \leq 0.05$  $p \leq 0.10$

	<i>E. pacifica</i> abundance in central CA	<i>T. spinifera</i> abundance in central CA
Hatch date (n=27)	-0.16	0.10
<i>T. spinifera</i> in diet (n=20)	-	0.22
<i>E. pacifica</i> in diet (n=20)	0.10	-
All euphausiids (n=20)	0.23	-0.04
Meal mass (n=16)	0.47	-0.07
Growth rate (n=14)	0.22	0.35
Productivity (n=27)-	0.47	0.48

Nestling growth rate varied significantly on an annual basis; the highest nestling growth rates observed occurred in 1996, which was also a year in which spring abundances of both *E. pacifica* and *T. spinifera* were at some of the highest densities recorded in the central California CalCOFI time series (19).

Interestingly, these high density years in southern California were consistently followed by a 90% decrease in *E. pacifica* abundance and a corresponding but less substantial decline in *T. spinifera* abundance within one to two years. This pattern of decline may help to explain the poor nestling growth observed in 1997, the lowest growth rate in the time series.

In El Niño years, winter, spring, and summer SST is typically warm, and auklets presumably use this as a cue to delay breeding until such time that conditions become more favorable. This was the case in 1998, and growth rates were relatively high. However, 1998 may not represent a typical El Niño year; several lines of evidence suggest that there was a dramatic recovery in ocean climate by May in the tropics (28) and July in Monterey Bay (18) to cold, La Niña-like conditions, which would facilitate auklet chick growth and development.

Therefore, the relatively high growth rates observed in 1998 may be attributed not only to a delay in breeding but also to dramatically increased ocean productivity during the critical chick-rearing period. The years of 1990 and 1997 were unique in the time series in that they were the only years (for which auklet growth data are available) in which SST was substantially warmer in summer (period of chick-rearing) than in spring. In 1997, this change likely reflected the start of the 1997-1998 El Niño event (28). Because both winter and spring sea temperatures were cold in 1990 and 1997, auklets did not delay breeding efforts in those years. The subsequent increase in sea temperature by summer may have resulted in reduced prey availability during the period of chick-rearing. Consequently, there was a mismatch between the timing of breeding and prey availability, resulting in the very low growth rates. When the breeding season becomes progressively warmer, the availability of euphausiids, and *T. spinifera* in particular, may be delayed and/or reduced, resulting in lower overall nestling growth rates.

There were no significant relationships between auklet diet composition and nestling growth. The two primary euphausiid species are similar in energy density (4900 cal g⁻¹ for *E. pacifica* and 4700-5200 cal g⁻¹ for *T. spinifera* (29)), and therefore, are equally valuable prey items energetically. Although meal mass is relatively high in years of extremely poor nestling growth (e.g., 1990 and 1997), it is possible that ocean conditions are so poor and prey availability so low that individual Cassin's Auklet parents are unable to increase their foraging effort to maintain adequate chick growth rates. In such years, although the mean meal mass is relatively high, parents may be, on average, delivering a smaller number of bill-loads to chicks throughout the nestling period, thereby reducing growth rate.

In these years, perhaps the total parental foraging effort (total mass of prey delivered throughout the nestling period) was insufficient to maintain adequate growth because the mismatch between timing of breeding and prey availability was too pronounced.

Questions concerning the local distribution, timing, and magnitude of prey abundance must be considered in any attempt to understand variability in characteristics such as growth rates on seabird colonies. These relationships are both complex and difficult to quantify.

In addition, the strategy utilized by seabirds and the magnitude in which seabirds respond to ocean and ecosystem fluctuations is complicated, and may vary differently within and between years and decades. Nevertheless, this study provides a good example of how seabird information can be used to understand zooplankton stock dynamics in this region of the CCS.

8.2 USE OF SEABIRD INFORMATION IN FISHERY MANAGEMENT PLANS AND FISH STOCK ASSESSMENTS

Seabirds are good indicators of forage fish abundance, independent of conventional (and usually more expensive) fisheries sampling methods (4, 30-35). Information from higher trophic level predators such as seabirds provides indices of prey abundance and availability that can supplement information from conventional surveys by sampling in different regions than the surveys (33) and by tracking patchily distributed prey (both spatially and temporally).

Because seabirds spend most of their time at sea — and depend on the sea for their survival and that of their young — they are sensitive to changes in the ocean, both positive and negative. For a seabird pair to be successful at raising chicks, the food supply must be adequate to meet the energetic demands of the adults as well as those of the growing chicks. Diet composition is one metric that can provide a direct link between prey resources and reproductive success. Another benefit of this parameter is that it can be compared with fisheries catches or other anthropogenic indices of fish abundance (33, 36).

Seabird data, such as diet composition and reproductive success, are valuable tools for understanding fish population dynamics, and can provide useful information in fishery management plans and stock assessments. Incorporating seabird (and other top level predator) requirements (see Chapter 5) in fishery management plans are important for managing fisheries in an effective and ecologically sustainable manner.

Such use of information from non-target species (i.e., seabirds) is not only of crucial importance for predicting and monitoring ecosystem health but is also required by California's Marine Life Management Act (MLMA) and federal law (Magnuson-Stevens Fishery Conservation and Management Act) for management based on an ecosystem perspective.

In this section we describe three examples of how information from seabirds can be used to further our understanding of certain fish stock population dynamics, in addition to providing valuable information for fisheries management.

8.2.1. Seabirds as indicators of Pacific Herring (*Clupea pallasii*) spawning biomass in San Francisco Bay, California

Seabird productivity on Southeast Farallon Island in the spring and summer may serve as a basis for understanding spawning Pacific herring (*Clupea pallasii*) biomass and body condition in San Francisco Bay in the following winter. If ocean feeding conditions are good for seabirds (indicated by high chick productivity estimates), then feeding conditions may also be good for herring (indicated by high spawning biomass and good body condition when herring enter the bay to spawn).

Herring spawn beginning at two or three years of age, during the late fall to early winter, after which they travel to the open ocean to feed for the next seven to nine months. The period of time when herring are feeding at sea is crucial for determining survival and the “health” of the fish stock when they return to spawn. The main

months when herring are feeding at sea coincide with the time that seabirds on the Farallon Islands are laying eggs and raising chicks. Despite the importance of this time period, little is known about conditions that affect the survival of herring while at sea.

Results from regression analyses indicate that during El Niño years — when coastal upwelling was reduced and ocean production was low (as occurred in the strong El Niño events of 1982-1983, 1992, and 1997-1998) — both seabird offspring production and the indicators of herring spawning biomass were generally low. Some planktivorous seabirds (seabirds that feed mainly on plankton, such as Cassin’s Auklets, Western Gulls, and Common Murres) have similar food habits to adult herring at sea and show association between their chick production and herring body weight and condition (Fig. 8.1, Table 8.3).

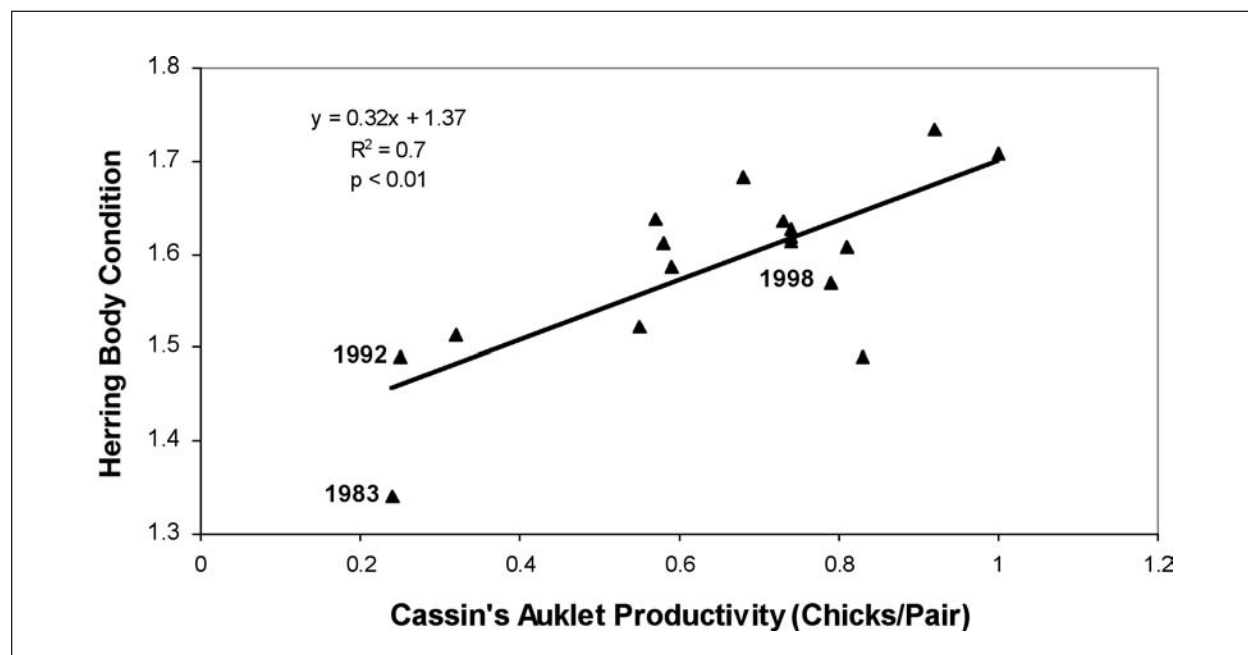


Figure 8.1. – Regression of herring body condition (weight/length³) at age 6 and Cassin’s Auklet chick productivity. Years in bold are El Niño years.

Table 8.3 - Significance table for herring body condition by age (years 1- 8) in relation to chick productivity of six seabird species that breed on the Farallon Islands. (Body condition = $\text{weight}/\text{length}^3$, * = significant at the 0.05 level. Species in bold are planktivorous species - Common Murres on the Farallon Islands are planktivorous during the winter and early spring.)

	Herring Age (years)						
	1	2	3	4	5	6	7
Western Gull					*	*	*
Common Murre		*			*	*	*
Cassin's Auklet			*	*	*	*	*
Brandt's Cormorant							
Pelagic Cormorant							
Pigeon Guillemot							

The California Department of Fish and Game (CDFG) manages the herring fishery, collecting population data during the spawning period when herring are within the Bay. The information that CDFG currently uses for assessing the status of the herring population to establish fishing quotas for the following season is of two types: information based on the previous season's spawning biomass, young-of-the-year abundance, and age composition; and information based on the current season's ocean conditions.

Favorable ocean feeding conditions appear to be reflected in the survival of young-of-the-year as well as in the body condition of adults that return to spawn in San Francisco Bay the following year. However, using biomass estimates from one year to predict the following year's estimate may be misleading, given the variable oceanographic conditions that affect herring foraging and survival at sea. Information concerning oceanographic conditions is available, but the link between ocean conditions and abundance of lower trophic level organisms, which is the basis of the marine food chain, is less clear and varies from year to year.

Seabird productivity, especially of planktivorous species, provides a proxy for the ocean conditions and prey availability that herring experience during those months they are feeding at sea. The results of this study suggest that there is a strong and predictable association between seabird productivity on the Farallones and herring abundance and body condition in the Bay.

This information can be incorporated into models used by CDFG to set fishing quotas based on the best available information, including the little-known information on feeding conditions for herring when they are at sea. Using seabird information to help understand the survival of herring while they are at sea can aid in the management of this commercially important fish species and is a novel approach to fish management.

8.2.2. Using seabird productivity information for predicting ocean conditions that affect chinook salmon

During their oceanic life stage, salmon are subjected to similar oceanographic and climatic conditions that affect seabirds. For example, the adult chinook salmon (*Oncorhynchus tshawytscha*) diet in central California is similar to the diet of several seabird species that breed in this region. Seabird diet and reproductive success on the Farallon Islands may provide many opportunities for finding the links between various marine species that depend on similar resources and that are affected by the same environmental variables.

In this example, the relationship between the reproductive success (chicks/pair, 1973-2002) of seven seabird species that breed on the Farallon Islands and the Central Valley Index (CVI), which is the annual index of chinook salmon abundance for the combined Central Valley chinook stocks is compared. Seabird species examined

included Common Murre, Pigeon Guillemot (*Cepphus columba*), Rhinoceros Auklet (*Cerorhinca monocerata*), Brandt's Cormorant (*Phalacrocorax penicillatus*), Pelagic Cormorant (*Phalacrocorax pelagicus*), Cassin's Auklet, and Ashy Storm-Petrel (*Oceanodroma homochroa*).

The Salmon Technical Team (STT) of the Pacific Fishery Management Council (PFMC) uses several methods for forecasting chinook salmon abundance, as part of the salmon fishery management off the coasts of Washington, Oregon, and California. In the case of chinook salmon in California's Central Valley, the STT considers the Central Valley Index, the sum of the ocean fishery chinook harvest in the area south of Point Arena, plus the Central Valley adult chinook spawning escapement (PFMC 2003). The STT has used and evaluated several predictors of the CVI, but since 1991 has used a linear regression estimator (1990-2002) based on the previous year's Central Valley age-two return ("jacks") to forecast the CVI for the following year (Fig. 8.2). This forecast has ranged from 0.50 to 1.67 times its postseason value.

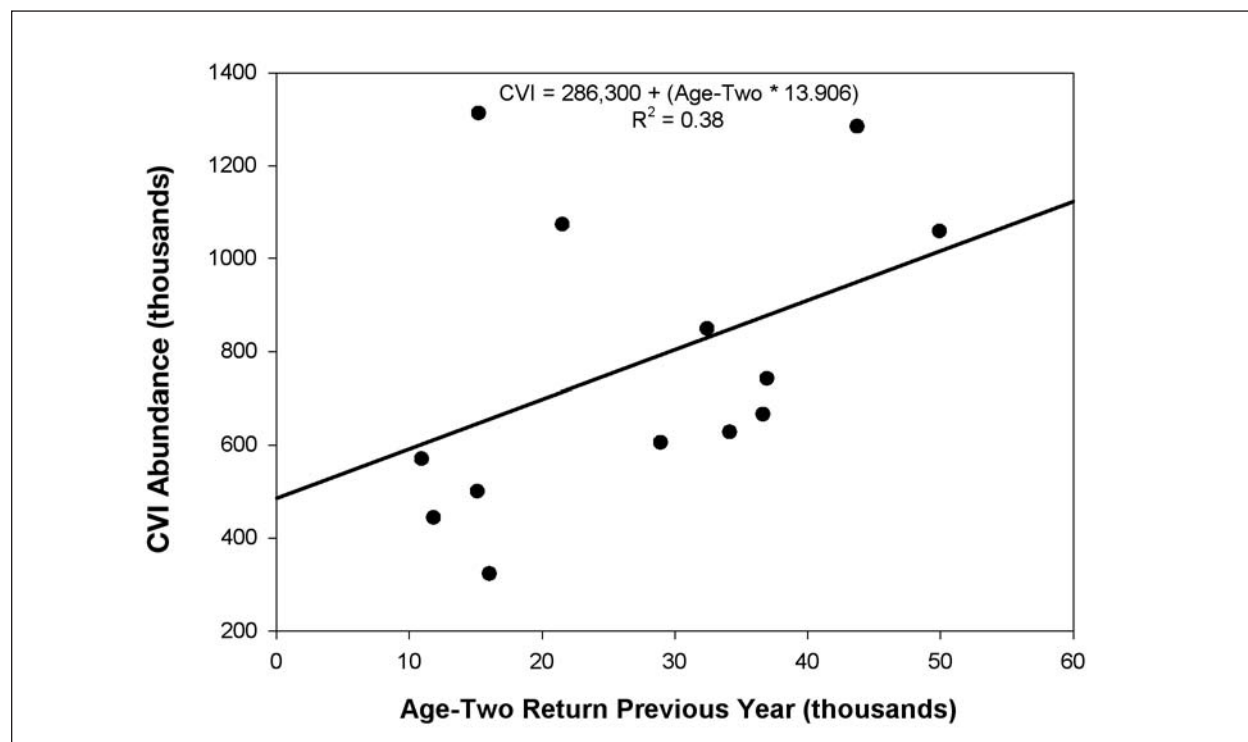


Figure 8.2 - Regression estimator for the Central Valley Index (CVI) based on previous year's river return of age-two Central Valley chinook, 1990-2002 (from PFMC 2003).

If we incorporated the bird and jack data into a combined index to predict CVI abundance (Fig. 8.3), this results in perhaps a “better” predictor than the use of age-two returns alone. When dividing the preseason forecast by the postseason estimate, a perfect predictor would result in 1.0, indicating that the preseason forecast exactly matched the postseason estimate. When the bird index was used to predict the CVI, the resulting preseason/postseason average was 0.983, compared to the jack return predictor, which averaged 0.913 between 1985-2002.

Therefore, the bird index, as well as the combined index of bird and jacks, had a higher predictive value than the age-two return predictor.

More conservative estimates, represented by underestimates rather than overestimates, should be a management goal for salmon and other marine resources. This is important because underestimates are less likely to predict a CVI above the postseason estimate, whereas a high CVI estimate might lead to higher salmon catch allocations when salmon are not as abundant.

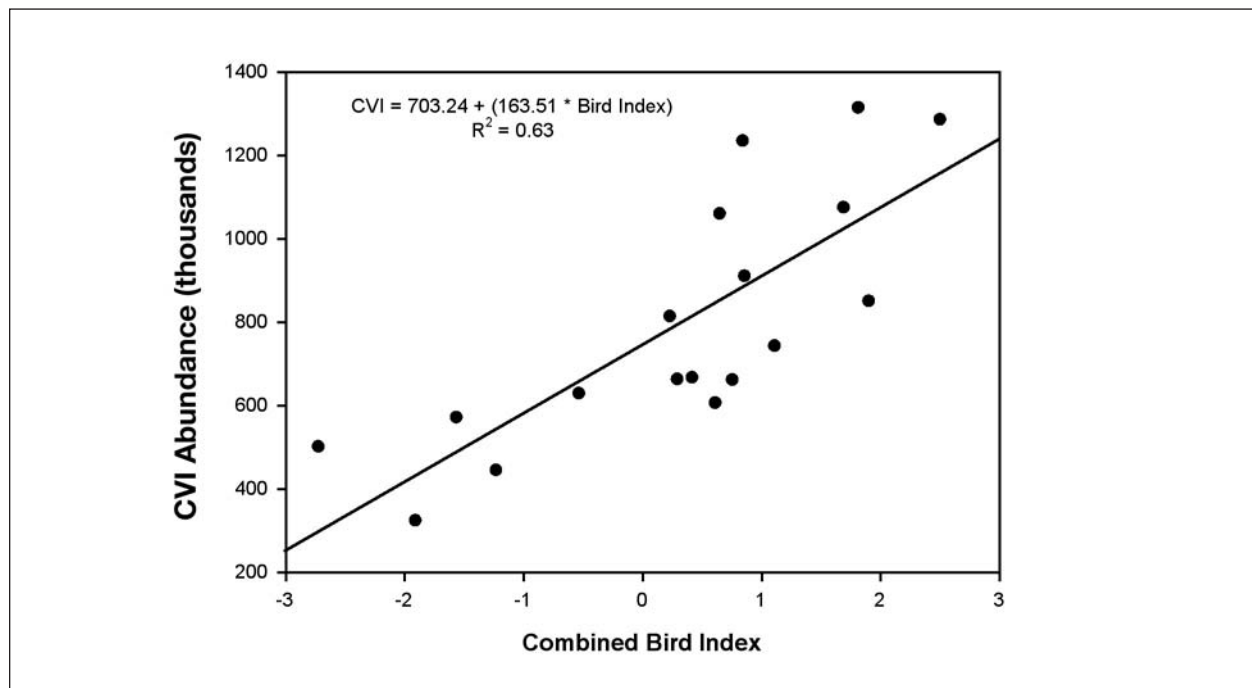


Figure 8.3 - Regression estimator for CVI based on a combined index that incorporates reproductive success of Brandt's Cormorants and Cassin's Auklets breeding on the Farallon Islands (1985-2002).

8.2.3. Temporal variability in seabird diet as a factor used to understand changes in rockfish abundance in central California

Estimates of monthly, annual, and interdecadal prey consumption by predators are valuable for understanding the role of seabirds and predatory fish as monitors of marine ecosystem change. Juvenile rockfish form an important prey item for many top marine predators in the California Current System, including chinook salmon and several species of marine birds and mammals.

Mills et al. (2005) used five independent rockfish abundance indices to develop a combined Multivariate Rockfish Index (MRI) that reflects juvenile rockfish abundance in central California for the 1980-2002 time period. The separate indices included: the diet of three species of seabirds (1973-2002) breeding on Southeast Farallon Island, the number of rockfish in salmon

stomachs (1980-1999), and the abundance of rockfish based upon National Marine Fisheries Service (NMFS) mid-water trawls (1983-2002).

Results indicate that all indices, and hence the MRI, demonstrate an overall decline in the abundance of pelagic juvenile rockfish in the central California coastal marine ecosystem between 1990 and 2000 and a subsequent increase in 2001 and 2002. The MRI demonstrates that groundfish populations in the CCS are affected by climate variability on multiple timescales.

This combined index may provide a more complete picture of juvenile rockfish population fluctuations in central California. Preliminary results indicate that the MRI has higher predictive power (i.e., the amount of variation explained is higher) when the data from all indices are included (Fig. 8.4).

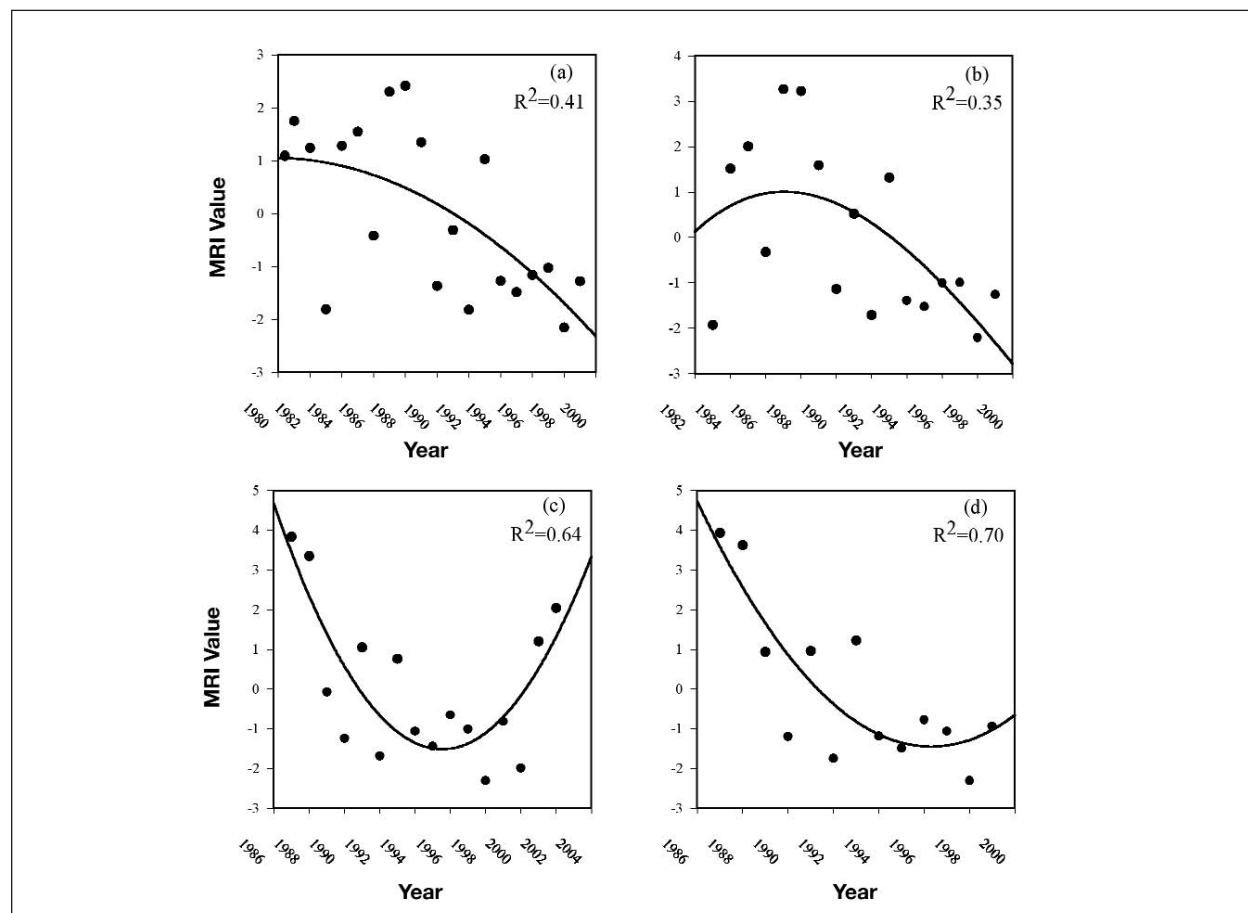


Figure 8.4 - PCA-derived Multivariate Rockfish Index (MRI) trends: (a) 1980-1999, includes Common Murre and Pigeon Guillemot diet data, and salmon diet data (excludes Rhinoceros Auklet diet and trawl surveys); (b) 1983-1999, includes Common Murre and Pigeon Guillemot diet (no Rhinoceros Auklet diet), salmon diet data, and trawl surveys; (c) 1987-2002, includes diet data from all three seabird species and trawl survey data (excludes the salmon diet data); and (d) 1987-1999, includes diet data from all trawl seabird species, as well as trawl and salmon diet data.

The addition of predator diet information in assessing rockfish recruitment strongly complements the traditional fishery-independent data (i.e., trawl surveys) to calculate stock size. These indices may prove important for back-calculating pelagic juvenile rockfish abundance in central California over the past few decades and before standardized trawl surveys were initiated.

Seabirds and predatory fish form an important component of the marine ecosystem, and as such, can be negatively impacted when fish stocks are managed without the inclusion of predator needs (4, 37, 43). It is therefore essential to include predator dietary information in order to manage rockfish fisheries in central California in an ecologically-sensitive manner. Additionally, management of the groundfish fishery and the recovery of stocks in central California and elsewhere along the West Coast are dependent upon understanding how long-term environmental variability impacts rockfish recruitment.

In general, population estimates of rockfish can be challenging, compounded by fluctuations in recruitment and year-class strength. An understanding of recruitment is critical to management of fisheries. Since rockfish are viviparous, pelagic egg surveys cannot be used for estimating spawning biomass. Trawl surveys, the preferred method for estimating the abundance of pelagic juvenile rockfish, can be problematic, given that mortality and dispersion may continue to increase during and after the pelagic juvenile phase.

Our results suggest that the MRI could be useful to fisheries biologists and managers as an integrated measurement of monthly, interannual, and possibly interdecadal variability in 0-age class rockfish abundance.

8.3 USE OF SEABIRD DATA TO ASSESS POLLUTANT LEVELS

Seabirds, as sensitive top predators in the marine environment, can be excellent biomonitors of pollution levels. To be useful as biomonitors, a good knowledge of species-specific life history and ecology is necessary, and the species used must fit certain criteria. To give a clear signal of pollution, the organism/population should respond in a quick, sensitive, and predictable way to the pollutant being monitored. The species' response to the pollutant should be obvious and unconfounded by other variables. In addition, for a biomonitoring program to be successful there must be a commitment to long-term collection of data (38).

Seabirds have been used as monitors of chemical pollution due to their visibility and position as upper-trophic level predators in marine systems (38). Sandwich Terns (*Sterna sandvicensis*) in the southern North Sea provide a good case study. Terns of all ages from a specific colony were reported having seizures and often dying from these convulsions. High concentrations of chlorinated hydrocarbon insecticides were found in the tissue of the terns and their prey.

From this evidence, action was taken to identify and shut down the source of the pollution, a pesticide plant. The effect on seabirds in this instance was extremely obvious; the tern colony crashed to less than 1,000 pairs from over 20,000 pairs a few years earlier (38).

Past studies have detailed the ecology, reproductive success, and productivity of many species of seabirds. Public interest in seabirds is such that a source of manpower for monitoring is available, making it more feasible to collect data in the long term. Colonially breeding seabirds are particularly well-suited for biomonitoring because a great deal of information can be gathered at one colony with relatively little effort (38).

Current pollutants monitored using seabird populations include chronic and single-event oil pollution, mercury, organochlorines, and plastic. Chronic oil pollution is monitored through the use of systematic beached bird surveys. These surveys can be used to study oiling rates in a relatively local area and to assess the impact that the oiling rate will have on specific species based on life history traits (39). Beached bird surveys also indicate which species are the most susceptible to oiling (39). There are limitations to these survey data, however. The deposition of dead birds on beaches is patchy and can be influenced by many factors. Clean birds noted on the surveys may be dead from oil ingestion, while birds oiled after death may also affect the accuracy of survey numbers (39). The feathers of beached birds can be used to monitor other lipophilic pollutants (38). These surveys can indicate trends, but a study must have a 10 – 15+ year data set to yield statistically significant results (38).

Mercury levels in seabirds can be used to illustrate geographic variation in contamination. Feather samples are used to assess mercury levels in seabirds, since approximately 70% of a bird's mercury content is found in the plumage (40). Mercury contamination can be back-calculated by using feathers from collected skins. Differences in prey mercury levels during egg development and chick-rearing can be ascertained by comparing mercury levels between downy and feathered chicks. In order to minimize confounding factors linked to shifting diet composition, long-term trends in mercury contamination are best monitored using a species that is a diet specialist, not a generalist.

Organochlorine contamination in seabirds can be most easily and least intrusively measured using eggshell thickness as a metric; eggshell thickness is negatively related to organochlorine (DDE) concentrations in females. Other methods of monitoring organochlorines are more damaging to seabird populations, as the birds must be killed for their internal tissues to be analyzed (38).

Quantifying plastic contamination can be problematic. Plastic intake in prey species is most commonly monitored through analyses of pellets (42). The result of this method varies with the species of prey taken and is not a reflection of total plastic, since smaller pieces tend to be lost from pellets. Another method involves looking at samples of stomach contents, typically from birds that die in the colony or as bycatch in fisheries.

In summary, pollution can be effectively monitored using seabird species, but care must be taken to understand the species and its reactions to the specific pollutants being monitored as well as to other possibly confounding causes.

8.4 RESEARCH AND MONITORING RECOMMENDATIONS

1. Assess seabird parameters for their utility as ecosystem indicators.
2. Identify and prioritize the most effective parameters and seabird species for use as samplers.
3. Investigate associations between seabird productivity (or other parameters) and forage fish condition and biomass. Attempt to develop predictive models based on this information.
4. Investigate relationships between seabird species and commercial fish species that forage on the same prey species (e.g., chinook salmon) and attempt to develop predictive models based on this information.
5. Investigate the use of seabird diet for developing fisheries recruitment indices (e.g., the Multivariate Rockfish Index); integrate seabird data with traditional methods to study these organisms.
6. Examine quantitative data on the local distribution, timing and magnitude of prey abundance in relation to variability in seabird reproductive and other life history parameters.

8.5 CONSERVATION AND MANAGEMENT RECOMMENDATIONS

1. Encourage the use of seabird-derived information (i.e. diet and reproductive parameters) in fishery management plans and fishery stock assessments.
2. Educate fisheries managers about the utility of seabird-based predictive models of fisheries and fish body condition.

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The California Current Marine Bird Conservation Plan

Chapter 10

Education and Outreach



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The California Current Marine Bird Conservation Plan Chapter 10

Education and Outreach

Version 1.0

**Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum**

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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CHAPTER 10. EDUCATION AND OUTREACH

Scientific efforts for conservation have little impact without the support of local communities, stakeholders, and government managers. To build understanding and support, research, management, and conservation programs must share their findings and involve community groups, individuals, and partners in conservation through education and outreach.

Moreover, education and outreach activities focused on the California Current System (CCS) should take an ecosystem approach that teaches across taxa – from zooplankton to humans.

For the purposes of this chapter, outreach refers to communication with land managers, agencies, planners, business interests, nonprofit organizations, academia, and volunteers. Outreach activities include, but are not limited to, conferences and workshops that facilitate communication among experts, participation in use planning, volunteer restoration and monitoring programs, field trips, and ecotourism.

Education, an important component of outreach, refers to the range of activities that educate and involve students and adults. Education activities include class and group visits to field sites, interpretive displays, specialized curricula, and participation in festivals.

In this chapter of the plan we will:

- outline key messages about the California Current System to be disseminated through education and outreach programs,
- identify user groups to address through outreach programs,
- summarize existing resources for use by educators and outreach groups, and
- highlight examples of educational opportunities and successful programs.

10.1 CHALLENGES AND KEY CONCEPTS FOR EDUCATION AND OUTREACH PROGRAMS

There are many complex conservation issues confronting seabirds in the CCS. Seabirds, however, also pose a major challenge to managers and educators, namely a lack of awareness about seabirds among the general public. In contrast with waterfowl, shorebirds, and songbirds, many people do not interact with most species of seabirds during their daily routines. With growing interest in outdoor adventure pursuits (e.g., kayaking, diving, and whale watching), there is both a greater opportunity and a need to raise public awareness about seabirds and coastal habitats, and how humans can negatively impact seabird populations.

The CCS is fortunate to have active marine refuges, state parks, and sanctuaries that support outreach programs and work alongside science and management. Moreover, there are numerous private organizations involved in marine education. All of these can serve as resources upon which to build CCS-focused education and outreach programs. For seabird and marine ecosystem education to be successful, lines of communication between educators and outreach specialists across the CCS must be developed, so that we can share resources and learn from successes and failures.

10.2 KEY CONCEPTS FOR SEABIRD CONSERVATION

The following list of *Key Concepts for Seabird Conservation* should be incorporated into education and outreach programs. These concepts are important to include in any program concerning conservation, and are indispensable for programs focusing on birds and the CCS.

1. ***To adequately support seabirds and other marine life, we must not overexploit marine resources.***

Ecosystem example:

Murres and cormorants (and many other seabirds) depend on a reliable supply of fish and zooplankton to feed themselves and their growing young. If the prey that they have come to depend on disappears or is drastically reduced due to over-fishing, this may jeopardize adult survival and successful chick-rearing.

2. ***To sustain healthy populations, seabirds must be able to evade predators and find food for several years before they reach breeding maturity.***

Ecosystem example:

Western Gulls (*Larus occidentalis*), endemic seabirds to the CCS, must be at least 4 years old to breed. To maintain their population, a sufficient number of fledged chicks must survive to replace birds that die or emigrate out of the population. In order to survive the first four years of their life, gulls must find safe, disturbance-free roosting areas; find enough food to eat; avoid disease; evade predators; and, finally, once old enough, find a breeding colony to raise their young.

3. ***Seabirds possess special adaptations that allow them to thrive in marine environment – often in harsh conditions.***

Ecosystem example:

Common Murres (*Uria aalge*), commonly seen seabirds of the San Francisco Bay area, spend most of their life at sea; but they depend on remote, rocky cliffs along the West Coast to roost and breed. Because murres lay one oblong-shaped egg that will not roll away during incubation, they can take advantage of steep and narrow rock ledges for nesting, which few land predators (e.g., coyotes) can negotiate.

4. ***Seabirds depend on habitats that are diverse in structure and flora.***

Ecosystem example:

Rhinoceros Auklets (*Cerorhinca monocerata*) need islands or mainland coasts with soft soil in which they can dig their nesting burrows. Without adequate plant cover, coastal soils are susceptible to erosion, which severely reduces the quality and availability of nesting habitat for this species.

5. ***Non-native plants and wildlife and an overabundance of native predators can upset the dynamic balance of seabird habitats.***

Ecosystem example:

Seabirds have evolved on islands and other isolated ecosystems that have been free from many mammal predators. When humans, whether inadvertently or purposefully, introduce non-native species (e.g., rats) to these sensitive ecosystems, the introduced species must find food and habitat to survive—often seabird eggs, young, and nesting burrows.

6. ***Seabirds are vulnerable to disturbance from humans and predators during the nesting cycle.***

Ecosystem example:

Brandt's and Pelagic cormorants (*Phalacrocorax penicillatus* and *P. pelagicus*, respectively) depend on steep, rocky cliffs above the ocean to nest during the spring and summer months. Approaching a cormorant colony by foot or watercraft can cause cormorants to fly away from their nests, thus leaving their eggs and young vulnerable to predation and exposure to inclement weather. Severe or repeated disturbances can even cause seabirds to abandon entire colonies.

10.3 “DID YOU KNOW?” AND “HOW YOU CAN HELP” FACTS ABOUT SEABIRDS IN THE CCS

Compelling facts can capture the interest of your audience on an educational display or can be incorporated into classroom activities. “Did you know?” facts are a great way to teach the public of all ages about seabirds in the CCS. We recommend including conservation action-items, like “How you can help” information in educational displays. Following are a few examples to include in educational programs, signs, curriculum, flyers, and presentations:

Did you know? Because of its unique physical, biological, and oceanographic properties, the CCS is one of the richest marine ecosystems of the Pacific Ocean, providing habitat and food for far-ranging and highly migratory species.

>>How you can help:

- Support your local National Marine Sanctuary or other marine refuge, park, preserve, or reserve in the CCS by becoming a volunteer.
- Encourage marine education programs in your local schools.
- Support research and conservation efforts in the CCS.

Did you know? The CCS supports 38 species of breeding birds and at least 54 bird species that commonly migrate through its waters and shores.

>>How you can help:

- Participate in International Coastal Clean-up Day (<http://www.coastalcleanup.org/index.cfm>) and clean your favorite beach of plastics and other dangerous marine debris that can injure and kill marine life.
- Support the establishment of Marine Protected Areas (MPAs) that support important habitats for migratory and resident seabirds in the CCS.

Did you know? Most seabirds only come ashore to breed, defend territories, or court mates; the rest of their life is spent feeding and roosting on the open ocean.

>>How you can help:

- Share our ocean resources with birds. Be a wise consumer of seafood, by consulting Monterey Bay Aquarium’s Seafood Watch program (<http://www.mbayaq.org/ct/seafoodwatch.asp>) for best-buy purchases at restaurants or markets.
- Learn more about the fascinating life cycles of seabirds.
- Share your knowledge about seabirds with a friend or a local school.

Did you know? Seabirds in the CCS depend on a food web that consists of small coastal pelagic fish, young of the year predatory fish (e.g., salmonids and rockfishes), macro-zooplankton (e.g., copepods and euphausiid crustaceans), and squids.

>>How you can help:

- Share our ocean resources with birds. Be a wise consumer of seafood, by consulting Monterey Bay Aquarium’s Seafood Watch program (<http://www.mbayaq.org/ct/seafoodwatch.asp>) for best-buy purchases at restaurants or markets.
- Become a volunteer at an aquarium or visitor center that teaches the public about diversity within the CCS.

Did you know? Domestic and feral cats kill approximately four million birds a day in this country alone, and have devastating impacts on seabirds across the world.

>>How you can help:

- Keep your cat indoors and educate your neighborhood about the impact of cats on birds and other wildlife. This unnecessary impact can easily be reduced if cat owners would keep their cats indoors, and if broad education on the impact of cats on wildlife is conducted.
- Support the American Bird Conservancy's (ABC) Cats Indoors! Campaign, which seeks to educate the public on the facts of cat predation on birds and other wildlife, and the hazards to free roaming cats. This information is available at the American Bird Conservancy's web site at <http://www.abcbirds.org>.
- Educate your community about outdoor cats as a conservation threat to birds and other wildlife and distribute brochures and information from ABC's website broadly.
- Attend town hall meeting to raise awareness, especially in problem areas where there are large concentrations of feral or stray cats.

Other actions that cat owners can take to help birds:

- Keep cats only as indoor pets.
- Don't abandon unwanted cats; rather, give them to the local SPCA or Humane Society.
- Spay and neuter your cats.
- Don't feed stray or feral cat populations. A more humane alternative for cats and wildlife is to reduce the unwanted cat population by limiting reproduction and facilitating adoption by responsible pet owners.
- Support local efforts to remove feral cats from the wild.

10.4 KEY AUDIENCES AND EXAMPLE PROGRAMS FOR OUTREACH

When designing and implementing outreach programs on seabirds and the CCS, it is a priority to share information with other groups who are conducting marine or seabird outreach in the CCS. Through sharing one can receive invaluable input on your program, possibly receive additional ideas, and avoid unnecessary redundancy with already established programs.

We identify four broad target groups for CCS seabird outreach programs:

- A. Stakeholders (e.g., fishers, marine tour operators, sport fishing boat operators, outdoor recreation companies)
- B. Community members (e.g., families, leisure boaters, sport fishers, outdoor recreators)
- C. Educators (school teachers and environmental educators)
- D. Land and marine managers (government agencies, private landowners, homeowners)

A. Stakeholders - Stakeholders are people who rely on the habitat for their livelihood, for example, fishers, outdoor recreation companies, etc. These are often the groups of people that have the highest potential for protecting CCS birds, yet they may be the most difficult to reach.

In order to communicate effectively with stakeholders, conservationists and educators need to find a common ground and build a relationship of trust. Highlighting the economic value of seabirds is often a great way to reach these groups. For example, fishers have come to depend on seabird flocks to guide them to their catch; thus, seabirds play an important role in the livelihood of fishers around the world.

Providing economically feasible alternatives to current practices is an asset to any outreach program targeted at stakeholders. For example, seabird entanglement on fishing lines is a problem in the CCS, both for seabirds and the fishers using this gear. Thus, solutions that diminish entanglement can be beneficial to both the birds and the fishers.

Outreach Example: Seabird Training Program for Seafood Industry.

Effective programs that target stakeholders must involve person-to-person contact. These programs can be as simple as a presentation to a local group of fishers or a field trip to view seabirds; they can also be as involved or structured as a training program. The following is an excellent example of the latter.

Although this program is not currently taking place in the CCS, it is a unique educational program established in New Zealand to teach and train new fishers about seabird-fisheries interactions and safe fishing practices to reduce seabird deaths and injuries. The Seafood Industry Training Organisation's (SITO) fisher-training program is aimed at heightening awareness and building a sense of pride about practicing good fishing at sea. See: <http://www.doc.govt.nz/Conservation/001-Plants-and-Animals/004-Seabirds/Southern-Seabird-Solutions/News/SS-media/training.asp>.

B. Community Members - Community members include the public, birders, local businesses, homeowners, families, and outdoor recreation groups. Economically, this group has a great deal of influence, especially in terms of access to recreation areas. In addition, community members can participate in conservation indirectly through creating favorable public sentiment, promoting legislation to protect marine habitats, and voting on measures to protect and enhance marine environments.

Appropriate programs for this group include general awareness-building activities such as informational flyers, birding trips, presentations within the community, outreach at local fairs, articles in newspapers and newsletters, and educational materials on the web.

In this broad audience there will be users that are receptive to messages about seabird conservation, such as birders or conservationists. Other users, such as rod and boat clubs or marinas, may be more difficult to reach because conservation measures may limit their activities. In this case, continued outreach is needed to slowly build a trusting relationship.

It is essential to provide conservation messages to diverse communities; this is often best done through partnerships with other groups who are already working and familiar with the community—a first step in building conservation connections!

Outreach Example: Seabird Hooking and Entanglement by Fishers.

City wharfs are places where both seabirds and sport fishers gather to fish. Unfortunately, this interaction can lead to entanglement or hooking of seabirds, including Brown Pelicans (*Pelecanus occidentalis*). The City of Santa Cruz, California, experienced this problem firsthand in 2002, when a school of anchovies near a city wharf drew pelicans and fishers in large numbers, leading to the entanglement and hooking of numerous pelicans. Targeting sport fishers, the City of Santa Cruz initiated a Pelican Protection Program to reduce entanglement and hooking on the wharf (<http://santacruzbirdclub.org/art-pel2.html>).

The Pelican Protection Program involved a variety of community groups and government agencies, including local bird conservationists, research institutions, rehabilitation specialists, and marine managers. Many fishers who use the wharf did not understand English, thus the program worked with translators to communicate the critical outreach messages. A training program was implemented for wharf staff and local lifeguards to raise awareness of the problem, and to inform them of when and what actions to take when they see a flock of pelicans in the area (including closing the wharf to fishing).

For more information about The Pelican Protection Program, contact Dan Buecher, Wharf Headquarters, 21 Municipal Wharf, Santa Cruz, CA 95060. NOAA's Channel Islands National Marine Sanctuary is also conducting an outreach campaign addressing this issue. Their plan is to distribute educational brochures and place signs on piers in Santa Barbara and Ventura counties, California, in the near future.

The seabird entanglement and hooking issue highlights the potential for coordinating outreach efforts between agencies and organizations across the CCS. Sharing successes, failures, and outreach messages, especially those that have been translated into different languages, will help ensure that we deliver consistent and clear messages to the public.

C. Educators - Educating educators expands the potential to reach larger numbers of people with fewer direct staff. It is essential to train educators such as school-teachers, naturalists, bird tour leaders, and docents in the key messages for seabird conservation. Identifying existing education programs in schools, nature centers, and visitor centers and partnering to infuse conservation messages into their existing programs is a cost-effective way to reach a broader audience.

To accomplish this, teacher trainings through existing networks and partnerships are an excellent way to train teachers. Providing them with materials in the form of activities, posters, and bird identification guides or cards is well received. Aligning educational programs with state science standards also makes the teachers more receptive to the messages presented through materials.

When trying to reach educators at nature centers or other docent groups, it is best to offer training for staff and provide them with outreach materials to distribute (informational flyers, posters, signs). (See the resource table for materials to distribute.)

Outreach Example: Involving Schools and Communities in Seabird Restoration.

By 1986, Common Murres had abandoned their "Devil's Slide Colony" south of San Francisco. The abandonment of this formerly thriving colony has been attributed to an overall population decline of murres in the early 1980s from the combined effects of gill netting and two devastating spills in San Francisco Bay area waters (*Puerto Rican* 1984 and *Apex Houston* 1986). The Common Murre Project was implemented in 1996 to restore this important colony for breeding murres.

In an innovative program involving researchers, managers, and educators, the project has been a great success, surpassing its goal of 100 breeding pairs at the colony. Employing a concept called "social attraction," the project placed murre decoys, a solar-powered sound system, and mirrors on the surfaces of the former colony. Classes from local schools were enlisted to paint and refurbish the murre decoys, and participating schools receive regular updates on the progress of the murres. See http://desfbay.fws.gov/Archives/Murre/Common_Murre.htm or <http://www.scc.ca.gov/coast&ocean/winter2002-03/pages/toc.htm>.

Outreach Example: Seabird Curriculum and Teacher Training at Moss Landing Marine Laboratories.

Moss Landing Marine Laboratories (MLML) runs a summer-time Teacher Enhancement Program on marine ecology, with a special focus on seabirds. One of the overarching goals of this program is to bring MLML research to the community through teachers. The program was structured for high school teachers; however, its curriculum is adaptable.

Key elements include:

- overview presentation about seabird ecology (e.g., their families, life-histories, their life cycles, and applicable conservation topics);
- hands-on labs using actual data and collected materials (stomach contents of Common Murres and diving physiology);
- classroom activities using actual data that are aligned with science standards (e.g., hypothesis testing).
- For more information about this program, see: <http://www.mlml.calstate.edu/forteachers.htm> or contact Dr. Simona Bartl, Adjunct Professor MLML (sbartl@mlml.calstate.edu).

D. Marine and Land Managers - Marine and land managers are user groups that require more technical information to make informed decisions about changing management practices to benefit seabirds. In addition, managers are often charged with managing their jurisdiction for a variety of resources and are often understaffed for the amount of work they are expected to accomplish. As a result, connecting land managers with seabirds in the CCS becomes extremely important.

It is critical to get managers into the field with biologists, connecting them to the resource and showing them the direct benefit their actions can produce for seabirds. Clear and concise messages advising managers on how to alter or enhance practices are needed. Slide presentations are also effective in reaching this group.

10. 5 EDUCATION PROGRAM OPPORTUNITIES

The concepts and guidelines outlined in this chapter can be presented to the public and to students through a variety of media. Following is a list of common education opportunities and some suggestions for content.

A. Classroom Education

Programs in the classroom should focus on communicating key concepts (see section 10.2) to students through hands-on activities. Lessons should stress studying seabirds in the field, e.g., a nearby marine sanctuary or wildlife refuge, and include observational or data collection activities. Coordinating a field trip with a group who is conducting bird conservation and monitoring projects is one way to foster interest and enthusiasm for wildlife and teaches students the importance of, and the science behind, conserving marine birds.

Project-based learning provides students and teachers with meaningful educational experiences that allow an open-ended approach to solving a conservation problem in the school or surrounding community or ecosystem. Students identify a local conservation issue in their community and through library and field research plan and implement a project from idea conception to project completion. Teachers and students work cooperatively to make important decisions, while simultaneously working with biologists, land managers, business people, private landowners, and others in the community. Because of this investment and emphasis on self-direction, students take ownership of their work, and the lessons learned are profound and long lasting (L. Rogers, pers. comm.).

An excellent example of project-based learning about seabirds in the CCS is The Murre Project (see section 10.4).

A great way to get students interested in marine birds is through observation in the field. While access to binoculars is sometimes limiting, you can contact your local Audubon Society chapter, nature center, or other local wildlife education group to see if pairs are available for check out. If you feel uncertain of your birding skills, contact your local Audubon Society chapter or nature center to see if there are any docents or naturalists who can join your class for a day of birding.

B. Volunteer Involvement

Using volunteers to aid in data collection or habitat restoration projects is an excellent way to gain additional help. It is one of the best ways to teach people about conservation. Increasingly, families, individuals, and school groups have opportunities to participate in docent programs or projects. Volunteers that participate in counting and studying birds quickly develop a connection to them, which directly and intimately involves the volunteer in the conservation effort. To ensure reliable data collection, supervisors must match monitoring techniques with the skill level of the volunteer.

C. Interpretation at Natural Areas

Interpretation is an excellent way to disseminate key concepts about bird conservation to the public. Displays at visitor centers should highlight the birds using the habitats and show the specific features of the habitat that are critical to bird reproduction and survival, including assemblages of native plants. Displays should be aimed at the general public, teaching the causes of the decline of marine birds and emphasizing solutions and simple ways to help. Again, integrating people as part of the solution encourages their support for conservation issues.

D. Participation in Community Festivals and Fairs

Birding festivals are becoming a popular means of enhancing local economies through ecotourism, which can help promote local support for conservation of natural areas—a requirement for long-term sustainability of conservation actions. Festivals also present an excellent opportunity to further educate people already familiar with birds about the scientific reasons behind bird conservation. Birders already recognize and love birds and can easily be taught the reasons for bird conservation and what a healthy bird population needs to survive. Birders also constitute a pool of experienced observers who may volunteer for monitoring programs.

Representation of bird conservation at environmental fairs is another way to reach large numbers of people, convey the key concepts behind bird conservation, and build conservation partnerships in the region. Booths that convey the key conservation messages and provide information on how individuals can help through interactive games or activities for children engage families and visitors in bird conservation topics.

The National Fish and Wildlife Foundation has published Bridges to Birding, an interactive program for introducing birds, bird watching, and bird conservation to your community. It contains step-by-step instructions on how to put on a festival or fair focusing on birds. To obtain a copy contact the International Migratory Bird Day (IMBD) Information Center at (703) 358-2318 or IMBD@fws.gov.

Conducting an IMBD celebration is another excellent way to get local recognition of birds through this international program of the National Fish and Wildlife Foundation. International Migratory Bird Day celebrates the incredible journeys of migratory birds between their breeding grounds in North America and their wintering grounds in Mexico, and Central and South America. For more information, [visit www.birdday.org](http://www.birdday.org).

10.6 RESOURCES FOR SEABIRD AND MARINE EDUCATION

The following table of resources is by no means complete; as the CCS Plan is a living document, we look forward to updating and building on this table in future versions.

Table 10.1 – *Resources for seabird and marine education in the CCS region.*

TOPIC or PROGRAM	WEB LINK
REGIONAL	
Oregon Coast National Wildlife Refuges – informational booklet	http://oregoncoast.fws.gov/OCR.pdf
Overview of breeding seabirds in WA, OR, CA	http://biology.usgs.gov/s+t/noframe/b022.htm
Save our Shores: Educational Resources and links, some of which are available in Spanish	http://www.saveourshores.org/Education_&_Outreach/index.html
Moss Landing Marine Laboratories: Teacher Enhancement Program	http://www.mlml.calstate.edu/summer_inst.htm
NATIONAL	
Marine Protected Areas	www.mpa.gov ; click on the MPA Center and then MPA Education project
Sea Education Association K-12 Lesson Plans	www.sea.edu/k12LessonPlans/k12pgmtop.htm
National Sea Grant Library	http://nsgd.gso.uri.edu/edu.html
BRIDGE: Oceans Sciences Teacher Resource Center	http://www.vims.edu/bridge/
Classroom Exploration of Oceans: Teacher Workshop Series	http://www.coexploration.org/ceo/
OBIS/SEAMAP: Marine Education Activities	http://obismap.env.duke.edu/outreach/
Environmental Education on the Internet – Searchable Resources	http://eelink.net/classroomresources-directories.html

10.7 EDUCATION AND OUTREACH RECOMMENDATIONS

Fishing Interactions:

1. Develop outreach programs that target commercial and recreational fishermen to inform them about the importance of protecting seabirds and how to minimize seabird bycatch.
2. Inform fishers of safe-fishing practices and heighten their awareness of threats facing seabirds.
3. Increase awareness of, and build interest in, seabird conservation and fisheries among the public by teaching basic marine ecosystem concepts, disseminating seabird findings and recommendations, and encouraging scientific inquiry.
4. Improve lines of communication between researchers, conservationists, resource managers, and fishers in CCS.
5. Build partnerships with other groups that are conducting educational outreach on fisheries-related issues (e.g., Monterey Bay Aquarium's Seafood Watch Program, Coastal Conservancy, The Nature Conservancy, Blue Ocean Institute, etc.).
6. Disseminate practical "how you can help" recommendations on how to minimize seabird bycatch.
7. Set up a CCS seabird observation network that allows fishers and other mariners to submit their at-sea or at-port seabird observations (e.g., location and size of feeding flocks, or unusual sightings) to promote more interest in marine birds.
8. Publish a CCS newsletter that collaborates with fishers (e.g., include an article or column written by a fisher in the CCS).
9. Collaborate with existing educator groups and/or teacher training workshops to heighten teacher awareness of seabird-fisheries interactions in order to successfully bring these concepts and messages into the classroom.
10. Improve public understanding of marine food webs (e.g., emphasizing how we and seabirds are connected by being predators of fish) and the need for balanced fishery practices and management.

11. Develop and disseminate multimedia resources to educators, including teaching tools and workshops, on seabird-fisheries interactions.
12. Conduct seabird and marine ecosystem educational outreach at fishing derbies, fairs, and events.
13. Conduct pelagic or coastal bird cruises to heighten public recognition and understanding of seabirds.
14. Heighten public understanding of existing marine laws that protect seabirds and fish.

Marine Ecosystem Protection:

1. Increase public awareness about the major threats to marine ecosystem protection (human disturbance, bycatch, prey competition, overfishing).
2. Educate public about seabird life histories in the CCS, highlighting diverse ecological requirements.
3. Educate public about the importance of Marine Protected Areas and "marine hotspots."
4. Collaborate and communicate with other groups and agencies in the CCS who are conducting educational outreach on marine topics.
5. Develop and disseminate multimedia resources, including teaching tools and workshops, to educators on marine ecosystems.
6. Conduct seabird and marine ecosystem educational outreach at fairs or other events.
7. Conduct pelagic or coastal bird cruises to heighten public recognition and understanding of marine ecosystems.
8. Heighten public understanding of existing marine laws that protect marine ecosystems.
9. Create a constituency for MPAs among the wildlife-watching public (bird and whale-watchers).

Habitat Protection:

1. Develop public education programs on the effects of human disturbance on seabird colonies; this is crucial for colony protection, especially for small colonies that exist near human habitation and ecotourism destinations (i.e., caves, sea kayaking).
2. Educate boaters on direct (running over adults and chicks, disruption of feeding flocks) and indirect effects (flushing and predation of eggs and chicks) of boat disturbance on seabirds.
3. Establish regular education programs (and distribution of leaflets) for pilots (both military and civilian) to educate them on the effects of aircraft disturbance to seabirds.
4. Initiate a U.S., Mexico, and Canada partnership to begin joint recovery/protection/ education programs. Coordinate protection of existing breeding habitat and restoration of historic habitat.
5. Heighten public awareness of the importance of protecting islands and rocky shore habitat for the life cycle of seabirds.
6. Disseminate to the general public and land managers “how you can help” recommendations that pertain to the protection of terrestrial habitats for seabirds.
7. Develop and disseminate multimedia resources to educators, including teaching tools and workshops, on marine habitats (e.g., a visual schematic showing different nesting seabird niches on a hypothetical island in the CCS).

Population Monitoring:

1. Initiate a U.S., Mexico, and Canada joint partnership to begin monitoring of breeding populations and development of education programs.
2. As part of this partnership, assist/coordinate training of researchers and volunteers to help standardize protocols and monitoring methodologies.
3. Organize forums to help disseminate information regarding the value of long-term monitoring in understanding ecosystem health, and why seabirds are great indicators of this.
4. Involve marine user-groups, e.g., fishers, in data collection and provide volunteer opportunities to the public on how they can become involved with seabird population monitoring.
5. Promote the importance of long-term population monitoring to the general public and marine managers.
6. Provide press releases on the health of seabird populations in the CCS, and publish this type of information in a CCS newsletter (i.e., how did the seabirds do this year?).
7. Place cameras in seabird nest boxes with a live feed to a website, which can be accessed by biologists, schools, and education groups.

Pollution Effects:

1. Educate the public on the effects of oil on seabirds (both at large scales, such as an oil spill, and small scales, such as oil in storm drain runoff usually ending up in the ocean).
2. Identify specific pollution threats and shape education recommendations around these threats. Also, working in parallel with management points is necessary for effectiveness.
3. Collaborate with other groups and agencies that are conducting educational outreach on pollution to provide information on effects of pollution on seabirds.
4. Use innovative outreach strategies (like painted fish over storm drains) to educate the public about urban runoff and pollution.
5. Conduct targeted outreach campaigns to primary marine polluters that provide practical recommendations on managing waste at sea and at port.
6. Develop and distribute educational flyers or brochures on different types of marine pollution—from oil spills to six-pack holders—and their effects on seabirds.
7. Create and disseminate teaching tools for educators, focusing on marine pollution and its effects on seabirds and marine ecosystems.

Ecological conditions/climate change/global warming:

1. Collaborate with groups and agencies that are conducting educational outreach on climate change to provide information on effects of climate change on seabirds.
2. Collaborate with existing educator groups and/or teacher training workshops to heighten teacher awareness of climate change and global warming to successfully bring these concepts and messages into the classroom.
3. Create and disseminate teaching tools for educators, focusing on ocean processes, climate change and global warming, their potential effects on seabirds and marine ecosystems, and what can be done to help.
4. Create and disseminate handouts, white papers, and brochures on climate change and global warming and their potential effects on oceans and seabirds.
5. Publish a column or article(s) in a CCS newsletter on climate and oceans, which defines and explains ocean climate condition indicators such as Pacific Decadal Oscillation and El Niño Southern Oscillation, etc.
6. Place cameras in seabird nest boxes with a live feed to a website, which can be accessed by biologists, schools, and education groups.

Other Recommendations:

1. Assure that CCS educational activities are aligned and coordinated with the North American Waterbird Conservation Plan.
2. Participate in regional and national waterbird education working group(s).
3. Increase visibility and awareness of seabird conservation, in general, since seabird-related issues are overlooked far too often.
4. Form committees and hold meetings and/or breakout groups that specifically address waterbird education and outreach at scientific and conservation conferences.
5. Encourage greater communication, coordination, and development of outreach components between the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, and organizations involved in seabird research and protection.

The California Current Marine Bird Conservation Plan

Chapter 11

Seabird Conservation Strategies and Needs



Photo: Dave Gardner, PRBO Conservation Science

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The California Current Marine Bird Conservation Plan Chapter 11

Seabird Conservation Strategies and Needs

Version 1.0

Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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CHAPTER 11. SEABIRD CONSERVATION STRATEGIES AND NEEDS

11.1 MITIGATION AND ELIMINATION OF BYCATCH

For the conservation of seabirds of the CCS, it is essential that injury and mortality from fishery bycatch is reduced and even eliminated. As long as fisheries exist, bycatch will be of concern. However, there are certain measures that fishers can take to reduce the risk of seabird entanglement.

It is of great importance to: (1) have observer programs that can identify the problem fisheries, (2) have knowledge of the seabird species affected and the areas where the problem exists, (3) have measures developed that can be taken to reduce or eliminate bycatch, and (4) work with fishers to accomplish this goal.

The appropriateness of measures that help decrease seabird bycatch and the effectiveness of these measures depend on several factors, including location where the fishery operates, season of operation, seabird species involved in the interactions, and environmental factors, among others.

Measures designed to mitigate seabird bycatch can target several different goals: decrease the attractiveness of the vessels to seabirds; prevent seabirds from becoming hooked; and if a seabird gets hooked, reduce the possibility of death (1).

Since 1991, mitigation measures to reduce incidental seabird bycatch have been developed and evaluated for effectiveness. In both pelagic and demersal longline fisheries, only five countries have active research programs designed to test the effectiveness of mitigation measures for addressing seabird bycatch: Australia, Japan, New Zealand, United Kingdom, and United States (2).

Several types of mitigation measures have been developed or are currently under development for reducing seabird bycatch in longlines. Table 11.1 summarizes these mitigation measures, their stage of development and testing, relative cost, and their effectiveness at reducing bycatch.

At an international level, a number of measures, both governmental and non-governmental, have been developed to address issues of seabird bycatch. In an effort to reduce seabird bycatch in longline fisheries in the high seas and in exclusive economic zones (EEZs), the Food and Agriculture Organization (FAO) of the United Nations created an International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries in 1999 (IPOA-Seabirds) (3).

As one of the recommendations of the IPOA-Seabirds, individual nations were encouraged to develop a National Plan of Action for reducing incidental catch of seabirds in longline fisheries (NPOA-Seabirds). Currently, NOAA Fisheries (formerly the National Marine Fisheries Service), the U.S. Fish and Wildlife Service, and the State Department are working together on an Interagency Seabird Working Group to implement the NPOA.

Seabirds, as highly migratory animals, do not necessarily remain within U.S. waters; many species frequent international waters as well as waters under the jurisdiction of other countries. This situation can add further levels of complexity to seabird conservation efforts. For example, longline fisheries operating outside of U.S. waters have high seabird bycatch rates, although there is little documentation and observer programs are rare, if present at all (2). Most vessels are required to submit catch data to fisheries agencies of their respective countries in addition to filling out logsheets, although logsheets do not provide data on bycatch of marine mammals, turtles, or seabirds.

Some longline fisheries do monitor bycatch. In the swordfish fisheries operated by Japan, Chile, and Australia, bycatch is monitored on Japanese and Australian vessels (4). However, observer coverage in these fisheries is not entirely random and logbook data may be incomplete or inaccurate.

The measures that appear to be most effective at reducing seabird bycatch in longlines are night line-setting, sinking hooks faster by adding weights, using bird-scaring lines, and enacting area and seasonal closures (1, 5) (Table 11.1). Additional strategies are being explored to develop new technologies, build awareness of seabird conservation among fishers, and encourage the use of mitigation measures (1, 2).

In response to growing recognition of the threats posed to seabirds by fisheries, several international efforts have been initiated to increase public awareness of the problem as well as cooperation and coordination between nations. A prominent example of such efforts is the “Save the Albatross” campaign begun by BirdLife International in 2000 (<http://www.birdlife.net/seabirds/index.cfm>). The first workshop to address seabird mortality in longline fisheries was held in Hobart, Australia in 1995, with a second workshop held in Honolulu, Hawaii in 2000. These workshops specifically addressed the mortality of albatrosses and petrels. In 1999, the Pacific Seabird Group held a symposium on seabird bycatch which resulted in production of the book, *Seabird Bycatch: Trends, Roadblocks, and Solutions* (6).

Table 11.1 – Mitigation measures for decreasing seabird bycatch, the stage of their development and testing, their relative cost, and their effectiveness in reducing bycatch.

MITIGATION MEASURE	DEVELOPMENT STAGE	TESTED	RELATIVE COST	CATCH REDUCTION EFFICIENCY
<i>Reduce bait visibility</i>	in use	in use	widely none, locally high initial	very high
<i>Reduce attractiveness of vessel</i>	fully	unknown	moderate initial	very high (line hauling)
<i>Weighted line</i>	partly	unknown low ongoing	high initial,	very high
<i>Brickle curtain</i>	fully	unknown	low	very high
<i>Preferential licensing for vessels</i>	concept only	no	unknown	high
<i>Bird-scaring line</i>	fully	yes, some	low ongoing	high but variable
<i>Area and seasonal closures</i>	not used	no	unknown	high potential
<i>Artificial bait or lures</i>	concept only	no low ongoing	high initial,	high potential
<i>Below-the-water setting</i>	partly	unknown	high initial	total
<i>Release live birds</i>	fully	unknown	no	moderate potential
<i>Hook modifications</i>	concept only	no	moderate initial	moderate potential
<i>Thawed bait</i>	partly	yes	low ongoing	moderate potential
<i>Punctured swim bladder</i>	partly	yes	low ongoing	moderate potential
<i>Line-setting machine</i>	fully	partly	moderate initial, low ongoing	moderate potential
<i>Bait casting machine</i>	fully	partly	high initial	moderate potential
<i>Water cannon</i>	fully	limited	moderate initial	unknown, low likelihood
<i>Acoustic deterrent</i>	fully	limited	low initial	unknown, low likelihood
<i>Magnetic deterrent</i>	fully	limited	moderate initial	very low likelihood

Observer Programs

Observer programs are crucial for documenting fisheries-induced seabird mortality and injury, although very little quantitative or qualitative information exists regarding seabird bycatch for most of the fisheries that operate in the North Pacific.

Categorization of fisheries under the Marine Mammal Protection Act's (MMPA) List of Fisheries (LOF) determines whether or not a specific fishery needs to comply with certain regulations imposed by the MMPA, such as mandatory observer coverage. However, the LOF only covers fisheries that operate within U.S. waters, notwithstanding the fact that several foreign fisheries also pose a significant threat to seabirds.

Although the majority of observer programs that document seabird bycatch were originally developed to monitor and minimize sea turtle and marine mammal bycatch, seabirds have indirectly benefited from this monitoring effort; much of the currently available information on seabird bycatch has been a result of this indirect monitoring. Currently, observer data are being collected for only 8 of the 17 fisheries that have documented seabird bycatch (see Table 6.1).

Rigorous scientific studies need to be conducted to develop gear and/or fishing techniques that have the primary goal of zero bycatch. These types of studies require an adaptive management approach, such that once the studies are completed and new regulations are implemented, the fishery will be monitored to document that the bycatch does decrease as expected. If it fails to do so, the regulations may need to be changed. Recent studies in Hawaii have provided promising results regarding the use of underwater setting chutes to eliminate the bycatch of albatrosses on pelagic longline gear.

Measures specifically targeted to help reduce seabird bycatch include the following:

1. High mortality of marine mammals, sea turtles, and seabirds caused a permanent closure of the set gillnet fishery in California (approved in September 2002), prohibiting the use of gill and trammel nets in the area from Point Reyes, Marin County to Point Arguello, Santa Barbara County, in waters 60 fathoms or less.
2. As one of the outcomes of California's Marine Life Management Act (MLMA), the development of Fisheries Management Plans (FMP) is required for all fisheries. These plans must address issues of bycatch. The MLMA requires a shift in fisheries management from a focus on individual populations to a focus on the sustainability and resiliency of the entire nearshore ecosystem, including seabirds.
3. The Washington Fish and Wildlife Commission adopted regulations in 1997 to reduce seabird bycatch (mostly Common Murre *Uria aalge* and Rhinoceros Auklet *Cerorhinca monocerata*) in the non-tribal Fraser River sockeye fishery in northern Puget Sound. These regulations included the elimination of dawn fishing and the use of modified nets that had 20-mesh visual alerts (7). These measures have only been partially effective because they do not apply to the tribal fisheries.
4. Mexican fisheries regulations set by the Ley de Pesca (D.O.F. 25-VI-1992) allow for fisheries closures to prevent overharvesting of target species. However, currently there are no closures based on reserving prey resources for seabird species of the Baja California islands (Q. García, pers. comm.).
5. In British Columbia, a 1998 workshop that focused on seabird bycatch issues led to the formation of a Pacific Seabird Bycatch Working Group in 2000. This group is active in determining levels of seabird bycatch in the different fisheries, training observers, and developing seabird salvage programs.

11.2 PROTECTING FOOD WEBS: MARINE RESERVES AND MINIMIZING FISHERIES PREY DEPLETION

The total area of the world's marine protected areas currently covers only about 0.5% of the world's oceans, while 0.01% of the sea is legally protected from fishing. Estimates show that more than 40% of the world's marine fishery populations are profoundly exploited, with an additional 25% overexploited, exhausted, or recovering. Prominent marine scientists are supporting a marine environment management program based on designating 20-30% with no-take and fully protected status (9).

Fully protected marine reserves are an emerging tool for marine conservation and management. Defined as "areas of the ocean completely protected from all extractive and destructive activities," fully protected marine reserves (hereafter, simply "marine reserves") have explicit prohibitions against fishing and the removal or disturbance of any living or nonliving marine resource, except as necessary for monitoring or research to evaluate reserve effectiveness.

Sometimes called "ecological reserves" or "no-take areas," marine reserves are a special class of "marine protected areas" (MPAs). MPAs are defined as "areas of the ocean designated to enhance conservation of marine resources." The actual level of protection within MPAs varies considerably; most allow some extractive activities such as fishing, while prohibiting others such as drilling for oil or gas. A "network of marine reserves" is "a set of marine reserves within a biogeographic region, connected by larval dispersal and juvenile or adult migration" (10-12).

By protecting geographical areas, including both resident species and their biophysical environments, marine reserves offer an ecosystem-based approach to conservation or fisheries management, which is distinct from the traditional focus on single-species conservation or management (10, 13, 14).

Halperin (15) quantitatively analyzed 69 studies of marine reserves of various sizes and found the diversity of communities and the mean size of the organisms within a reserve were between 20% and 30% higher relative to unprotected areas. The density of organisms was roughly double in reserves, while the biomass of organisms was nearly triple. The establishment of marine reserves increased catch and size of individuals caught in adjacent fisheries (16).

Marine reserves facilitate the recovery of degraded marine habitat (17), and it is believed that habitat protection in reserves underpins fish productivity and provides the link between reserves and augmented catches (18).

The few studies investigating fisheries effects of marine reserves have occurred in tropical and subtropical marine environments, where most reserves have been established; however, modeling of fisheries-marine reserve interactions has yielded promising results.

A wide range of models suggest reserves will be most effective for species that are relatively sedentary as adults, but produce offspring that disperse widely. Adult spawning stocks will be secure from capture in reserves, while their offspring disperse freely into fishing grounds. Such species include animals like reef fish, mollusks, and echinoderms, and models typically indicate that when they are over-fished, catches will be higher with reserves than without.

By contrast, the same models suggest that reserves will be ineffective for animals that are mobile as adults—species like cod, tuna, or sharks. These species remain vulnerable to fishing whenever they move outside reserves.

Unfortunately, most models lack sufficient realism to effectively gauge reserve effects on migratory species. They usually assume that individuals are homogeneously distributed in a uniform sea and move randomly. They also assume that fishers hunt at random. Neither is true. For centuries, fishers have targeted places and times when their focal species are most vulnerable to capture. Protecting these sites and/or temporal windows could have disproportionately large effects on stocks.

Furthermore, models rarely take into account possible benefits from improvements in habitat within reserves. Such changes, like increased biomass and complexity of bottom-living organisms, could alter fish movement patterns and reduce natural mortality rates in ways that enhance reserve benefits. A simple model of reserve effects on a migratory fish species that incorporated spatial variation in vulnerability to capture showed that strategically placed reserves can offer benefits in the form of increased spawning stock and catch, especially when fishing intensities are high (19).

The Ecosed MPA model considered both multiple fleets and ecosystem-scale dynamics for the North Sea. This realistic model suggested that policy goals that did not include ecological considerations negatively impacted rents obtained by the different fishing sectors.

Size of the MPA was another important variable; the conservation value of an MPA was negatively impacted unless the MPA was very large. The Ecosed model also suggested that policy goals based solely on conservation negatively impacted most fisheries. Under policy options that included ecological considerations, maximum benefits were derived from an MPA that covered 25-40% of the North Sea, situated along the southern and eastern coasts.

Finally, the Ecosed model suggested that small-to-substantial positive impacts to most species and fleets occurred by excluding only the trawl fishery from the MPA; this relative impact depended on the level of interaction between the trawl fleet and the target species of other fleets (e.g., through bycatch) (20).

Studies of effects of marine reserves on marine birds are slowly forthcoming. Satellite data from foraging penguins indicated that marine reserves near colonies may effectively protect gentoo penguins, but will be inadequate to protect other penguin species.

Many seabird species are wide ranging and, thus, would require marine reserves on immense spatial scales to protect their full foraging range. For such highly mobile species, marine zoning (regulating location and timing of human activities over large areas of the marine environment) will be required to minimize seabird-human use conflicts (21).

11.3 SEABIRD RESTORATION

Due to their proximity to highly populated areas, major shipping lanes, and commercially important fishing grounds, seabird communities in the CCS region have been subjected to numerous anthropogenic impacts. Oil spills, gillnet fisheries, habitat degradation, introduction of non-native plants and animals, and disturbance to breeding colonies and roost sites have all had detrimental effects on seabirds. These effects range from increased mortality and decreased reproductive success to large-scale population reductions and loss of breeding colonies. Restoration is becoming an increasingly popular and effective management tool to counteract these effects and aid in the conservation of seabirds (22).

Restoration has been defined by the Pacific Seabird Group as “any action taken directly or indirectly to manipulate a system for the repair or recovery of injured populations, colonies, or communities” (23). Unlike previous definitions by NOAA and the U.S. Department of the Interior (reviewed in Warheit et al., (23)), this does not consider natural recovery as restoration unless a specific management action is taken to facilitate the recovery.

Successful restoration plans aim to return populations, communities, or systems to the level and function that would have occurred had the disturbance not taken place.

Successful restoration of seabird communities requires a few key pieces of information: 1) reliable estimates of the population size and trends, productivity, and survival prior to perturbation, 2) reliable injury assessment; that is, information on the number of birds directly or indirectly affected, 3) knowledge of the factors (both natural and anthropogenic) that may limit population growth or recovery, and 4) regular monitoring as a follow-up to the restoration initiative in order to gauge its effectiveness.

Past seabird restoration efforts have focused on four main strategies:

1. Reintroduction or supplementation of populations:

Reintroduction of species or supplementation of existing populations is perhaps the most direct method for restoring a seabird community. Efforts have been made involving translocation of adults or chicks from existing colonies to those that had been reduced or extirpated (24). Social attraction is another effective method for drawing adults and first-time breeders into a new colony. This technique employs a variety of methods, including decoys, mirrors, and call playback, to entice birds from nearby colonies to settle and eventually reestablish breeding (25-27). Captive rearing and release is another option that has been employed in the restoration of species such as the California Condor (*Gymnogyps californianus*), but is not frequently used with seabirds due to relatively high costs and low returns for the investment (23).

2. Creation or enhancement of seabird habitat:

Habitat enhancement is most effective where suitable habitat is either limited or degraded due to perturbation. Installation of artificial nest boxes has been an effective means of restoration for cavity-nesting seabirds such as the Rhinoceros Auklet, Cassin's Auklet (*Ptychoramphus aleuticus*), and Pigeon Guillemot (*Cepphus columba*) (28). Artificial ledges or structures for cliff-nesting species such as Pelagic Cormorants (*Phalacrocorax pelagicus*) and Common Murres have also been successful (S. Hatch, pers. comm.). Enhancement of habitat may also be accomplished through the removal of introduced plant species and/or reestablishment of native vegetation. Efforts such as these may provide additional available habitat, slow erosion (particularly important for burrowing seabirds), and mitigate damages caused by human disturbance (29).

3. Management of human activities around colonies:

Managing human activities can have a positive restorative effect by removing or lessening impacts on the colony and allowing natural recovery. Creation of protected areas, enhanced regulation of fisheries that compete with seabirds for food or result in bycatch, reductions of disturbance through public education and closure of sensitive areas, and regulation of pollutants are all ways to reduce negative anthropogenic impacts on seabird communities.

4. Management of non-native species:

Seabirds are adapted to breed in remote locations and on islands that are free of mammalian predators. The accidental introductions of mice and rats and the intentional introduction of cats, foxes, and rabbits have had devastating impacts on seabird colonies (30). These species prey on eggs, chicks, and adults and in some cases compete for available resources such as nesting habitat (28). Eradication of these introduced predators and prevention of reintroduction allow colonies to recover from disturbance (21, 31). Non-native plants can also have detrimental effects on seabird communities by altering the habitat and making it unsuitable for use by seabirds (21).

Regardless of the methods employed, all restoration efforts require direct management action to preserve or enhance seabird resources and require substantial investment of time and money by managers and researchers to ensure their success. It is likely that restoration will become increasingly important in the future management of threatened or highly impacted seabirds.

11.4 SEABIRD CONSERVATION IN RELATION TO HABITAT THREATS

The Pacific coastlines of the United States, British Columbia, and Baja California and their offshore islands provide not only diverse breeding and roosting habitat but also rich feeding grounds for millions of seabirds, both migrants and residents. Nesting habitat and roosting sites, free of disturbance and predators, are critical to the survival of seabird species, yet habitat degradation and alteration continue to pose a serious threat to seabird populations in the CCS region.

Habitat usage by seabirds can be broadly lumped into three major categories: 1) nesting and roosting habitat, 2) foraging habitat, and 3) at-sea habitat (21).

Threats to nesting and roosting habitat may include direct damage caused to breeding and roosting sites through coastal development; introduction of non-native plant species which alter habitat, thereby making it unsuitable to use by seabirds; increased erosion due to loss of vegetation or overgrazing by introduced animals; and mining or guano harvesting operations. Indirect damage is also a concern. Increased disturbance caused by human encroachment around important seabird breeding and roosting areas and increased boat traffic and aircraft overflights can have serious detrimental impacts. Repeated disturbance may force seabirds to use less-preferred habitats, thereby increasing their energy expenditure and/or vulnerability to predation. Additionally, the amount of time spent traveling to and from food sources may increase (32), causing added stress.

Although they are most conspicuous when concentrated at breeding colonies, seabirds spend the majority of their life on the oceans. Effective conservation of seabirds must aim to protect not only the terrestrial habitats important for breeding and roosting, but also the marine habitat that is the source of their sustenance. Marine habitat protection is equally important for the many migrant species (such as the Sooty Shearwater *Puffinus griseus* and Black-footed Albatross *Phoebastria nigripes*) that rely on the marine resources of the CCS region, but do not breed within it.

Threats to marine habitat include, but are not limited to, oil spills, increased pollutant levels, destruction of benthic habitats through bottom trawling, overharvesting of prey species or direct competition with fisheries, alteration of coastal ocean communities through sediment runoff, and oil and natural gas exploration (21).

Protection of marine habitat for seabirds requires detailed baseline data on seabird abundance and distribution, foraging techniques and locations, and potential interactions with human interests such as fisheries. This information is critical to natural resources damage assessment when catastrophes such as oil spills occur, as well as to managers attempting to craft regulations to reduce harmful interactions with fisheries (both direct and indirect) and decrease human disturbance. Prey consumption models (see Chapter 5) are also important as baseline data that can yield information on where seabirds forage and how much food they require, which is essential information for responsible management of current and emerging fisheries.

National marine sanctuaries, marine protected areas, and marine reserves can indirectly provide protection to seabirds by limiting disturbance around roosting and breeding sites and by protecting important feeding areas and resources. Comprehensive seabird conservation programs require the inclusion of both nesting habitat and important roost sites within their management scheme to protect sites from disturbance and habitat degradation. In addition, it is essential to understand habitat usage patterns by seabirds, especially concentrations and seasonal distributions of seabirds near major colonies, at sea, and in nearshore waters, where anthropogenic threats are numerous and effects are potentially substantial.

11.5 SEABIRD CONSERVATION IN RELATION TO CLIMATE VARIABILITY

An increased understanding of fundamental processes affecting marine environments and ecosystems of seabirds is fundamental to effective management and sound conservation decisions for marine birds. Indications are that “bottom-up” oceanographic processes create suitable oceanic seabird habitat and affect seabird population dynamics in both tropical and temperate regions of the Pacific Ocean. The manner in which year-to-year and, possibly more importantly, decade-to-decade changes in ocean characteristics affect ocean habitats, foraging ecology, and demographic processes of Pacific Ocean marine birds will require renewed attention in the next decade.

Climate variability can result in periods of depressed reproductive success, decreased survival of adults and juveniles, reduced colony recruitment, and overall population declines (33-35). The coupling of multiple climatological events, such as Pacific Decadal Oscillation (PDO), El Niño, and global warming, may have devastating effects on seabirds. Furthermore, the understanding of natural climate variability is crucial to the ability of managers to accurately assess the impacts of perturbations and the probability of recovery (23). A catastrophic event such as an oil spill would be more devastating to seabird communities during periods of low productivity and survival related to climate variability, than at other times.

A coordinated study of the effects of the next few El Niño/La Niña events will provide novel information concerning ecosystem response after a shift in the state of the PDO (36). For the first time in nearly 30 years, the effects of an El Niño/La Niña can be investigated relative to a prevailing “cold-water” regime in the CCS. The last El Niño event of this nature occurred in 1973, more than 30 years ago, when El Niño had yet to be recognized as part of the natural climate cycle.

In addition, anthropogenic global warming represents a poorly understood threat to ocean processes and the California Current ecosystems (discussed in greater detail in Chapter 5). The ways in which human activities may influence these cycles need to be investigated. However, developing an understanding of the relative effects of anthropogenic factors and natural variability on ocean warming at multiple temporal scales remains a serious conservation challenge.

Functional relationships between seabird life history parameters, demographic traits, and environmental conditions have rarely been established (reviewed by Hamer et al. (33)); (37), yet knowledge of such relationships is critical. Marine wildlife and ocean managers are just beginning to understand that inherent environmental variability in the CCS is among the causes of marine bird population fluctuations, and management of marine bird resources and marine ecosystems will need to embrace this variability.

The need to both interpret population change and orient appropriate conservation actions in relation to climate variability and change is critical to effective seabird conservation in the CCS and will be equally important when assessing the potential for seabird restoration and recovery.

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The California Current Marine Bird Conservation Plan

Chapter 12

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The California Current Marine Bird Conservation Plan Chapter 12

Implementation of the California Current Marine Bird Conservation Plan

Version 1.0

**Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum**

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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CHAPTER 12. IMPLEMENTATION OF THE CALIFORNIA CURRENT MARINE BIRD CONSERVATION PLAN

SEABIRD CONSERVATION IMPLEMENTATION IN THE MARINE ENVIRONMENT

Implementation of any marine bird conservation plan requires actions that protect seabirds at sea as well as on land. There is the need to protect colonies and important roost sites from threats such as disturbance, “predator spills” (the introduction of new predators to a sensitive area), and the introduction of non-native species. There is also a need to restore lost or degraded habitats, for example by eradication of introduced mammalian predators from colonies.

Somewhat more of a challenge is the need to properly manage resources at sea, where different management tools are usually required. Effective management of this vast oceanic domain will require comprehensive cross-jurisdictional approaches, innovative tools, and new partnerships. The ocean cannot be protected by unilateral or private action to purchase easements or fee titles on key areas in the way that land can be protected. Nevertheless, marine protected areas offer a similar solution by protecting key habitats that may provide foraging opportunities for seabirds or protect prey stocks.

Regulatory change is one of the most effective tools for addressing threats that seabirds face in the ocean. Seabird biologists and managers need to work closely with organizations and agencies that regulate fisheries such as the Pacific Fisheries Management Council, Oregon’s Policy Advisory Council, and the various state fish and game agencies. Open communication is key to minimizing seabird bycatch, protecting foraging reserves for seabirds, and beginning the process of ecosystem management.

12.2 LINKAGE WITH ONGOING CONSERVATION INITIATIVES

The North American Bird Conservation Initiative (NABCI) is a multinational independent partnership between individuals and institutions to conserve bird species and their habitats by enhancing communication and collaboration among nations and agencies. NABCI facilitates coordination of the four major bird initiatives: the North American Waterfowl Management Plan (NAWMP), the U.S. Shorebird Conservation Plan (USSCP), Partners In Flight (PIF), and the North American Waterbird Conservation Plan (NAWCP). The NAWMP, USSCP, and PIF bird conservation plans have largely been developed and are in the implementation stage, whereas the NAWCP is at an earlier stage of development.

The NAWCP includes all species not covered under any of the other plans, including seabirds, wading birds (gulls, terns, pelicans, and cormorants), and marshbirds (grebes and bitterns); the geographic range is Canada through Central America and the Caribbean (28 countries, 209 species) (1). Importantly, the NAWCP provides a continental framework for regional planning efforts; however, conservation ultimately happens at the local scale, and individual regional plans are therefore essential.

Within the Pacific region, two marine bird conservation plans have been completed. The **U.S. Fish and Wildlife Service (USFWS) Pacific Region Seabird Conservation Plan** is a strategic planning effort to review seabird conservation and identify USFWS priorities for management, monitoring, research, and outreach in California, Oregon, Washington, Hawaii, and the U.S. Pacific islands. The intent is to provide an overarching review and discussion of seabird conservation in the Pacific region and outline priority actions needed to ensure the long-term health of these populations. The plan includes the coastal and marine populations of over 60 bird species in the orders Procellariiformes, Pelecaniformes, and Charadriiformes. The plan facilitates collaborative efforts between the USFWS and various local, national, and international partners in seabird conservation. Contact Maura Naughton for more information (Maura_Naughton@fws.gov).

The Canadian Wildlife Service (CWS) has developed an adaptive seabird conservation plan for the British Columbia region (the **Pacific and Yukon Regional Seabird Conservation Plan**) with an overarching goal of restoring seabird populations to historical numbers. To achieve this goal, priority actions include developing programs that address the threat of introduced predators to seabird habitats, seabird bycatch, and oil-spill preparedness. The protection of important seabird colonies and foraging areas is also considered high priority (2). Contact Mark Hipfner for more information (Mark.Hipfner@ec.gc.ca).

Marine bird conservation planning in the Pacific coastal and marine regions is well underway, with several conservation plans already having been developed. The overall goal is the same for each of these planning efforts: long-term conservation of Pacific seabirds. The CCS Plan, which links the various planning efforts, forms the Pacific Coast regional plan (excluding Alaska) as part of the NAWCP.

During the process of development of the CCS Plan, PRBO consulted with the USFWS and the CWS to coordinate efforts, receive input, and decrease the possibility of material overlap. Portions of the USFWS plan have been modified and incorporated into the CCS Plan in an ecosystem backbone. With other conservation plans as models, the CCS Plan had a solid framework upon which to build, ultimately benefiting both migratory and resident Pacific seabirds.

12.3 IMPLEMENTATION STRATEGIES

Implementation and success of the CCS Plan requires involvement and collaboration with regulatory authorities at the local, state, national, and international levels. The hallmark of an ecosystem approach in the CCS will be integrative, cross-border planning, monitoring, management, fisheries management, restoration, research, and education.

Additional strategies for promoting the recommendations of the CCS Plan include highlighting seabirds as sentinels of ecosystem health and making the link to human health; increasing funding or access to existing funds for seabird/ecosystem conservation; creating linkages to ongoing marine reserve initiatives; and increasing research at sea and on habitat use.

Increased collaboration among researchers and fishers will be fundamentally important to the plan's success. Fisheries pose a serious threat to Pacific seabirds; as such, research into gear types and fishing practices that minimize seabird bycatch in commercial fisheries is needed. Fisheries observer programs are necessary to accurately monitor the scope and magnitude of seabird mortality associated with commercial fisheries and to evaluate the response when regulations are enacted to benefit seabirds (see Chapter 11).

Identifying high-priority conservation activities is a potentially contentious but necessary step in plan development and implementation. Several key conservation actions include the development and implementation of a standardized system for monitoring seabird population trends. Species diversity, high priority species, and threats to the habitat need to be evaluated and the habitats and species with the highest conservation priority need to be identified. A typical CCS Plan implementation project might involve the removal of invasive species from areas that have declining populations, such as the removal of rats from Anacapa Island (Channel Islands, California) to protect Xantus's Murrelets (*Synthliboramphus hypoleucus*) and Ashy Storm-Petrels (*Oceanodroma homochroa*).

A critical element for measuring the success of a conservation plan is a comprehensive seabird monitoring program (3). A program designed to detect population trends will in turn help determine whether conservation actions are effective or if they need adjustment, thereby implementing an adaptive management approach.

Monitoring of conservation projects needs to be sensitive to detect declining population trends in a relatively short period of time. Standardization of monitoring programs is crucial for comparing data sets and detecting trends. Collaboration and increased coordination among the many government agencies and private researchers collecting seabird data also will be required to ensure consistent long-term monitoring of key areas and populations. Given the importance of monitoring programs to measuring success of a conservation plan, dedicated funding needs to be secured for such long-term monitoring.

12.4 THE JOINT VENTURE MODEL FOR COORDINATED CONSERVATION

A *joint venture* is a voluntary partnership among a unique set of partners who are seeking to achieve a set of natural resource objectives in a specific geographic region. Joint ventures have been used as successful plan implementation tools for other conservation efforts such as the NAWMP, PIF, and the USSCP.

The formation of a joint venture has potential as an effective method of bringing together the various stakeholders for seabird conservation plan implementation. Any such "California Current Joint Venture" established to address seabird conservation in the CCS will be most effective if its vision and goals embrace a holistic approach to marine management, including a focus on other taxa.

The Pew Oceans Commission recommended in 2003 that a cohesive National Ocean Policy establish the primacy of protecting, maintaining, and restoring our nation's marine and coastal ecosystems. It further recommended that Congress establish regional ocean ecosystem councils consisting of appropriate federal, state, and tribal representatives, with permanent advisory committees to obtain the views and advice of fishermen, environmental organizations, and others (4).

The Pew Commission description of regional ocean ecosystem councils is not very different from the joint venture model, with the exception that joint ventures are completely voluntary. A joint venture management board would include federal, state, and tribal representatives as well as industry and interest groups. One or more joint venture technical committees would function as scientific advisory board(s).

12.5 A PROPOSED JOINT VENTURE FOR THE CALIFORNIA CURRENT

A “California Current Joint Venture” (CCJV) is proposed as the primary vehicle for implementing the CCS Plan. Its overarching function will be to bring the combined programmatic capabilities of many partners to bear in a coordinated fashion to effect seascape-scale change in the CCS where it is truly needed.

A CCJV will focus on the health of top ocean predators as both a conservation goal in itself as well as an indicator of changes in ocean conditions (both natural and anthropogenic); it will also provide a means to gauge the success of marine management.

A CCJV will bridge cultural barriers in ocean and wildlife management; promote data sharing, information exchange, and collaboration among disparate entities; and provide a forum for “apolitical” discussions to identify common problems and interests that will lay the groundwork for implementation of conservation goals. A broad array of user groups will be recruited for the CCJV management board.

The goals of a CCJV are to:

- recognize and protect the food webs and habitats that support marine predators, including whales, dolphins, seabirds, turtles, swordfish, tuna, sharks, and many commercial and recreational fish;
- ensure that biodiversity conservation and fisheries health is promoted over short-term economic or political gain;
- recognize that fish are an integral part of the food web, and hence must be managed as such, including an accounting of fish species interactions with other species in the ecosystem;
- develop management, mitigation, or action plans demanded by the public for anthropogenic influences in the system, such as bycatch and pollution;
- implement multi-species adaptive conservation plans that are regularly updated with the most current scientific data;
- seek to protect and support our marine economy through all of the approaches listed above, as well as an openness to working directly with fishers and other marine-dependent industries.

The projects of a joint venture are dependent upon the interests and expertise of joint venture partners. Joint ventures are *not* meant to duplicate government-led processes already in place.

The potential benefits of working in the context of a joint venture partnership include:

- a long-term, programmatic approach vs. individual, disconnected projects;
- “front-loading” support for projects from a broad self-directed constituency;
- elevating ecosystem/top predator issues within management agencies;
- reflecting jurisdictional realities while enhancing cross-border and cross-jurisdictional cooperation;
- creating and publicly highlighting beneficial partnerships with business, particularly the fishing industry;
- developing the capacity to fund and execute research and conservation projects, including pooling of resources;
- coordinated action in space and time (also attractive to funders);
- achieving objectives that are beyond the scope of any single entity while reducing competition and redundancy.

The CCJV vision is to join conservation science with real-time management in a true adaptive management framework.

The functions of a CCJV will be to:

- Identify crucial research questions and information gaps.
- Identify critical conservation opportunities.
- Identify opportunities for win/win projects; create good news.
- Identify economic, political, and international concerns relative to conservation efforts.
- Jointly raise funds for projects.
- Test ideas through project implementation; successes can serve as pilots for more widespread adoption and implementation.
- Identify attainable and realistic conservation targets and identify mechanisms to monitor success in attaining targets.
- Provide a forum for making recommendations to appropriate bodies (governments, industries, etc.) to voluntarily develop and implement tools to mitigate negative impacts and to reverse declines in marine life populations.
- Incorporate new findings into the California Current Marine Bird Conservation Plan by adding data, analyses, and conservation recommendations from additional disciplines and taxa.
- Train and conduct outreach to marine managers and other user groups in current marine science applications.

Two meetings of regional seabird managers and scientists, the skeleton of a CCJV seabird technical committee, were held in September (covering the northern CCS) and November 2003 (covering the southern CCS). These meetings resulted in a consensus to move forward with formation of a joint venture management board (recruiting high-level agency heads).

Although these meetings were seabird focused, participants agreed that a CCJV will be ecosystem focused. Also as a result of these meetings, informal working groups have formed to address various ecosystem-wide issues, such as creation of a seabird stranding network and range-wide cross-border population assessment of Xantus's Murrelets.

PRBO Conservation Science is currently researching opportunities and avenues for the implementation of a California Current Joint Venture. For further information on the progress, contact PRBO Conservation Science at www.prbo.org.

Appendix D offers a list of *potential* future partners envisioned for a CCJV.

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The California Current Marine Bird Conservation Plan Appendix 6

Potential Future Partners Envisioned for a CCJV

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**Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum**

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

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APPENDIX 6: POTENTIAL FUTURE PARTNERS ENVISIONED FOR A CCJV

The following is a partial list of *potential* future partners envisioned for a California Current Joint Venture:

American Bird Conservancy	National Oceanic and Atmospheric Administration
American Sportfishing Association	Natural Resources Defense Council
Audubon Societies (local organizations)	The Nature Conservancy
British Columbia Ministry of Sustainable Resource Management	The Ocean Conservancy
California Department of Fish and Game, Marine Region	Oregon Department of Fish and Wildlife
California State Parks	Pacific Coast Federation of Fishermen's Associations
California Wetfish Industry	Pacific Coast wildlife refuges
Canadian Parks and Wilderness Society	Pacific Fisheries Management Council
Canadian Wildlife Service	Pacific Seabird Group
Chevron	Pacific States Marine Fisheries Commission
CIBNOR (Centro de Investigaciones Biológicas de Noroeste; Mexico)	Packard Foundation
CISESE (Centro de Investigación Científica y de Estudios Superiores de Ensenada; Mexico)	Parks Canada
Coastal Commissions (state/province)	Point Reyes National Seashore
CONABIO (Comisión Nacional para El Conocimiento de la Biodiversidad; Mexico)	PRBO Conservation Science
Council on Environmental Cooperation	Resources Law Group
Department of Fisheries and Oceans, Canada	Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca, y Alimentación (Mexico)
Environmental Defense	Comisión Nacional de Acuacultura y Pesca (Mexico)
Grupo de Ecología y Conservación de Islas (Mexico)	Secretaría de Gobernación (Mexico)
Island Conservation	Secretaría de Medio Ambiente y Recursos Naturales (Mexico)
International Halibut Consortium	United Anglers
Marine Conservation Biology Institute	U.S. Department of Interior
Marine Mammal Commission	U.S. Coast Guard
Monterey Bay Aquatic Research Institute	Washington Department of Fish and Wildlife
The Moore Foundation	Wildlife Trust
National Audubon Society	
National Fish and Wildlife Foundation	