Ecology and Conservation of North American Sea Ducks

EDITED BY

Jean-Pierre L. Savard • Dirk V. Derksen
Dan Esler • John M. Eadie

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FOREWORD

Regardless of one's experience with sea ducks, the name seems to bring an immediate vision of fast-flying, goal-oriented ducks in tight formation flying low over cold waters: eiders, scoters, Long-tailed Ducks, goldeneyes, or mergansers. There is a feeling of excitement behind the binoculars, camera, bola, arrow, or gun. And it is true: most sea ducks are found in the northern hemisphere, high latitude, cold water, near-shore marine, bay, or large lakes and rivers. The richness and abundance of animal resources in cold waters is well known, and the diving waterfowl can access them not only in freezing temperatures but also at great depths. During the breeding season, in which the air may be sharp, the newly hatched young have dense down suitable for their tundra or rugged shoreline nest site. Islands are favored nesting areas, and some species or populations are colonial, some clustered, and others solitary—dictated in part by habitat. But that distribution pattern is not without variation for some species like goldeneyes, Red-breasted Mergansers, and Harlequin Ducks, which nest in cool forested areas along inland lakes and streams. Tree-hole nest sites are common among Buffleheads, Common Mergansers, and especially Hooded Mergansers, which may nest in southern wooded swamps and even use nest sites serially shared with distant relatives, such as Wood Ducks. To gain perspective, the tribe Mergini contains 21 recent species worldwide, of which 19 are still living. Remarkably, these birds are separated with little controversy into 10 genera, reflecting dramatic morphological and ecological differentiation. Of the 21 species, 19 (18 living) are from the northern hemisphere and only 2 (1 living) have distributions in the southern hemisphere. The last known specimen of the northeastern Labrador Duck was taken in 1878, before we learned much about their breeding range and habits. Although they were abundant in coastal Labrador at some seasons and shot by east coast duck hunters as far south as the Long Island, early observers suggested that they may have nested in the St. Lawrence Estuary. Recent DNA studies suggest that their tribal relationship is still uncertain. The Chinese or Scaly-sided Merganser survives in small numbers (perhaps 2,500 total); its distribution in several countries complicates surveys but enhances chances for survival. At least three North American species or distinct populations are also threatened, as will become clear in several chapters. There were two species of sea ducks in the southern hemisphere, where I have searched for them in vain. The Auckland Islands Merganser—seemingly now extinct—was known only from a few specimens taken at the mouths of small estuaries and along small streams on Auckland Island and also from skeletal remains elsewhere that indicate a once-larger range. The Brazilian Merganser, a rare and isolated resident of subtropical forested rivers of Brazil, Argentina, and perhaps Paraguay, nests in tree holes. The discovery of new breeding populations in Brazil is encouraging, where estimates are now in the range of 200–250 individuals. However, the status of former populations in Argentina is uncertain.

One ponders the *why* of this distribution pattern. Obviously, a few pioneers made it south, seemingly derived from the Common Merganser stock, which are forest lake and stream birds. But North American species that choose seashores may winter well south along both coasts, and a few make it to the Gulf Coast. Remarkably, as I was writing this, an e-mail arrived stating that the Common Eider has been accepted as the 631st species recorded in Texas. But these coastal species have not pioneered into or beyond the tropics. There is, however, another tribe of cold-water ducks, unrelated to Mergini, that form an ecological counterpart of northern eiders: the steamer ducks of Patagonia and the Falkland Islands. Climatically less pressured to move to warmth in winter, three of the four species are flightless. Most of the species and genera of Mergini considered in this volume occur in both North America and Eurasia, but the emphasis in this treatise is on North America with the direct involvement of this unique set of authors intent on studying a fascinating group of ducks. While they produced original and important results from personal field and laboratory studies, their work, like that of all scientists, is based on the work of many early and current European scientists who have lived closely with sea ducks for many years. Collectively, all strive for the same goal: understanding the group, their adaptations, their limitations in facing societal stresses, and ultimately their conservation. Arctic tundra– and northern island–based societies have utilized and managed products from these birds—down, eggs, and meat—for centuries via strategic harvesting of down to minimize the impact on egg success, creation of shelters (ranging from canopies to man-made holes) to reduce the high rate of egg loss to aerial predators, and focus on postbreeding season harvest such as the renowned eider pass near Barrow, Alaska.

But times have changed dramatically, and seas, rivers, lakes, and associated nesting habitats are not what they once were because of climactic events and impacts of human activities. Moreover, the problems that impact sea ducks and other seabirds impact all of the society as well, demanding that we address such integrative ecological, political, and conservation problems collectively using approaches and analyses that transcend species or even generic features. The results reflect the multispecies thinking that stimulated the cooperative Sea Duck Joint Venture (SDJV). These summaries are truly current and will demand rewriting of some current textbooks, old or traditional laws, and government policies at all levels. The chapters will also present goals and approaches to guide future research. By necessity then, this work will provide a must-read foundation for resource ecologists working in associated disciplines: survival of native customs and societal needs; hunting and related harvest policies; soil erosion and riverine water quality; streamside forest removal; oil and chemical pollution at sea and in-stream; coal, tar sand, and oil extraction; marine and inland riverine transport problems; wind and geothermal energy development; and management of both inland and coastal fisheries as well as marine mammal resources. Although global warming has impacted sea duck habitat many times in geologic history, coastlines have never been under great pressure from human developments—with no reductions in sight. How to identify and understand such current problems, impending threats, possible solutions, and future research directions is discussed in this book. After reading this book, I think you will agree that our knowledge of sea duck ecology has significantly grown.

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PREFACE

People have long been fascinated by sea ducks because of their spectacular courtship displays, brightly colored and patterned plumage, remarkable variation in life history traits, remote northern breeding locations, unique migrations, and the many mysteries that remain about their ecology and behavior. However, the past decade has witnessed a dramatic increase in the interest and attention directed toward the 15 species of North American sea ducks, which include four species of eiders, the Harlequin Duck, three species of scoters, Long-tailed Duck, Bufflehead, two species of goldeneyes, and three species of mergansers that breed largely in arctic and subarctic habitats across the continent. We were motivated to produce this book, in large part, by the conservation concerns associated with simultaneous declines in several sea duck species and populations. Additionally, we wanted to synthesize the considerable research that has recently been conducted on this small tribe of ducks. These studies form the basis for identifying factors that may be limiting population recovery and will help to develop a conservation strategy for sea ducks in North America. We thus felt it was imperative to capture the current state of knowledge and to offer future research directions for researchers, managers, students, conservationists, and avian enthusiasts. *Ecology and Conservation of North American Sea Ducks* is a collection of 15 linked chapters focused on population dynamics, ecology, and behavior of sea ducks in North America. When we outlined this volume, we brought together researchers and managers who had field and laboratory experiences with all members of the sea duck tribe Mergini in North America. This in turn led to collaborations among specialists from different geographic areas of the continent to develop comprehensive treatises on key life history and management topics important for the conservation of sea duck species and their diverse marine and freshwater habitats. The chapter authors have combined the summaries of published accounts with new data, as well as presented additional analyses, models, and interpretations to advance our understanding of sea duck population dynamics and genetics, infectious diseases and parasites, breeding costs and cross-seasonal effects, contaminant burdens, foraging behavior and energetics, migration strategies, molt ecology, breeding systems and reproductive behavior, harvest history and contemporary trends, and habitat affinities and dynamics, and to document conservation concerns. We hope this volume of the *Studies in Avian Biology* series will stimulate further interest and research on the sea ducks of North America and worldwide.

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Introduction

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Sea ducks breed across the entire continent of North America. Different species nest as far north as eastern Greenland, westward through the Aleutian Islands of Alaska, and south into the Canadian Prairie Provinces, Rocky Mountains, Mississippi River Valley, and Atlantic Coastal States. Sea ducks have diverse migration strategies, ranging from species that travel thousands of kilometers to the near-sedentary populations of Common Eider (*Somateria mollissima sedentaria*) residing in Hudson Bay. As a result, wintering locations vary greatly within the tribe from arctic marine polynyas to the Great Lakes of the midcontinent and south to temperate ocean waters of the Gulf of Mexico and along the east and west coasts of the Baja Peninsula.

The waterfowl tribe Mergini includes 21 species (Table I.1). Our focus in this volume of *Studies in Avian Biology* is on the 15 extant species of sea ducks indigenous to North America, not including the Labrador Duck (*Camptorhynchus labradorius*), which became extinct by 1875 (Livezey 1995, Chilton 1997, Kear 2005).

The tribe Mergini is a fascinating group of waterfowl because of the unique and diverse ecology, behavior, and life histories of these species. Sea ducks reach sexual maturity between two and three years of age and have long life spans and low annual recruitment. All sea ducks dive to forage, and their diet is largely animal matter, including mollusks, crustaceans, echinoderms, polychaete worms, insects, fishes, and fish eggs, although some species also consume smaller quantities of aquatic plants and algae. Sea ducks exhibit dimorphic plumage and spectacular courtship displays (Myres 1959, Johnsgard 1965). In most species, males are the larger sex and more numerous in the population than females.

Nearly all sea ducks rely on marine habitats for most of the annual cycle. Nine North American species are found exclusively in salt water habitats during winter. Four species—White-winged Scoter (*Melanitta fusca*), Long-tailed Duck (*Clangula hyemalis*), Bufflehead (*Bucephala albeola*), and Common Goldeneye (*B. clangula*)—occur mostly in marine waters during winter but are known to exploit freshwater systems during winter. Only two species—Hooded Merganser (*Lophodytes cucullatus*) and Common Merganser (*Mergus merganser*)—occur primarily in freshwater habitats during winter (Table I.1). Some sea duck species nest exclusively on freshwater wetlands and streams at a considerable distance from the sea, while other members of the tribe breed on freshwater sites, barrier islands, and other habitats that are in close proximity to oceans and estuaries.

Within the complex of eider species, Steller's Eiders (*Polysticta stelleri*) are of special interest because the North American breeding population is small and currently restricted to two discrete areas in western and northern Alaska (Flint and Herzog 1999, Petersen et al. 2000, Fredrickson 2001). Spectacled Eiders (*Somateria fischeri*) are remarkable birds because their pelagic wintering locations are far offshore in the pack ice of the mid-Bering Sea (Petersen et al. 1999). King Eiders (*Somateria spectabilis*) breed at especially high northern latitudes, and their coastal

TABLE I.1

Distribution and general habitat affinities of species within the tribe Mergini.

Common name	Scientific name[a]	Distribution	Focal species	Breed	Winter	Molt
Steller's Eider	*Polysticta stelleri*	NA, EU	x	FW, SW	SW	SW
Spectacled Eider	*Somateria fischeri*	NA, RU	x	FW, SW	SW	SW
King Eider	*Somateria spectabilis*	NA, EU, RU	x	FW	SW	SW
Common Eider	*Somateria mollissima*	NA, IC, EU, RU	x	FW, SW	SW	SW
Harlequin Duck	*Histrionicus histrionicus*	NA, IC	x	FW	SW	SW
Labrador Duck	*Camptorhynchus labradorius*	NA	Extinct	?	SW	?
Surf Scoter	*Melanitta perspicillata*	NA	x	FW	SW	SW
White-winged Scoter	*Melanitta fusca*	NA, EU, RU	x	FW	FW, SW	SW
Common Scoter	*Melanitta nigra*	EU, RU, IC		FW	SW	SW
Black Scoter	*Melanitta americana*	NA	x	FW	SW	SW
Long-tailed Duck	*Clangula hyemalis*	NA, EU, RU	x	FW, SW	FW, SW	FW, SW
Bufflehead	*Bucephala albeola*	NA	x	FW	FW, SW	FW, SW
Common Goldeneye	*Bucephala clangula*	NA, EU, RU	x	FW	FW, SW	FW, SW
Barrow's Goldeneye	*Bucephala islandica*	NA, IC	x	FW	SW	FW, SW
Smew	*Mergellus albellus*	EU, RU		FW	FW	FW, SW
Hooded Merganser	*Lophodytes cucullatus*	NA	x	FW	FW	FW
Auckland Islands Merganser	*Mergus australis*	AI	Extinct	?	?	?
Brazilian Merganser	*Mergus octosetaceus*	BR, AR		FW	FW	FW
Common Merganser	*Mergus merganser*	NA, EU, RU	x	FW	FW	FW
Red-breasted Merganser	*Mergus serrator*	NA, EU, RU	x	FW, SW	SW	SW
Scaly-sided Merganser	*Mergus squamatus*	RU, KO, CH		FW	SW	FW

NOTES: NA, North America; IC, Iceland; EU, Europe; RU, Russia; BR, Brazil; AR, Argentina; AI, Auckland Islands; KO, Korea; CH, China; FW, freshwaters; SW, salt waters; Sea ducks addressed in this volume are identified as focal species (x).

[a] Taxonomy follows American Ornithologists' Union (1998), Kear (2005), Chesser et al. (2010), and Harrop et al. (2013).

migrations are considered spectacular among sea ducks because of the protracted passage of large flocks along ice-free ocean leads (Suydam 2000). Common Eiders nest in colonies and are perhaps more closely tied to marine habitats than any other sea duck (Goudie et al. 2000, Bédard et al. 2008). Harlequin Ducks (*Histrionicus histrionicus*) are river specialists that exploit fast-flowing, fluvial systems for breeding in two widely separated areas of North America (Robertson and Goudie 1999), where Atlantic and Pacific populations are thought to be genetically isolated (Scribner et al., Michigan State University, unpubl. report). All three of the North American scoter species inhabit Nearctic waters and exhibit long-distance migrations from coastal winter habitats to breeding areas (Bordage and Savard 1995, Brown and Fredrickson 1997, Savard et al. 1998). Surf Scoters (*Melanitta perspicillata*) and White-winged Scoters are largely dependent on the continental boreal forest biome during the breeding period, whereas Black Scoters (*M. americana*) breed more commonly in tundra and taiga habitats in Alaska and Canada. Long-tailed Ducks breed at high latitudes up to 80°N and have unique and complex molt patterns with three distinct plumages, in contrast to other sea ducks that exhibit only two plumages (Robertson and Savard 2002). The genus *Bucephala*, which includes the Bufflehead and two species of goldeneyes, is well known for cavity nesting, nest parasitism, and strong intra- and interspecific territorial behavior (Gauthier 1993; Eadie et al. 1995, 2000). The three North American species of mergansers use a great diversity of marine and freshwater habitats across the continent. Common Mergansers breed on rivers and large lakes and like their congener, the Red-breasted Merganser (*Mergus serrator*), are reviled by some fishermen because their diet is largely piscivorous (Mallory and Metz 1999, Titman 1999). The Hooded Merganser is restricted in distribution to North America, where the species nests in natural cavities as well as man-made boxes and commonly lays its eggs in the nests of conspecifics and other cavity-nesting ducks (Dugger et al. 1994).

Why are sea ducks of interest in North America? Sea ducks have been important as sources of food and material to northern communities for centuries and remain so to this day. North American Inuit continue to use the down and eggs of Common Eiders, and in northern Québec and in the St. Lawrence River Estuary, eiderdown is harvested commercially (Bédard et al. 2008). Arctic and subarctic villages at northern latitudes across the continent have a long history of sea duck harvest throughout the year (Phillips 1925, 1926; Bellrose 1976; Gilliland et al. 2009; Naves 2012). Similarly, sea ducks have historically been harvested in large numbers by commercial interests. The practice has been discontinued along the northeastern coast of the United States, but the commercial take of Common Eiders still occurs in west Greenland (Merkel 2004, 2010; Gilliland et al. 2009). Sport hunters also have a long tradition of taking sea ducks as part of the regulated harvest in Canada and the United States (Caithamer et al. 2000). Now, more than ever, sea ducks are enjoyed by increasing numbers of birding enthusiasts and conservationists who contribute to our knowledge of their status, trends, and distribution through citizen-based observation networks and surveys (Bond et al. 2007, Greenwood 2007, Sullivan et al. 2009).

Early in the twentieth century, little was known about most sea ducks in North America, with the exception of the Common Eider (Phillips 1925, 1926). Not much had changed by 1951 (Bent 1951) or even 1976 when Bellrose (1976) wrote, "Of all the ducks in North America, the Surf Scoter has the dubious distinction of being the least studied." Of course, the primary reasons for a lack of information on the status and biology of sea ducks were that most species occurred in remote breeding and wintering areas, and waterfowl management placed greater emphasis on the biology of geese and dabbling ducks (Phillips and Lincoln 1930).

Importantly, with limited availability of population data, uncertainty existed concerning the status of most sea duck species in North America. Nevertheless, as early as the 1920s, John C. Phillips, who wrote *A Natural History of the Ducks*, identified declines of some species and populations of sea ducks, especially Common Eiders of the Atlantic region during the era of market hunting and feather trade (Phillips 1925, 1926; Austin 1932). It is now clear that subsistence hunting and harvest of eggs and down from the Common Eider were the primary factors limiting the Greenland breeding population (Hansen 2002, Merkel 2004) and that recent protection measures have resulted in population recovery (Merkel 2010). Similarly, colonies of Common Eiders along the New England coast, Canadian Maritime Provinces, and the Gulf of St. Lawrence have rebounded with increased protection (Todd 1963, Bellrose 1976).

In 1986, the Committee on the Status of Endangered Wildlife in Canada listed the eastern population of Harlequin Duck as *endangered*. Subsequently, the eastern populations of Harlequin Duck and Barrow's Goldeneye were determined to be *species of concern* (Robert et al. 2000, Thomas and Robert 2001). In the United States, sea ducks have been listed under the authority of the U.S. Endangered Species Act: the global population of Spectacled Eider was listed as *threatened* in 1993 (U.S. Fish and Wildlife Service 1996), and in 1994, the North American breeding population of Steller's Eider was determined to be *threatened* (U.S. Fish and Wildlife Service 2002). Collectively, these listings stimulated research interest in these four sea duck species as well as other members of the tribe Mergini, which for decades had largely been overlooked with regard to collecting fundamental population data through surveys because of the emphasis placed on hunted species of waterfowl that were more popular with the public. During the same period, Goudie et al. (1994) reviewed the status of sea ducks in the North Pacific and recommended a suite of management changes to reduce mortality. The authors also stressed the need for long-term ecological studies and basic surveys of sea ducks as essential for making informed management decisions. Importantly, the North American Waterfowl Management Plan (NAWMP) was updated in 1994 with immediate objectives to improve the understanding of population status, production, harvest, and factors affecting mortality and survival of sea ducks (U.S. Fish and Wildlife Service and the Canadian Wildlife Service 1994). Thereafter, Petersen and Hogan (1996) presented a paper at the 7th International Waterfowl Symposium that summarized the status of sea ducks in North

America, identified factors that may have been limiting sea ducks, and proposed studies to collect information critical to develop species-specific management plans. In 1997, a coalition of the US and Canadian federal, state, provincial, and nongovernment conservation organizations proposed the establishment of the Sea Duck Joint Venture (SDJV). In 1998, the NAWMP Committee approved the creation of the SDJV to "promote development of short- and long-term information gathering programs to determine basic parameters of sea duck populations, such as delineation of ranges and subunits, abundance and trends, production, harvest, and survival rates" (Sea Duck Joint Venture Management Board 2008). To achieve these goals, the SDJV relies on international partnerships and is guided by detailed strategic and implementation plans (Sea Duck Joint Venture Management Board 2008, Sea Duck Joint Venture 2013).

Much has been accomplished to fill the enormous gaps in our knowledge of North American sea ducks since Canada and the United States took actions to list and fund studies of the eastern populations of Harlequin Duck and Barrow's Goldeneye, the world population of Spectacled Eider, and the North American breeding population of Steller's Eider. Likewise, funding provided by the SDJV for priority monitoring and research has resulted in a much clearer picture of the status and biology of North American sea ducks. Inspired by the recent rapid increase in our knowledge of sea duck ecology, we conceived this volume of *Studies in Avian Biology* to summarize and synthesize what we now know about the tribe Mergini in North America and highlight the remaining data gaps that must be addressed to facilitate continued efforts to conserve this fascinating group of waterfowl.

This book is composed of 15 interrelated chapters that focus on many aspects of the ecology of members of the tribe Mergini that occur in North America (Table I.1). The chapters are organized conceptually so as to not duplicate other efforts that have been prepared on a species-by-species basis such as the species accounts in the *Birds of North America* series, and to compare and contrast the ecological attributes of birds in the tribe. To enhance the interpretation of our results, conclusions, and recommendations, we have drawn on research conducted on the same species as well as other sea duck populations outside of North America. To create this volume, 27 subject experts developed in-depth treatments of sea duck population status and trends, phylogeography and phylogenetics, population dynamics and demography, diseases, reproductive energetics and cross-seasonal effects, contaminant burdens, foraging behavior and energetics, migration strategies, molt ecology, reproductive strategies and behavior, harvest, habitat affinities, and conservation issues. We hope that the collection of integrated chapters will serve as a primary reference for researchers, managers, teachers, and students interested in detailed treatments of the biology, ecology, and conservation of this unique and widespread tribe of marine-dependent waterfowl.

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CHAPTER ONE

Status and Trends of North American Sea Ducks*

REINFORCING THE NEED FOR BETTER MONITORING

Timothy D. Bowman, Emily D. Silverman, Scott G. Gilliland, and Jeffery B. Leirness

Abstract. The value of existing waterfowl survey data for assessing the status and trends of North American sea duck populations is limited due to short time series, insufficient geographic coverage, improper timing, and species identification problems. Despite these shortcomings, contemporary data provide insights into the status of several sea duck populations. In this chapter, we synthesize available information on population status and trends in abundance for sea ducks and recommend efforts that could improve our ability to monitor sea duck populations. The Alaska breeding population of Spectacled Eiders is currently stable (Arctic Coastal Plain) or increasing (Yukon-Kuskokwim Delta) in numbers. Steller's Eiders (*Polysticta stelleri*) wintering in Alaska have declined since the early 1990s. Spectacled and Steller's Eiders remain below historic levels and are listed as threatened in the United States. In western North America, King Eiders (*Somateria spectabilis*) declined substantially between the mid-1970s and mid-1990s; recent data suggest regional differences, but a stable population overall. There is insufficient information on trend for King Eiders in eastern North America. An assessment of trends for Pacific Common Eiders (*S. mollissima v-nigra*) is based on limited information, but data suggest that this subspecies declined substantially in northern parts of its range in the 1980s to the early 2000s. Recent regional trend estimates note declines in central arctic Canada and northwestern Alaska, and stable to increasing numbers in other parts of Alaska. Population trends for American Common Eiders (*S. dresseri*) are variable range-wide, with apparent increases in northern parts of their range and decreases in southern parts. Trends for Hudson Bay (*S. m. sedentaria*) and Northern subspecies (*S. m. borealis*) of Common Eiders are uncertain. The population trajectories of the three scoter species (*Melanitta* spp.) are also not well understood, but available data suggest that, as a group, scoters decreased from the 1980s to the early 2000s, with greater declines noted in the northern boreal forest and northern prairies than in Alaska, and with overall increases since about 2004. Black Scoters on Pacific breeding areas have declined significantly since the mid-1970s, but have increased in number in the last decade. There is no measurable trend for eastern Black Scoters. The limited data for Long-tailed Ducks (*Clangula hyemalis*) suggest long-term declines in the parts of their range that are surveyed, with

* Bowman, T. D., E. D. Silverman, S. G. Gilliland, and J. B. Leirness. 2015. Status and trends of North American sea ducks: Reinforcing the need for better monitoring. Pp. 1–28 in J.-P. L. Savard, D. V. Derksen, D. Esler, and J. M. Eadie (editors). Ecology and conservation of North American sea ducks. Studies in Avian Biology (no. 46), CRC Press, Boca Raton, FL.

more stable numbers in recent years. Buffleheads (*Bucephala albeola*), goldeneyes (*B. clangula* and *B. islandica*) and mergansers (*Mergus* spp. and *Lophodytes cucullatus*) have increased, although lack of differentiation among species of both goldeneyes and mergansers prohibits reliable species-specific evaluations. Numbers of Harlequin Ducks (*Histrionicus histrionicus*) along the Atlantic coast are increasing, while the Pacific trend is unknown. Data suggest that, for the 22 populations of North America sea ducks currently recognized as distinct or allopatric, 11 populations appear to be stable or have increased in abundance over the last 10–20 years, and two populations are apparently declining. Data are insufficient to determine status for the remaining nine populations. Reliable information about population status and trends requires surveys designed with specific consideration of sea duck distribution and phenology. We recommend increasing observer training, incorporating detection adjustments, and using aerial photography to improve the accuracy of species identification and abundance estimation. Management agencies in the United States and Canada must devote greater resources to monitoring sea ducks if they wish to better inform harvest management, focus habitat conservation efforts on areas of greatest importance to sea ducks, and effectively evaluate their management actions.

Key Words: aerial and nest surveys, Christmas Bird Count, population trends, species identification.

Estimates of trends in waterfowl abundance are critical to understand population status, to determine the causes of changes in population size, and to assess the need for, and response to, management actions. In North America, measures of status are typically derived from breeding ground surveys or, for a few species, winter inventories. However, estimates of abundance and population trends for sea ducks are generally poor or lacking altogether. These species inhabit vast, remote breeding areas, and molting and wintering birds often gather on large lakes, coastal waters, and far at sea—habitats that are difficult, costly, and risky to survey. Even the distributions of sea duck species are poorly understood. For some species, population assessment is further complicated by the fact that their ranges cross international boundaries into countries that do not adequately monitor sea duck populations including Russia, Japan, Mexico, and Greenland.

Many previous and ongoing waterfowl surveys are of limited value for monitoring sea duck populations because they do not cover large portions of breeding ranges or offshore wintering areas, are not optimally timed to capture peak counts of breeding birds, or only identify sea ducks to genus or species groups such as scoters, goldeneyes, or mergansers. Indices of abundance from such surveys are often highly variable and of limited utility in evaluating trends (Stott and Olson 1972, Heusmann 1999).

Currently, only two sea duck populations are adequately monitored on a routine basis in North America: Spectacled Eiders (*Somateria fischeri*) and the Pacific population of Black Scoters (*Melanitta americana*). Within North America, both species breed only in Alaska. In 1993, Spectacled Eiders were listed as threatened under the U.S. Endangered Species Act, prompting development of surveys of this species on its breeding areas. A Pacific Black Scoter survey encompassing most of its breeding area was initiated in 2004, evolving from several years of design and operational adjustments informed by satellite telemetry studies that identified proper timing and appropriate geographic coverage.

Despite the limitations of most waterfowl surveys for sea duck assessment, several large-scale, long-term monitoring programs provide information on sea duck populations. Most notable is the Waterfowl Breeding Population and Habitat Survey (WBPHS), which is conducted annually by the U.S. Fish and Wildlife Service (USFWS) and the Canadian Wildlife Service. There are also a number of rigorous smaller-scale, shorter-duration surveys that contribute to our understanding of sea duck status.

In this chapter, we drew upon a variety of data sources to examine population status and trends for sea ducks. The timing and methods of these surveys can differ substantially, so it is not possible to directly compare the abundance estimates they produce nor resolve contradictory information about population trends. For example, spring breeding season surveys enumerate adult breeders, while late summer molting surveys count primarily adult males, and winter surveys enumerate both adults and young following the fall migration. Because they are measuring different demographic components of the population, population estimates and trends among these various surveys may differ.

In addition, most surveys do not incorporate an adjustment for incomplete detection of birds or nests. A limited number of surveys have employed double-observer techniques to estimate detection (Raven and Dickson 2006; Stehn and Platte 2012; J. B. Fischer and R. A. Stehn, U.S. Fish and Wildlife Service, unpubl. report). Double-observer methods account for perception bias of observers missing birds that are within view, but not availability bias if birds are present but out of view under water or in vegetation (Williams et al. 2002). Surveys from helicopters have low perception bias for sea ducks (estimates from Eastern Canada are 0.97, N. Plante and D. Bordage, Canadian Wildlife Service, unpubl. data, and 0.98, Gilliland et al. 2009b) and surveys in the WBPHS protocols correct counts from fixed-wing platforms using paired helicopter data, but these corrections are subject to additional availability bias, because the fixed-wing airplanes and helicopters do not fly at the same time, nor do they cover exactly the same survey area, and sample sizes are often small (Smith 1995; E. D. Silverman, pers. obs.). Given the infrequent use of detection correction in sea duck surveys, and the limits of the existing methods, most estimates of abundance should be considered indices and not necessarily comparable across surveys. Thus, aside from the annotated summary in the electronic Appendix (www.crcpress.com/product/isbn/9781482248975), we have generally refrained from reporting numerical estimates of abundance for most sea duck populations and include indices only if they provide perspective on the relative size or order of magnitude of surveyed populations or subpopulations.

In general and unlike most goose and some duck populations, sea ducks have not been classified into distinct management units based on survey or banding data. Nonetheless, Black Scoters, Harlequin Ducks (*Histrionicus histrionicus*), and Barrow's Goldeneyes (*Bucephala islandica*) are well documented as having distinct populations in eastern and western North America, which should be considered separately for purposes of conservation and management. Currently, the Sea Duck Joint Venture recognizes 22 distinct populations for the 15 species of sea ducks in North America (Sea Duck Joint Venture Management Board 2008).

We use data from surveys that cover a large geographic range such as multiple provinces and states or entire coastlines, a significant portion of a species range, or a long time series (>10 years). When such survey data were lacking, we have also presented less detailed information and analyses from local or periodic surveys. We chose not to consider data from surveys that, for various reasons, do a relatively poor job of monitoring sea ducks. For example, several surveys do not adequately cover offshore habitats used by some sea ducks; these include the Mid-Winter Waterfowl Survey (Heusmann 1999), the Breeding Bird Survey (Sauer et al. 2013), and the Atlantic Sea Duck Survey conducted from 1990 to 2002 (D. F. Caithamer et al., U.S. Fish and Wildlife Service, unpubl. report). Because we have access to the WBPHS data, we included some original analyses for these data; all other estimates and summaries were obtained from existing reports, publications, or pers. comms. with researchers.

DATA SOURCES

Waterfowl Breeding Population and Habitat Survey

A large-scale study of North American waterfowl breeding habitats was initiated by the USFWS and its partners in 1947 (Crissey 1949). These fixed-wing aerial surveys evolved into the WBPHS with the current design established in Alaska in 1966 and in Canada and the US prairies in 1974 and with the current survey protocol mostly unchanged since 1974. The survey is divided into two broad areas: (1) the midcontinent area, which covers waterfowl habitats in the northern Yukon, the Northwest Territories, Alberta, Saskatchewan, Manitoba, and western Ontario in Canada, and in Alaska, Montana, and the Dakotas in the United States (hereafter, midcontinent and Alaska); and (2) the eastern survey area, which includes parts of Ontario, Quebec, Newfoundland and Labrador, and the Maritime provinces in Canada, and New York and Maine in the United States (hereafter, eastern; Figure 1.1). Historically, the survey was focused on estimating population sizes for prairie dabbling ducks. As a result, the survey is optimally timed for these species and is too early for sea ducks. Also, effort is concentrated in the prairie-pothole region, which constitutes only

Figure 1.1. Transects surveyed by the WBPHS: the midcontinent and Alaska transects are thick solid lines; the eastern transects are dashed lines. Stratum 50, which is considered part of the midcontinent survey, but analyzed here with the eastern survey data, is indicated by thin solid lines.

a fraction of the habitat types used by sea ducks during the breeding season. Smith (1995) provides a description of the survey protocol. Survey observers record the abundance of Buffleheads (*Bucephala albeola*), Long-tailed Ducks (*Clangula hyemalis*), and species groups of goldeneyes, mergansers, eiders, and scoters on 200 m wide strip transects.

Eastern Waterfowl Survey

The Eastern Waterfowl Survey, conducted by the Canadian Wildlife Service, was developed primarily to survey American Black Ducks (*Anas rubripes*), but it has also monitored several species of inland breeding sea ducks since 1990 (M. C. Bateman et al., Canadian Wildlife Service, unpubl. data). All waterfowl are recorded within square plots located in parts of Quebec, Ontario, New Brunswick, Nova Scotia, Newfoundland, and Labrador (Figure 1.2). The current protocol involves surveying 304, 5 km × 5 km, plots by helicopter on a rotational basis with about half of all plots surveyed in a given year. The survey covers only a small portion of breeding ranges for several eastern sea duck populations but provides species-specific estimates of trend and population size for the three merganser and three scoter species that occur there. The survey is well timed for mergansers, Buffleheads, and Common Goldeneyes (*Bucephala clangula*) but overlaps only with the early part of the breeding period for scoters.

Yukon–Kuskokwim Delta Aerial Goose–Duck–Waterbird Survey

Although this aerial transect survey was designed primarily to estimate breeding populations of geese on the Yukon–Kuskokwim Delta, Alaska, ducks are also recorded. The survey is flown by the USFWS in early June using fixed-wing aircraft and covers most of the high-density waterfowl habitats in the coastal zone of the Yukon–Kuskokwim Delta, Alaska (Figure 1.3). A backseat observer records only ducks and other waterbirds. Since 1988, survey techniques and observers have been relatively consistent and indices of breeding duck populations are available for every year except 2011 (R. M. Platte and R. A. Stehn, U.S. Fish and Wildlife Service, unpubl. report). This survey covers the primary breeding areas and provides reliable estimates of Common Eiders (*Somateria*

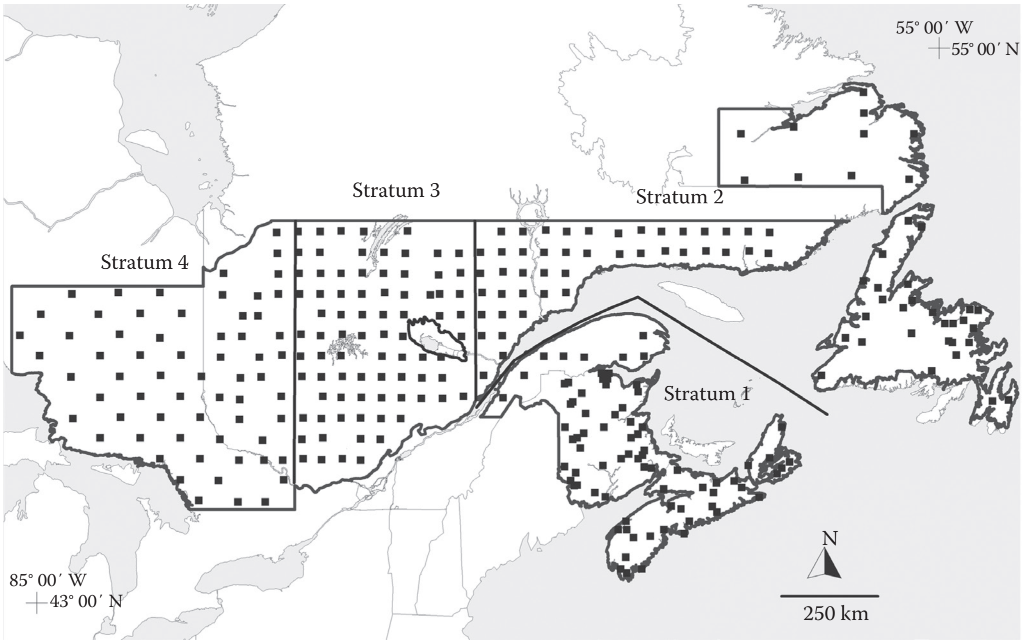

Figure 1.2. Plot locations for the Eastern Waterfowl Breeding Survey.

Figure 1.3. Alaskan survey areas for the Arctic Coastal Plain Breeding Waterfowl Survey (gray) and Pacific Black Scoter Breeding Survey (black) and location of Yukon–Kuskokwim Delta.

mollissima) and Spectacled Eiders but is of limited use for Long-tailed Ducks and Black Scoters, which are more abundant in areas further inland.

Yukon–Kuskokwim Delta Nest Survey

Since 1985, the USFWS has conducted ground-based sampling to monitor nest populations of waterfowl and waterbirds on the coastal zone of the Yukon–Kuskokwim Delta, Alaska (Figure 1.3). Two to four biologists search all nesting habitat within randomly located plots and record data for all nests found. This survey is currently designed to optimize estimates of nesting Spectacled Eider but also provides indices of local nesting populations of geese and other duck and waterbird species (J. B. Fischer and R. A. Stehn, unpubl. report). Counts of nests are adjusted for incomplete detection, and species-specific estimates from the nest plot survey are expanded to the entire Yukon–Kuskokwim

Delta using data from the concurrent aerial survey (R. M. Platte and R. A. Stehn, unpubl. report).

Alaska Arctic Coastal Plain Breeding Waterfowl Survey

This breeding population survey, initiated in 1992 and restricted to northern Alaska, is important because it is one of the few long-running surveys conducted on arctic breeding grounds (Figure 1.3). It is a fixed-wing stratified transect survey conducted annually by USFWS. The survey was redesigned in 2007 to combine two previously independent surveys: an eider-specific survey (W. W. Larned et al., U.S. Fish and Wildlife Service, unpubl. report) and a more general waterfowl survey (E. J. Mallek et al., U.S. Fish and Wildlife Service, unpubl. report). Data were reanalyzed to provide indices of breeding population size (R. A. Stehn et al., unpubl. report). The survey is appropriately timed (mid-June) and covers extensive breeding habitat for several species of sea ducks including Long-tailed Ducks, King Eiders (*Somateria spectabilis*), and Spectacled Eiders.

Pacific Black Scoter Breeding Survey

From 2004 to 2012, an aerial transect survey was flown annually (except 2011) in western Alaska to estimate breeding population size for Pacific Black Scoters (R. A. Stehn and R. M. Platte, U.S. Fish and Wildlife Service, unpubl. report). This survey was designed based on data from previous reconnaissance surveys and satellite telemetry studies to cover most (>80%) of the breeding range of Pacific Black Scoters (Figure 1.3) and is timed appropriately for breeding scoters. The survey is intended to provide precise estimates of breeding population size for Pacific Black Scoters. Using fixed-wing aircraft, two observers record all scoters, scaup (*Aythya* spp.), and Long-tailed Ducks. Most scoters are identified to species, and >95% are identified as Black Scoters. On a subset of transects, a double-observer technique is employed in most years to estimate observer-specific detection rates, which are used to adjust estimates (Magnussen et al. 1978, Pollock and Kendall 1987, Graham and Bell 1989).

British Columbia Coastal Waterbird Survey

Bird Studies Canada implemented a winter, shore-based survey in the Strait of Georgia in 1999 (Crewe et al. 2012). Observers count all species of waterbirds at more than 200 predefined sites between December and February each year. Although the survey covers a relatively small geographic area, it is the only survey that provides trend information for several species of sea ducks not covered by other surveys in that region. Annual mean counts per site are used as indices of abundance and to estimate variance and trends in abundance.

Audubon Christmas Bird Counts

The National Audubon Society has conducted Christmas Bird Counts (CBC) annually since 1900. Between December 14 and January 5, volunteer teams count all birds in a count circle with a diameter of 24 km along assigned routes. The benefits of CBC data are its long time series, continental scope, and ability to examine species-specific trends, which can complement aerial survey data for species that are recorded only to species groups such as mergansers or goldeneyes and for species that are difficult to count during aerial surveys such as Hooded Mergansers (*Lophodytes cucullatus*) and Harlequin Ducks. The drawbacks to CBC data are that they are derived from nonrandom samples with variable effort, based on volunteer data, and do not cover offshore habitats and areas in the far north. We restricted summaries of CBC data to 1974–2011 to be consistent with analyses of WBPHS and only to sea duck species with more freshwater and near-coastal winter distributions. Data derived from CBC online (National Audubon Society 2011) were reported as birds observed per party hour; an effort to standardize for variable effort among years.

METHODS

WBPHS Trend Analysis

We used count data from the WBPHS to estimate trends in sea duck abundance. We fit trend models independently to the midcontinent and Alaska data from 1974 to 2012 and to the eastern data from 1996 to 2012. Although midcontinent survey work was initiated in 1947 and the eastern survey in 1990, we limited the trend analysis for the midcontinent and Alaska survey areas to post-1973 data because the survey protocols, transect locations, and effort allocation were variable prior to 1974. Likewise, the complete eastern survey area has been consistently surveyed only since 1996.

We did not combine observations from the two areas for the trend estimation because of the large discrepancy in the time span of the available data and because some species have distinct eastern and western breeding populations. We included the data from western Ontario, usually considered part of the midcontinent, in the eastern analysis because the area was not flown between 1974 and 1984 and is contiguous with the eastern area. Although WBPHS analyses typically employ visibility corrections based on helicopter surveys, we did not adjust the WBPHS counts by visibility because the corrections used for sea ducks are based on small data sets collected before GPS technology allowed the helicopter crews to track the actual airplane path and the corrections vary little over the regions where sea ducks are observed and are not annually adjusted.

Trend Estimates

Trends were estimated by fitting cubic polynomial regression models to the total indicated birds (TIBs, Smith 1995) counted on all survey transects by year. Models were fit assuming normal (Gaussian) errors and included an offset for total number of miles flown per year. If the P-value for the coefficient of the highest-order polynomial was greater than 0.05, this term was dropped and the model was updated. The process was repeated as necessary to find the simplest, adequate model for TIBs per year (cubic, polynomial, or linear). We examined the residuals from each resulting model using autocorrelation and partial autocorrelation plots and found the assumption of independent observations to be reasonable; probability plots indicated that the normality assumption was also reasonable.

For cases where the quadratic or cubic model was selected, we estimated the annual trend for each survey year as the value of the derivative of the fitted curve in that year and determined the associated 95% confidence interval for each annual trend estimate. All analyses were completed using R version 3.0.1 (R Development Core Team 2013) and ArcGIS version 10.1 (Environmental Systems Research Institute 2012).

Scoter Trends by Species

In 1993, the protocol in the Alaska area was modified so that all scoters within the innermost 100 m of each transect were identified to species. These data provided a consistent index of species-specific abundance and species composition across the Alaskan survey area between 1993 and 2012. We used these records to estimate species-specific scoter trends for the Alaska survey area (including also Old Crow Flats in the Northwest Territories) from 1993 to 2012. We also divided the Alaska survey area into two regions based on the scoter species composition: the Bering and Chukchi Sea coastal survey areas, where Black Scoters are more common, and the interior and Gulf of Alaska survey areas, where most White-winged Scoters (*Melanitta fusca*) and Surf Scoters (*M. perspicillata*) occur. We then separately fit trend models to the scoter TIBs from 1974 to 2012 for these regions to differentiate Black Scoter population trends from those of the other two species.

RESULTS

Spectacled Eider

The majority of the worldwide population of Spectacled Eiders breed in arctic Russia. A single aerial survey, conducted over 3 years, 1993–1995, provided a minimum population index of 146,000 birds for the arctic Russia breeding population (Hodges and Eldridge 2001; R. A. Stehn et al., unpubl. report). In North America, there are two smaller breeding populations of Spectacled Eiders, both in Alaska, on the Yukon–Kuskokwim Delta and Arctic Coastal Plain. Both the Alaskan and Russian populations winter together among the pack ice of the northern Bering Sea near St. Lawrence Island (Petersen et al. 1999).

Almost all eiders recorded during the WBPHS are observed on the Yukon–Kuskokwim Delta, Alaska (Figure 1.4). Eiders are not differentiated to species during this survey, and indices represent a mix of Spectacled, Common, and Steller's Eiders (*Polysticta stelleri*). However, Spectacled Eiders were formerly the more common species on the Delta; thus, the >90% decline documented between the 1970s and early 1990s is thought to have been driven largely by declines in Spectacled Eiders (Stehn et al. 1993). Anecdotal information indicated that populations in the other two primary breeding areas, Russia and Alaska Arctic Coastal Plain, also declined, along with the much smaller breeding population on St. Lawrence Island in the Bering Sea (U.S. Fish and Wildlife Service 1996).

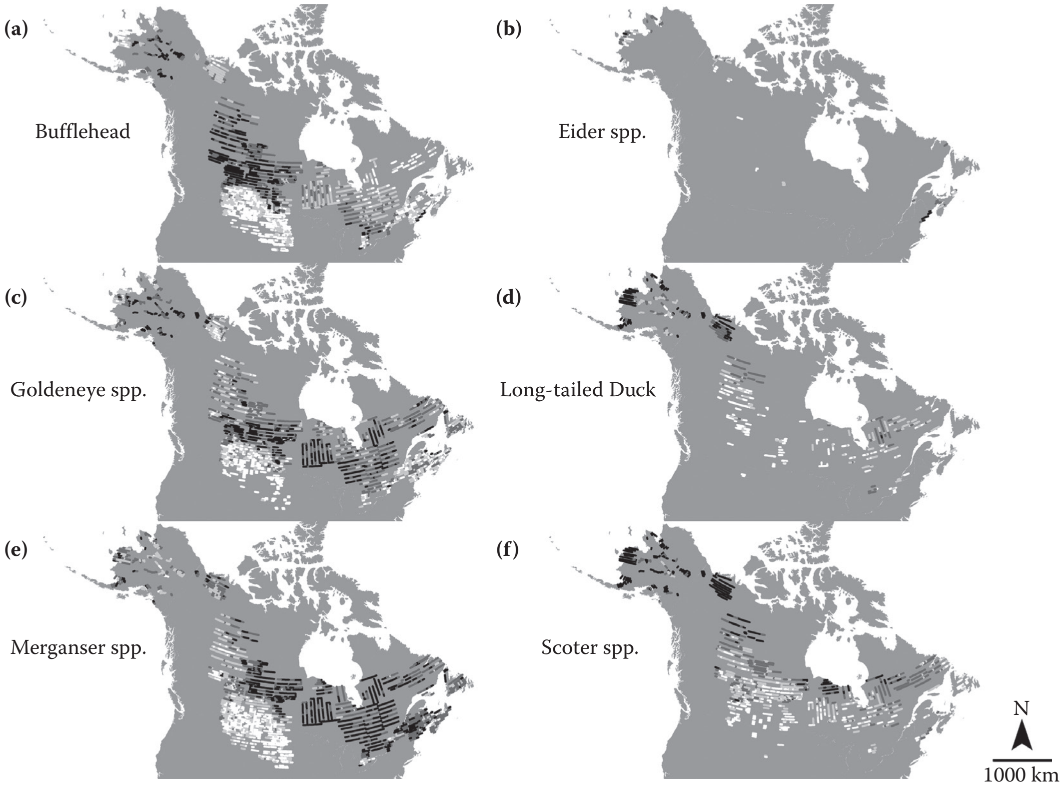

Figure 1.4. Average segment density (TIBs per km) for (a) Bufflehead (*B. albeola*), (b) eiders (*Somateria* spp. and *P. stelleri*), (c) goldeneyes (*B. clangula* and *B. islandica*), (d) Long-tailed Duck (*C. hyemalis*), (e) mergansers (*Mergus* spp. and *L. cucullatus*), and (f) scoters (*Melanitta* spp.) from the WBPHS for 1974–2012 in the midcontinent and Alaska and for 1996–2012 in the east. Segments are colored according to log density, low to high: white–light gray–dark gray–black. Segments where no birds were present (zero density) are not shown.

All Spectacled Eider breeding populations were listed as threatened in 1993 because of documented population declines.

Surveys of the only known wintering area of this species, presumed to represent the world population, were conducted in 1997, 1998, 2009, and 2010. Photographic surveys estimated a total population ranging from about 305,000 to 375,000 birds (Petersen et al. 1999; W. W. Larned et al., unpubl. report).

Surveys for breeding population trend were developed for the two Alaska breeding populations. The Yukon–Kuskokwim Delta Nest Survey counts are used in conjunction with the Yukon–Kuskokwim Delta Aerial Goose–Duck–Waterbird Survey to provide an annual estimate of the Yukon–Kuskokwim Delta breeding population. Recent estimates are about 6,000 nests with an increasing population trend since the early 1990s (J. B. Fischer and R. A. Stehn, unpubl. report). The Alaska Arctic Coastal Plain Breeding Waterfowl Survey estimates approximately 6,400 total birds (not adjusted for incomplete detection) with a stable population since surveys began in 1992 (R. A. Stehn et al., unpubl. report).

Steller's Eider

The vast majority of Steller's Eiders in the Pacific originate from breeding areas in eastern Siberia, with only remnant or small breeding populations in western and northern Alaska. In 1997, the Alaska breeding population was listed as a threatened species under the U.S. Endangered Species Act based on a substantial decrease in abundance, reduction in breeding range, and vulnerability of the remaining Alaska breeding population to extirpation. Worldwide, Steller's Eiders are listed as vulnerable in the IUCN Red List of Threatened Species (BirdLife International 2012). An extensive survey of the Russian Far East in 1993–1995 reported more than 129,000 birds in the Pacific population (Hodges and Eldridge 2001).

Steller's Eiders have nearly disappeared as a breeding species from the Yukon–Kuskokwim Delta where there were perhaps several thousand breeding prior to the 1960s; only a few nests have been found there in recent years and the current population probably numbers fewer than a dozen (Kertell 1991, Flint and Herzog 1999). Numbers of breeding Steller's Eiders on the Arctic Coastal Plain are highly variable, with highest densities around the Barrow area (Obritschkewitsch and Ritchie 2011; Safine 2012; U.S. Fish and Wildlife Service, unpubl. report). Although ground and aerial surveys estimate several hundred birds occur in mid-June on the Arctic Coastal Plain, Alaska, in most years, the number of observations are few and highly variable (Obritschkewitsch and Ritchie 2011, Safine 2012). For example, the aerial survey index for indicated breeding birds resulted in an uninformative estimate (–1.5% per year; 90% CI: –7.3 to 5.4) for 1989–2013 growth rate (R. A. Stehn, U.S. Fish and Wildlife Service, unpubl. data).

Most Steller's Eiders breeding in eastern Russia and Alaska molt and winter along the Alaska Peninsula, the southwest coast of Alaska, and Aleutian Islands and migrate north to breeding areas during spring along the coast of western Alaska. A spring aerial survey for Steller's Eiders begun in 1992 provided an index to population size of birds migrating northward in coastal habitats in southwest Alaska (W. W. Larned, unpubl. report). This survey has yielded counts ranging from 55,000 to 138,000 birds, with an average of about 82,000 birds. The survey indicated a long-term average annual decline of 2.3% but a stable estimate from 2003 to 2011. Although the survey was subject to several potential biases and the estimates imprecise, it represented the only long-term data set specifically targeting population trend for Steller's Eiders in the Pacific. That said, Steller's Eiders are opportunistically counted during two other aerial surveys targeting Emperor Geese (*Chen canagica*), one in fall (E. J. Mallek and C. P. Dau, unpubl. report) and one in spring (C. P. Dau and E. J. Mallek, U.S. Fish and Wildlife Service, unpubl. report). Those two surveys are conducted in similar areas of Alaska, but at different times, and both surveys indicate similar rates of decline over the same period beginning in 1992 (spring survey: −3.5% per year; fall survey: −4.2% per year). The spring aerial survey was replaced in 2012 by a photographic aerial survey of molting Steller's Eiders during fall on the primary molting areas in southwest Alaska, which yielded an index of 50,400 molting Steller's Eiders, primarily males (H. M. Wilson et al., U.S. Fish and Wildlife Service, unpubl. report).

Common Eider

Common Eiders breed extensively throughout Canada and Alaska, inhabiting arctic and subarctic marine environments most of the year and breeding in near-coastal wetlands or on coastal islands. There are four subspecies of Common Eiders in North America: Pacific (*S. mollissima v-nigra*), American (*S. m. dresseri*), Hudson Bay (*S. m. sedentaria*), and Northern (*S. m. borealis*). Survey methods for Common Eiders vary throughout their range, and most surveys of Common Eiders are specific to a particular subspecies based on geography. Status and trends for each of the four subspecies are discussed separately below.

Pacific Common Eider

Pacific Common Eiders nest on islands and a few mainland areas throughout the western and central Canadian Arctic from the Yukon coast to Queen Maud Gulf and north to include Victoria and Banks islands (Barry 1986, Cornish and Dickson 1997). Within Alaska, the largest breeding aggregations of Pacific Common Eiders have been found along the coastlines of the Aleutian Islands, Yukon–Kuskokwim Delta, Northwest Alaska, in the vicinity of the Seward Peninsula, and barrier islands of the Chukchi and Beaufort seas. Birds from breeding areas in northern Alaska and Canada winter primarily along the Chukotka Peninsula and near St. Lawrence Island in the northern Bering Sea (Petersen and Flint 2002, Dickson 2012a), and birds from the Yukon–Kuskokwim Delta winter along the north coast of Bristol Bay (Petersen and Flint 2002). Common Eiders breeding in the Aleutians Islands, Alaska, remain there during winter (M. R. Petersen, U.S. Geological Survey, pers. comm.). There has been no systematic effort to census the entire population (U.S. Fish and Wildlife Service, unpubl. report).

In the western Canadian Arctic, Barry (1986) estimated a total of 81,500 breeders, while spring migration data from 1993 suggested a total Canadian population of 90,500 birds (Alexander et al. 1997). This number is consistent with estimates of spring migrants passing Point Barrow (Suydam et al. 2000) from roughly the same time period. Numbers of Common Eiders breeding in the Bathurst Inlet area of Nunavut, Canada, declined by 43%–50% from nearly 17,000 to <10,000 over a 13-year period between 1995 and 2007–2008 (Raven and Dickson 2009).

Spring migration counts at Point Barrow, Alaska, which sample both Alaska Arctic Coastal Plain and western Canadian Arctic Common Eiders, suggested a decline of more than 50% between 1976 and 1996 (Woodby and Divoky 1982, Suydam et al. 2000), but the spring migration count in 2003 (about 120,000 birds; Suydam et al. 2004) increased 70% above the 1996 count, suggesting that the Canadian Arctic and Alaska Arctic Coastal Plain populations may have partially rebounded since the mid-1990s. The trends obtained from these migration counts should be viewed with caution, as considerable variation may be attributed to sampling methods and environmental variables (Day et al. 2004, Quakenbush et al. 2009). Aerial surveys specifically targeting Common Eiders in near-shore waters and along barrier islands of Alaska's Arctic Coastal Plain indicated a stable population of about 2400 birds from 1999 to 2009 (C. P. Dau and K. S. Bollinger, U.S. Fish and Wildlife Service, unpubl. report). Similar surveys of coastal areas between the Yukon Delta and the Arctic Coastal Plain in 2008 and 2009 estimated 4,000–5,000 Common Eiders (K. S. Bollinger and R. M. Platte, U.S. Fish and Wildlife Service, unpubl. report), which was 37% fewer than estimated in 1992 using similar survey methods (W. W. Larned et al., U.S. Fish and Wildlife Service, unpubl. report).

Nest surveys have been conducted by ground crews on the Yukon–Kuskokwim Delta since 1985 (J. B. Fischer and R. A. Stehn, unpubl. report). An average of approximately 3,500 Common Eider nests were estimated (after correcting for undetected nests; J. B. Fischer and R. A. Stehn, unpubl. report) on the Yukon–Kuskokwim Delta during the most recent 5-year period (2008–2012). The 25-year trend is increasing (7.5% per year; 90% CI: 5.0–10.1). An increasing trend (3.5% per year; 90% CI: 1.6–5.5) was also estimated from an aerial survey of the coastal zone of the Yukon–Kuskokwim Delta from 1988 to 2012 (R. M. Platte and R. A. Stehn, unpubl. report).

In the Aleutian Islands, various surveys conducted periodically since the 1970s provide minimal estimates for the region. Combining the most recent counts for all islands, about 25,000–30,000 Common Eiders reside in the Aleutians (U.S. Fish and Wildlife Service, unpubl. report). Reliable long-term trend data are nearly nonexistent for most of the Aleutians, as is the case for other large sections of the breeding range for the Pacific Common Eider.

Based on all available data throughout their range, it appears that overall Pacific Common Eiders are below historic levels, but with considerable uncertainty in the estimates and regional differences in trends.

American Common Eider

The American Common Eider subspecies breeds on islands in coastal waters from Labrador to Massachusetts and winters from Newfoundland to Rhode Island, with greatest numbers wintering in Maine and Massachusetts. While abundance for some segments of the population has been monitored regularly such as the St. Lawrence Estuary, there has been no comprehensive, range-wide survey of American Common Eider abundance and no estimates of overall trend in abundance exist.

Along the Lower North Shore of the Gulf of St. Lawrence, Quebec, ground-based colony counts have been made almost every 5 years since 1925 (Rail and Chapdelaine 2002, Rail and Cotter 2007) and indicate strong positive growth over the last 30 years (Figure 1.5), with a current estimate of about 17,000–20,000 breeding pairs for this region. Little information on numbers or trend exists for Newfoundland and Labrador. The number of male eider ducks counted on the Labrador coast during the breeding season increased from 8,800 in 1980 (Lock 1986) to 18,000 males in 1994—an increase of about 5% per year (S. G. Gilliland, Canadian Wildlife Service, unpubl. data). Similar growth has been observed across several archipelagos in northern Newfoundland with an average increase of 5% per year between 1988 and 2006 and a current index of about 6,000 males (S. G. Gilliland, unpubl. data).

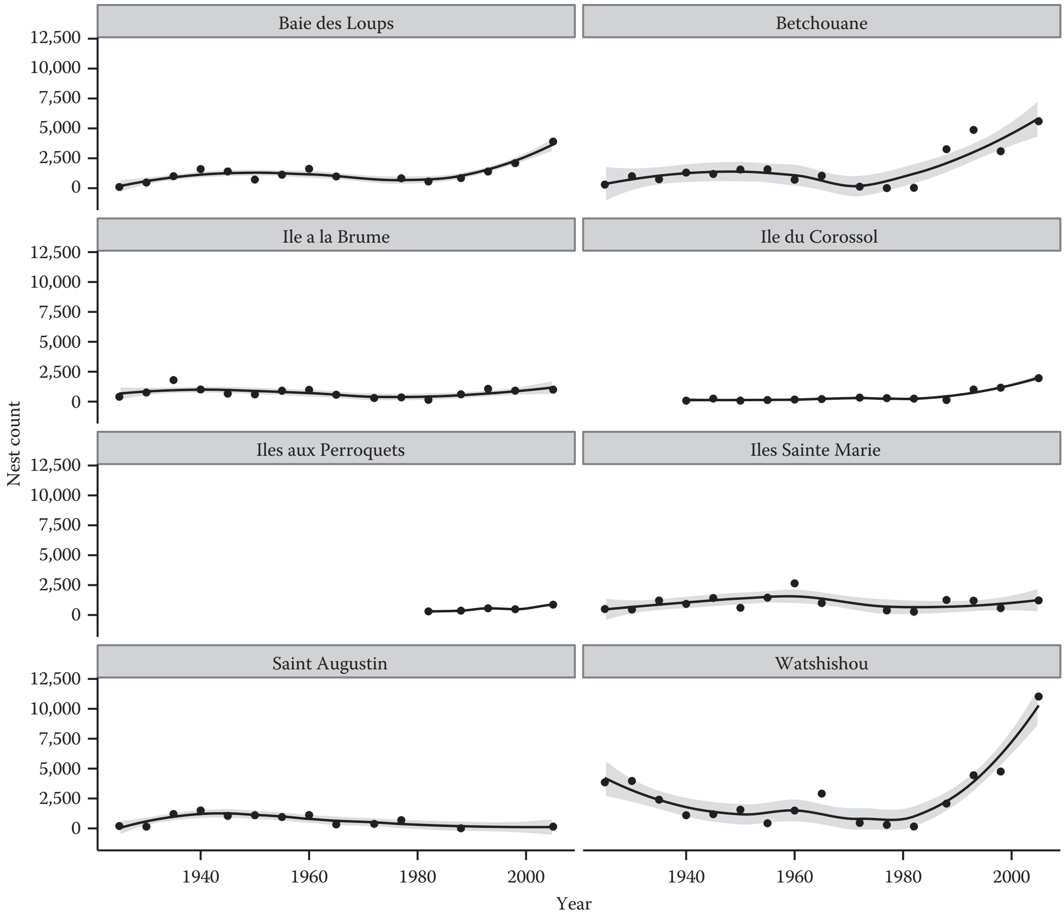

Figure 1.5. Number of American Common Eider (*S. m. dresseri*) nests detected in seabird colonies on Migratory Bird Sanctuaries along the Lower North Shore of the Gulf of St. Lawrence, Quebec, 1925–2005. Fitted local polynomial regressions (solid curve) with 95% confidence intervals (gray shading) for fitted values are also plotted. (From Rail and Chapdelaine 2002, Rail and Cotter 2007.)

In the St. Lawrence Estuary, Duvetnor and the Société Protectrice des Eiders de l'Estuaire have collected eiderdown from various colonies, which has provided valuable information on colony size for this segment of the population. The number of eiders breeding in the estuary was stable from the mid-1960s to the late 1990s (Figure 1.6). Epidemics of avian cholera occurred in eider colonies in the estuary in 1976, 1985, and, most recently, in 2002, when an estimated 6,000 breeding females died (Joint Working Group on the Management of the Common Eider 2004). The number of nests in the estuary has not increased since the 2002 epidemic, and current estimates are between 20,000 and 30,000 nests.

In southwestern New Brunswick, a comprehensive aerial survey of breeding areas in the Bay of Fundy has been conducted biannually since 1991 and indicates an overall decline of 3.1% per year between 1991 and 2012 ($P = 0.003$; K. Conner, New Brunswick Department of Natural Resources, unpubl. data; Figure 1.7). The number of males detected on the survey was stable until the late 1990s then declined at a rate of about 5% per year since 2000 ($P = 0.027$, Figure 1.7).

In coastal Maine, Common Eiders were nearly extirpated in the early 1900s but rebounded in response to protective measures (Krohn et al. 1992, Allen 2000). By 2000, an estimated 29,000 pairs of eiders nested in 320 colonies. In 2012, the population estimate was revised to 22,740 pairs nesting on 312 islands, based on updated data for several colonies,

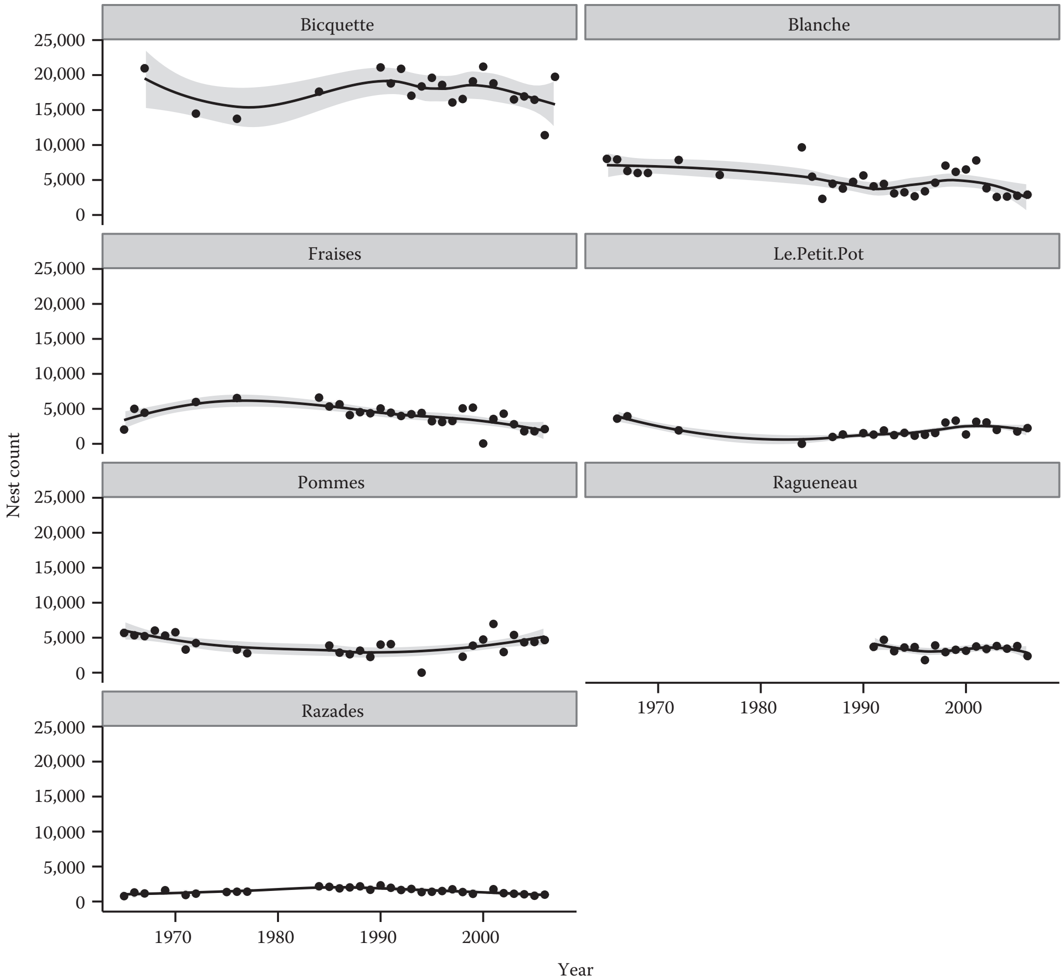

Figure 1.6. Number of American Common Eider (*S. m. dresseri*) nests detected in the largest colonies of the St. Lawrence Estuary, Quebec, during eiderdown collections, 1965–2007. Fitted local polynomial regressions (solid curve) with 95% confidence intervals (gray shading) for fitted values are also plotted. (From Duvetnor and Société Protectrice des Eiders de l'Estuaire, unpubl. data.)

although no comprehensive coast-wide survey has been conducted (R. B. Allen, Maine Department of Inland Fisheries and Wildlife, unpubl. data).

Numbers of American Common Eiders in the southern part of their breeding range appeared to peak in the late 1990s; however, data from colonies in the St. Lawrence Estuary, Quebec, and Bay of Fundy, New Brunswick, suggest this segment of the population has declined since then. Although there are no data available to evaluate trends, long-term banding programs in Nova Scotia and Maine have experienced increasing difficulty capturing breeding females at several major colonies suggesting their numbers have been declining in these regions during the same period (R. B. Allen and R. Milton, Nova Scotia Department of Natural Resources, pers. comm.). In contrast, numbers of American Common Eiders in the northern part of their breeding range appear to have increased throughout the latter part of the twentieth and early twenty-first centuries.

Hudson Bay Common Eider

Hudson Bay Common Eiders are resident to Hudson Bay, where it is logistically difficult and expensive to conduct surveys for this subspecies. The breeding population was estimated to

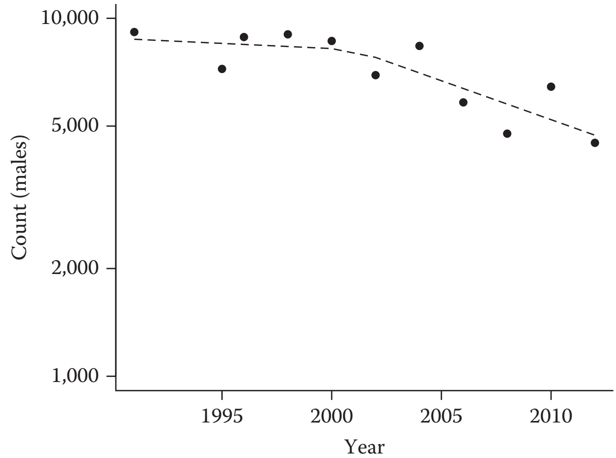

Figure 1.7. Number of male American Common Eiders (*S. m. dresseri*) counted during aerial breeding season surveys of southwestern Bay of Fundy, New Brunswick, between 1991 and 2012. Broken line represents fitted linear models broken at 2000. (From K. Connor, New Brunswick Department of Natural Resources, Fredericton, New Brunswick, Canada, unpubl. data.)

be 83,000 pairs in the 1980s (Nakashima and Murray 1988). The wintering population was estimated at about 255,000 birds in 2006 (Gilliland et al. 2008a). Ground-based colony surveys in the Belcher Islands were conducted twice, once between 1985 and 1989 as part of Nakashima and Murray's (1988) survey and in 1997 following a large winter kill in 1991–1992 (Robertson and Gilchrist 1998); a 75% decline in numbers of nesting eiders was documented. There is no recent estimate of trend for Hudson Bay Common Eiders.

Northern Common Eider

Northern Common Eiders breed in the Eastern Canadian Arctic, as well as in west Greenland. About 75% of the Canadian breeding population overwinter primarily in Greenland, with smaller numbers wintering in coastal Newfoundland and along the North Shore of the Gulf of St. Lawrence (Gilliland et al. 2009a). Obtaining reliable estimates of abundance during winter is complicated because they occur in three countries, including Canada, Greenland, and the French islands of St. Pierre and Miquelon, and mix to an unknown degree with other subspecies of Common Eiders (*S. m. dresseri*, Gilliland and Robertson 2009, Gilliland et al. 2009a).

An island colony at East Bay, Southampton Island, Nunavut, has been monitored since 1996. The colony was stable from 1996 to 2004, then increased to a maximum of 9,400 nests (G. Gilchrist, Environment Canada, pers. comm.) apparently in response to harvest reductions in Greenland that were implemented in 2002–2004 (Gilliland et al. 2008b, Merkel et al. 2008). Avian cholera was detected in 2005 resulting in a loss of a large portion of the colony in 2006 (Descamps et al. 2009). Cholera was still present on the colony in 2013 when the colony was about 2,300 nests, and recovery now appears to be restricted by frequent depredation by polar bears (*Ursus maritimus*, Iverson et al. 2014).

In northern Labrador, Northern Common Eiders appear to be doing well. In 1980, Lock (1986) estimated about 6,700 bred along the north coast of Labrador, and their numbers have been increasing at about 5% per year from 1980 to 2006 (Chaulk 2009). Numbers of breeding eiders along the central and southern coast of Ungava Bay have been stable to increasing between 1980 and 2000 (Chapdelaine et al. 1986, Falardeau et al. 2003). However, fewer eiders were detected breeding across northwestern Ungava Bay during the same time period, suggesting a significant decline of breeding eiders in that region (Falardeau et al. 2003).

Using photographic counts and ratio and regression estimators, Bordage et al. (1998) surveyed wintering areas in the Gulf of St. Lawrence, off Newfoundland, and off the French Islands of St. Pierre and Miquelon in 2003 and have since repeated the survey on a 3-year cycle. Estimates were 204,000 (SE = 23,000), 176,000 (SE = 8,000), and 204,800 (SE = 22,500) eiders in 2003, 2006, and 2009, respectively, suggesting that the segment of the population wintering in Canada has been relatively stable over the last 10 years (C. Lepage and S. G. Gilliland, Canadian Wildlife Service, unpubl. data).

King Eider

No comprehensive range-wide survey for King Eiders has been undertaken; only intermittent or regional surveys provide insights into abundance and population trends. Monitoring is complicated by the fact that many King Eiders that breed in western Canada and Alaska winter off the east coast of Russia (Phillips et al. 2006, Dickson 2012b), while many King Eiders breeding in Eastern Canada winter along the west coast of Greenland (Mosbech et al. 2006). The Sea Duck Joint Venture recognizes two populations of King Eiders in North America: a western arctic population and an eastern arctic population, although the dividing line between the two is not well documented and there likely is an area of overlap (Mehl et al. 2004, Dickson 2012b, Sea Duck Joint Venture 2013).

Western North America

King Eiders migrating past Point Barrow, Alaska, in spring represent the northern Alaska and western Canadian Arctic populations and have been counted there at periodic intervals between 1976 and 2003. From 1976 to 1996, counts suggested a decline of more than 50%, from 800,000 to 350,000 (Suydam et al. 2000), although a spring 2003 count estimated about 362,000 King Eiders (Suydam et al. 2004), suggesting the population may have stabilized since 1996. As noted for Pacific Common Eiders, these migration counts and apparent trends may be biased due to variation in sampling methods and environmental variables (Day et al. 2004, Quakenbush et al. 2009).

Systematic aerial surveys of breeding areas on western Victoria Island, Northwest Territories, documented a 50% decline in King Eider abundance from over 70,000 in 1992–1994 to 33,000 in 2004–2005 (Raven and Dickson 2006). On Alaska's Arctic Coastal Plain, an average total bird index of 21,000 birds was estimated for the most recent 5-year period, 2008–2012. This survey indicates an increasing population with a long-term (1986–2012) average annual growth rate of 3.1% (90% CI: 2.1–4.1) and a growth rate of 2.4% (90% CI: 1.1–3.7) for the most recent 10-year period (2003–2012; R. A. Stehn et al., unpubl. report).

Eastern North America

No range-wide or contemporary trend information exists for King Eiders in eastern North America. A substantial decrease in numbers of wintering and molting King Eiders in Greenland, most of which breed in Canada, suggests that the eastern arctic population is declining (Environment Canada 2013). A significant decrease in numbers of King Eiders was observed in the Rasmussen Lowlands of Nunavut, a relatively small breeding area, between 1975–1976 and 1994–1995 (Gratto-Trevor et al. 1998).

Scoters

The WBPHS is the only long-term, broad-scale survey in which scoters have been consistently counted, although the survey is not optimally timed for scoters, which arrive relatively late on their breeding grounds. The annual counts are variable and may not accurately represent the breeding population in a given area. Based on satellite telemetry studies (De La Cruz et al. 2009, Sea Duck Joint Venture 2012), the midcontinent and Alaska areas include a substantial portion of the continental breeding range of White-winged and Surf Scoters. Highest densities of scoters are observed in the northern boreal and Alaska areas (Figure 1.4). During this survey, scoter species (Black, Surf, and White-winged) are typically recorded only to genera, so species-specific trends are difficult to determine. Nevertheless, the long time series is valuable for understanding overall trends of scoters, and some species-specific conclusions can be drawn based on known differences in breeding habitats and from observations recorded to species on Alaska areas since 1993.

WBPHS data for the midcontinent and Alaska region suggest a decreasing trend from the early 1980s to early 2000s, and increasing trend since about 2004 (Figure 1.8) with somewhat smaller declines in interior Alaska (~2% average annual decline in counted birds between the early 1980s

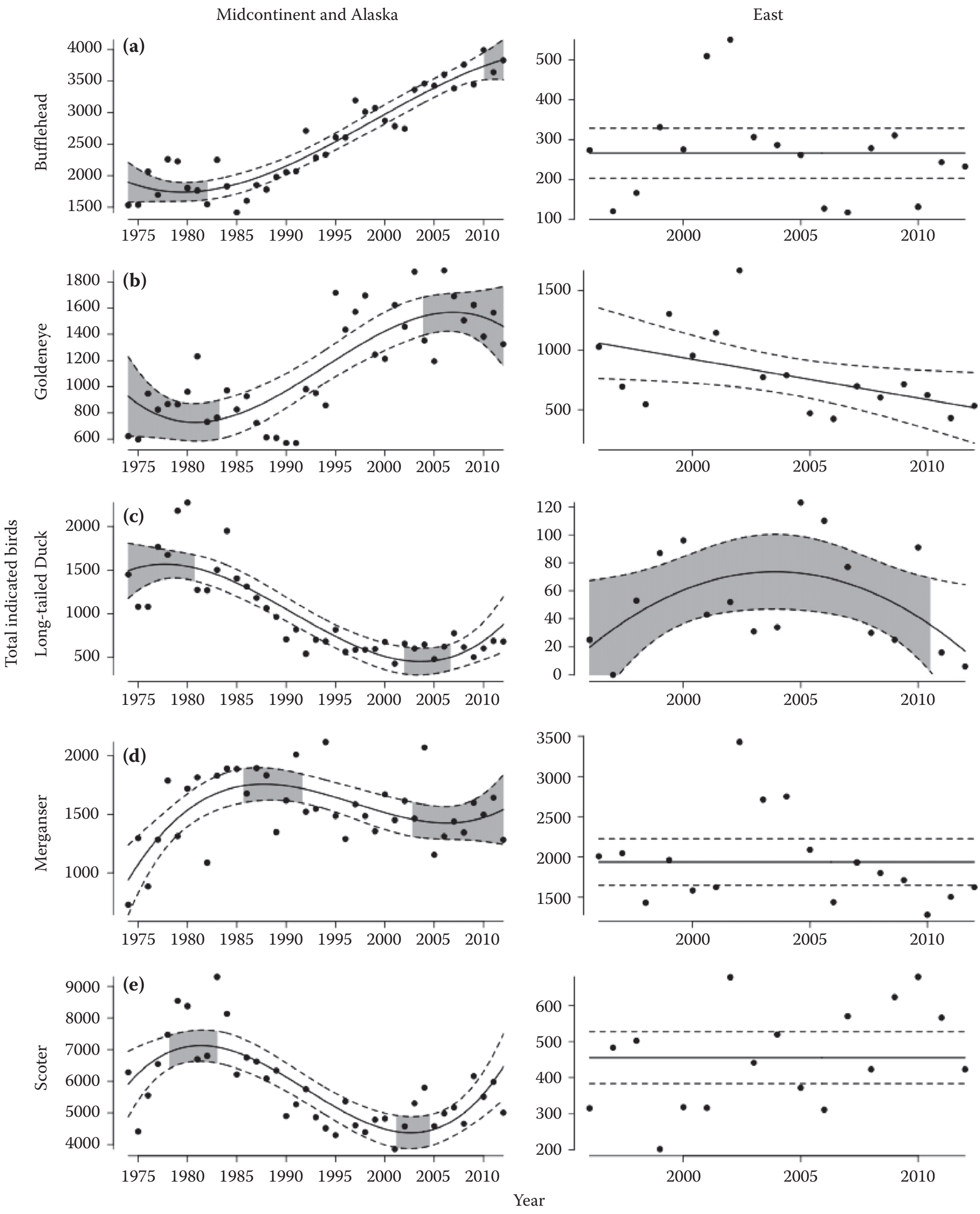

Figure 1.8. TIBs recorded on the WBPHS by year for (a) Bufflehead (*B. albeola*), (b) goldeneyes (*B. clangula* and *B. islandica*), (c) Long-tailed Duck (*C. hyemalis*), (d) mergansers (*Mergus* spp. and *L. cucullatus*), and (e) scoters (*Melanitta* spp.). Separate plots are shown for the midcontinent and Alaska (first column) and eastern (second column) survey areas. Fitted polynomial models (solid curve) with 95% confidence intervals for the fitted values (dashed curves) are also plotted. Gray shading indicates years when the estimated annual trend (change in TIBs per year) was not significantly different from zero (P-value > 0.05).

and early 2000s) than in northern boreal and prairie regions (~5% average annual decline). In the eastern strata of the WBPHS, counts are highly variable, with no discernible trend since 1996 (Figure 1.8). In what follows, we present species-specific summaries where data permit.

Black Scoter

Based on satellite telemetry studies of Black Scoter in both western (Bowman et al. 2008) and eastern North America (S. G. Gilliland, pers. comm.), it is clear that there are two distinct populations of Black Scoters: one that breeds in Alaska and one that breeds in Eastern Canada. We refer to these populations as Pacific and Atlantic Black Scoters, respectively.

Pacific Black Scoter

The WBPHS covers part of the breeding range of Pacific Black Scoters, mainly in western Alaska (Figure 1.4). Aerial survey and ground observations have indicated that nearly all scoters in the Alaska tundra strata are Black Scoters. Data from WBPHS for the Alaska tundra suggest a long-term (1974–2012) downward trend for Black Scoters, although no observable trend over all of the Alaska survey area in the last 20 years (Figure 1.9).

The Pacific Black Scoter survey, initiated in 2004 specifically to monitor this breeding population, indicates an increasing trend from 2004 to 2012. This survey should provide a more reliable indicator of trend than the WBPHS, although a cautious interpretation is required because the time series for this survey is relatively short. This survey employs an adjustment for incomplete detection, so that the index could be interpreted as an estimate of the breeding population size in the survey area. The average population size from 2004 to 2012 was about 140,000 indicated total birds and 133,000 indicated breeding birds (Stehn and Platte 2012). These estimates do not include breeding or nonbreeding birds that occur outside the survey area, so the numbers should be considered a minimum estimate of range-wide population size.

Atlantic Black Scoter

Estimates of abundance do not exist for the entire population and there are no reliable data to evaluate long-term trends for Atlantic Black Scoters. The WBPHS covers little of the breeding range of Atlantic Black Scoters and the lack of observations recorded to species precludes any species-specific assessment in eastern North America.

Surf Scoter

Satellite telemetry studies (De La Cruz et al. 2009, Sea Duck Joint Venture 2012) suggest that there may be two separate populations of Surf Scoters in North America—one in eastern North America, and one in western North America, although further study is needed to confirm this (Sea Duck Joint Venture 2012). In western North America, the scoter species-specific data (i.e., positive identifications) from the WBPHS indicate a decreasing trend for Surf Scoters in Alaska from 1993 to 2012 (Figure 1.9). In the Strait of Georgia, British Columbia, shore-based winter waterbird surveys indicated no trend in Surf Scoters over the 1999–2011 period (Crewe et al. 2012). Based on aerial surveys during winter in Puget Sound, Washington, Surf Scoters have declined by 37% from 1999 to 2013 with recent indices of about 40,000 birds (J. R. Evenson, Washington Department of Fish and Wildlife, pers. comm.). In eastern Canada, the Eastern Waterfowl Survey indicates a stable population of Surf Scoters from 1990 to 2012 (Figure 1.10).

White-winged Scoter

Using only the scoter species-specific data with positive identifications from the WBPHS, White-winged Scoters appear to have an increasing trend in Alaska from 1993 to 2012 (Figure 1.9). In 2001, an aerial survey specifically targeting scoters was initiated at Yukon Flats National Wildlife Refuge, an area that supports the highest densities of scoters in interior Alaska. About 99% of the scoters are positively identified as White-winged Scoters. The population has been stable for the 10-year period beginning 2001 (N. Guldager et al., U.S. Fish and Wildlife Service, unpubl. report). Winter aerial surveys in Puget Sound, Washington, suggest that White-winged Scoters have declined by 35% from 1999 to 2013 (~12,000 birds; J. R. Evenson, pers. comm.).

Long-tailed Duck

Estimates of abundance for Long-tailed Ducks in North America are difficult to ascertain due to

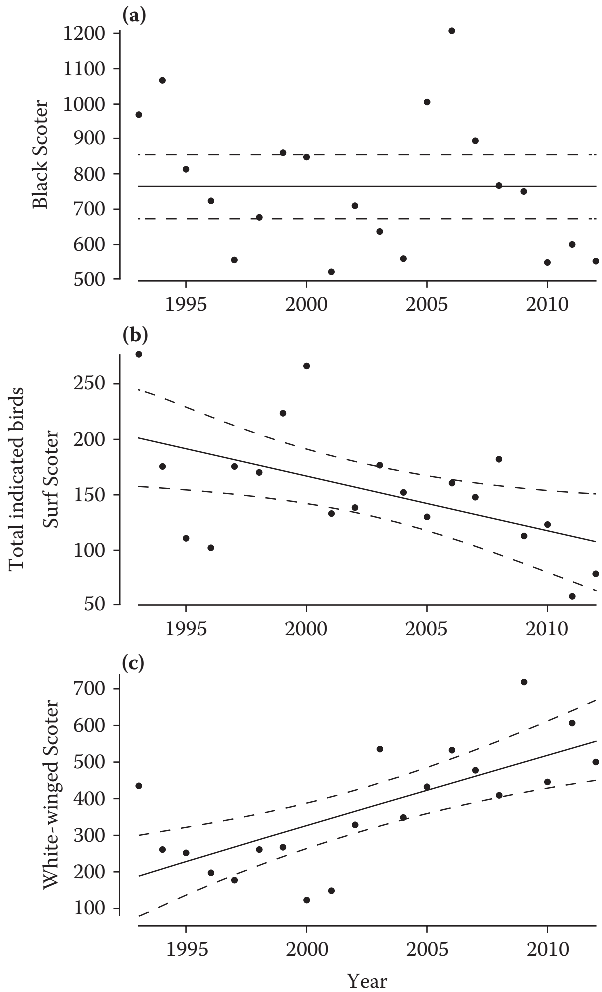

Figure 1.9. TIBs recorded for (a) Black Scoter (*M. americana*), (b) Surf Scoter (*M. fusca*), and (c) White-winged Scoter (*M. perspicillata*) in the innermost 100 m of the survey transects for the Alaska survey area of the WBPHS, 1993–2012. In those years, all scoters within the innermost 100 m of each transect were identified to species. Fitted polynomial models (solid lines) with 95% confidence intervals for the fitted values (dashed curves) are shown.

their vast breeding range including areas that are largely outside survey boundaries. Further, satellite telemetry has revealed that many Long-tailed Ducks that breed in western North America winter along the coast of Asia (Petersen et al. 2003; B. Bartzen et al., Canadian Wildlife Service, unpubl. report). A rough estimate of one million birds in North America has been used previously, but without a strong basis (Robertson and Savard 2002). Long-tailed Ducks remain one of the most poorly surveyed species of sea ducks in North America.

The WBPHS covers only a small part of the North American breeding range for Long-tailed Ducks, primarily on the Yukon–Kuskokwim Delta, Alaska, and northern Northwest Territories (Figure 1.4). Data indicate substantial declines from about 1980 to 2002, and an increasing trend from the most recent 6 years (2007–2012; Figure 1.8). Few Long-tailed Ducks are encountered in the eastern survey area of the WBPHS, and no discernible trend is evident since 1996 (Figure 1.8).

Aerial transect surveys of breeding birds on western Victoria Island in central arctic Canada indicate a decline from a mean population estimate of 21,100 for 1992–1994 to 14,900 for 2004–2005 (Raven and Dickson 2006). The Yukon–Kuskokwim Delta Aerial Goose–Duck–Waterbird Survey, which also covers a fairly small proportion of the continental population of Long-tailed Ducks, suggests a stable population from

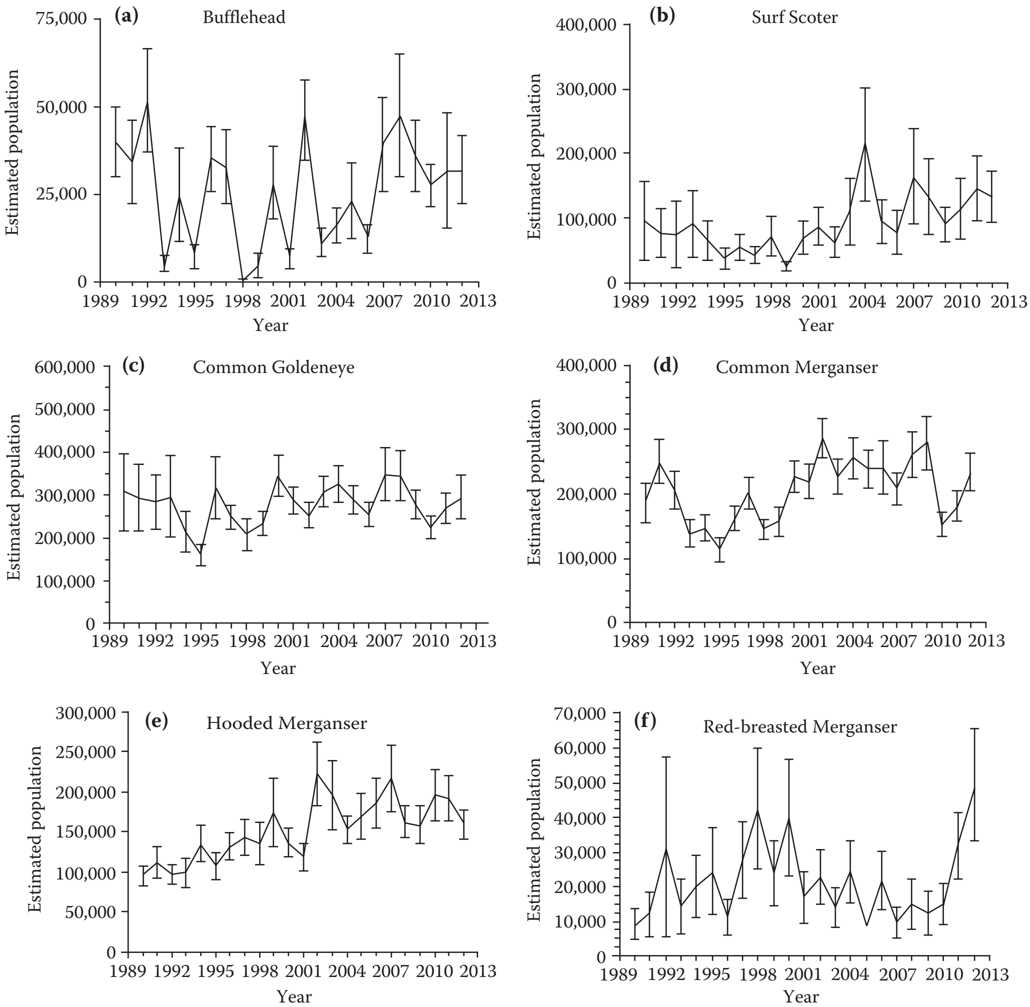

Figure 1.10. Population estimates (mean and SE) for (a) Bufflehead (*B. albeola*), (b) Surf Scoter (*M. fusca*), (c) Common Goldeneye (*B. clangula*), (d) Common Merganser (*M. merganser*), (e) Hooded Merganser (*L. cucullatus*), and (f) Red-breasted Merganser (*M. serrator*) in the Eastern Waterfowl Survey area, 1990–2012. Figures represent results from the helicopter surveys only. (From Environment Canada, Population status of migratory game birds in Canada, November 2012, Canadian Wildlife Service Migratory Birds Regulatory Report, No. 37, Canadian Wildlife Service, Ottawa, Ontario, Canada, 2013.)

1988 to 2012 (−0.5% per year; 90% CI: −1.8 to 0.9) but a declining trend for the most recent 10-year period 2003–2012 (−7.2% per year; 90% CI: −10.9 to −3.3) and a recent index of about 4,200 TIBs (R. M. Platte and R. A. Stehn, unpubl. report).

An extensive survey of the Alaska Arctic Coastal Plain, begun in 1986, estimated an average population index (uncorrected for incomplete detection) of 47,000 birds from 2008 to 2012, long-term (1986–2012) stability (−0.1% per year; 90% CI: −1.6 to 0), and an increasing trend (2.5% per year; 90% CI: 0.1–5.0) in recent years (2003–2012; R. A. Stehn et al., unpubl. report), consistent with the positive trajectory observed in the WBPHS from 2007 to 2012. Overall, while several surveys suggest long-term declines in populations of Long-tailed Ducks, more recent data (mid-2000s to 2012) suggest stabilization or slight increases, albeit at levels below historical estimates.

Harlequin Duck

There are two distinct populations of Harlequin Ducks in North America—a relatively small population that resides primarily in Eastern Canada and a much larger population that breeds from Alaska south through the far western provinces and northwest states (Robertson and Goudie 1999). The western population winters in coastal areas from Alaska to California. Harlequin Ducks are a challenge to survey from aircraft during the breeding season because they are difficult to see in riverine breeding habitats; thus, most population estimates are based on winter counts.

Eastern North America

In Canada, the eastern population is designated as a species of Special Concern under the federal Species at Risk Act, and under provincial legislation, it is listed as endangered in New Brunswick and Nova Scotia and vulnerable in Newfoundland, Labrador, and Quebec. In the United States, Harlequin Ducks are listed as a threatened species in Maine.

In eastern North America, the breeding range of Harlequin Ducks covers northern Quebec and Labrador east to Newfoundland and south into northern New Brunswick. This population was formerly thought to contain two distinct segments based on where birds winter, although recent satellite telemetry studies suggest there may be some intermixing between the two population segments (Chubbs et al. 2008, Robert et al. 2008). Birds breeding in northern Quebec and Labrador molt and winter primarily along the southwest coast of Greenland, whereas birds in southern parts of the breeding range typically molt along the southwest Labrador coast and other areas to the south. The southern segment of the breeding population winters in southern Newfoundland, the Maritime Provinces, and New England states, mostly in Maine.

There are no range-wide abundance estimates for the breeding population. Abundance estimates for the eastern population are primarily based on counts of males at molting areas and counts of birds at wintering sites. Recent surveys suggest there are between 3,000 and 3,500 birds wintering in eastern North America (Boyne 2008, Mittelhauser 2008) and 5,000–10,000 birds wintering in Greenland, many of which originated from breeding areas in Eastern Canada (Boertmann 2008).

Harlequin Ducks have been counted at key wintering sites in Atlantic Canada at various intervals from 2001 to 2013. These counts suggest the number of Harlequin Ducks has been rapidly increasing in Atlantic Canada during the last 12 years (8.6% per year; Figure 1.11). However, these surveys have similar drawbacks to CBC data because they rely on nonrandom samples and counts were not standardized within or among sites. Also, refinement of survey effort and increasing observer experience may be partially responsible for some of the observed increases.

Western North America

There are no range-wide surveys that provide robust estimates of population size or long-term trend data for Harlequin Ducks in western North America. CBC data show a steadily increasing trend along the Pacific coast since 1974 (Niven et al. 2004, National Audubon Society 2011). Most other data on trend are from relatively small geographic areas.

In Prince William Sound, Alaska, winter surveys conducted in most years between 1997 and 2009 suggest an increasing trend for Harlequin Duck densities (Rosenberg et al. 2013). Densities also appeared slightly higher in 2007–2009 compared with 1972–1973. In 1989, the *Exxon Valdez* oil spill had a significant impact on the Harlequin Duck population in Prince William Sound, and recovery has been slow (Iverson and Esler 2010). The most recent survey in 2009 estimated 12,500 Harlequin Ducks in surveyed areas of Prince William Sound—a minimal estimate of total population size because not all areas were surveyed.

On Kodiak Island, Alaska, several bays with a combined population of at least 3,000 Harlequin Ducks were surveyed from 1994–1997 and 2004–2007. The mean population remained stable between these time periods, with the exception of one bay that showed decreased numbers suspected to be the result of high hunting pressure (D. Zwiefelhofer, U.S. Fish and Wildlife Service, unpubl. report).

The majority of the Pacific population of Harlequin Ducks winter in the Aleutian Islands in Alaska. Byrd et al. (1992) estimated about 147,000 harlequins in the Aleutian Islands in the early 1990s. A subjective estimate of 600,000 to 1 million Harlequin Ducks in the Aleutians for the period 1967–1969 was put forth by Bellrose (1976). There are no reliable data to evaluate trend

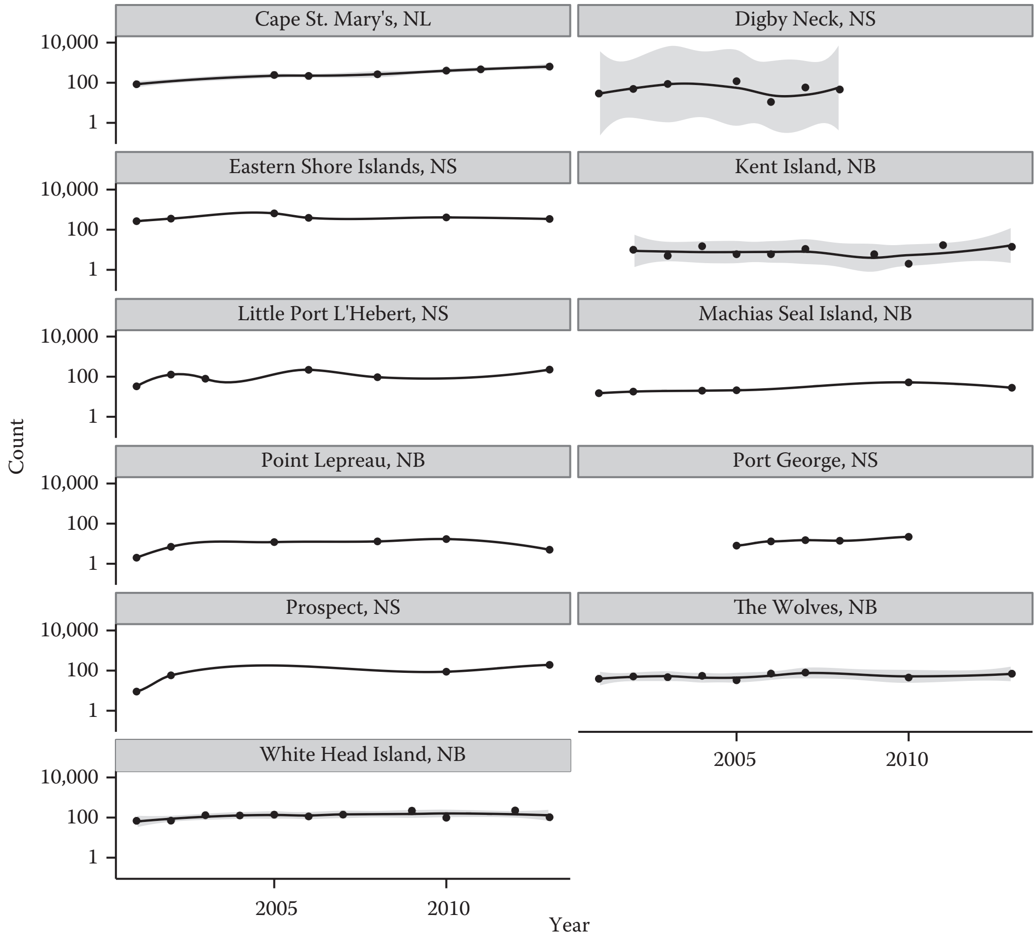

Figure 1.11. Annual trends in number of Harlequin Ducks (*H. histrionicus*) detected at key wintering locations in Atlantic Canada from 2001 to 2013. Fitted local polynomial regressions (solid curve) with 95% confidence intervals (gray shading) for fitted values are also plotted. (From Canadian Wildlife Service, Ottawa, Ontario, Canada, unpubl. data.)

in the Aleutian Islands. In the Strait of Georgia, British Columbia, shore-based winter waterbird surveys indicated a significant declining trend (−2.6% per year) for Harlequin Ducks for the period 1999–2011 (Crewe et al. 2012).

Goldeneyes

Common Goldeneyes and Barrow's Goldeneyes are difficult to identify to species during aerial surveys and are often lumped into a generic goldeneye category, including during the WBPHS. Based on the location of survey transects and the respective ranges of Common and Barrow's Goldeneyes, data from the WBPHS are likely more indicative of trends for Common Goldeneyes, which breed widely across the continent (Figure 1.4). Few of the midcontinent and Alaska WBPHS transects are located in the range of Barrow's Goldeneyes. In surveyed areas, the trend from the early 1980s to early 2000s is clearly positive with no significant trend in the 5–10 years prior to, and after, that period (Figure 1.8). In the eastern portion of the WBPHS, goldeneyes showed a downward trend from 1996 to 2012 (Figure 1.8).

In Puget Sound, Washington, goldeneyes have declined slightly from 1996 to 2013 (J. R. Evenson, Washington Department of Fish and Wildlife, unpubl. data). While both species of goldeneyes occur there, species-specific trends cannot be ascertained because species composition has been estimated only in recent years (2008–2013).

Common Goldeneye

CBC data show a steadily increasing trend for Common Goldeneyes since 1974 (Niven et al. 2004, National Audubon Society 2011). In Eastern Canada, the Eastern Waterfowl Survey indicates no trend for Common Goldeneyes from 1990 to 2012 (Figure 1.10). In coastal British Columbia, shore-based winter waterbird surveys in the Strait of Georgia indicated no trend in Common Goldeneyes over the 1999–2011 period (Crewe et al. 2012).

Barrow's Goldeneye

Two distinct populations of Barrow's Goldeneyes occur in North America. The eastern population is relatively small and breeding is restricted largely to Quebec (Robert et al. 2000, Savard and Robert 2013), although there have been incidental observations of Barrow's Goldeneyes along the Quebec–Labrador border in northeast Quebec and in insular Newfoundland suggesting their breeding range may be somewhat larger (S. G. Gilliland, pers. comm.). In Canada, the eastern population of Barrow's Goldeneyes is designated as a species of Special Concern under the federal Species at Risk Act, and under provincial legislation, it is listed as endangered in New Brunswick and Nova Scotia and vulnerable in Newfoundland and Labrador and Quebec. In the eastern United States, Barrow's Goldeneyes are listed as a threatened species in Maine due to low numbers and vulnerability to extirpation. The Pacific population is more numerous and breeds over a much larger area from British Columbia into western Alberta and as far north as central Alaska.

Eastern North America

Barrow's Goldeneyes primarily winter along the St. Lawrence Estuary and Gulf coasts, with small concentrations of birds occurring in New Brunswick, Prince Edward Island, Nova Scotia, and Maine. Robert and Savard (2006) estimated the wintering population to be about 5200 birds. A helicopter survey of the major overwintering sites in Quebec has been conducted at regular 3–5 year intervals since 1999. The survey suggests the population is stable, but the results are imprecise and are considered inadequate for monitoring trends (M. Robert, Canadian Wildlife Service, pers. comm.). Thus, there are few data on trends for eastern Barrow's Goldeneyes during winter, and no data on trends for breeding populations.

Western North America

No range-wide surveys provide estimates of population size or long-term trends. Most available data are from relatively small geographic areas. In Prince William Sound, Alaska, winter surveys conducted in most years between 1997 and 2009 suggested a stable population for Barrow's Goldeneyes (Rosenberg et al. 2013). In coastal British Columbia, shore-based winter waterbird surveys in the Strait of Georgia indicated a significant declining trend (−4.3% per year) for Barrow's Goldeneyes for the period 1999–2011 (Crewe et al. 2012).

Bufflehead

Buffleheads are widely distributed across most of the northern United States including Alaska, as well as in Canada from western Quebec to British Columbia, with higher densities in western North America. They winter along the entire ice-free portions of the Atlantic and Pacific coasts as well as inland waterways of the southern United States and Mexico. The best large-scale, consistent survey for Buffleheads in North America is the WBPHS. The timing of the WBPHS for Buffleheads is excellent (Smith 1995), and surveyed areas coincide well with their breeding range (Figure 1.4). In the midcontinent and Alaska survey areas, the trend since the early 1980s has been decidedly upward (Figure 1.8). CBC data show a steadily increasing trend continentally for Buffleheads since 1974 (Niven et al. 2004, National Audubon Society 2011). Data from the eastern area suggest a stable population since 1996 (Figure 1.8). The Eastern Waterfowl Survey shows highly variable numbers of Buffleheads with no obvious trend from 1990 to 2012 (Figure 1.10). Buffleheads have been stable in Puget Sound, Washington, from 1996 to 2013 (index = 50,000 birds, uncorrected for incomplete detection; J. R. Evenson, unpubl. data).

Mergansers

Mergansers are not identified to species during the WBPHS, but data for the generic merganser category represent some unknown proportion of Common Mergansers (*Mergus merganser*) and Red-breasted Mergansers (*M. serrator*); both species occur in surveyed areas and their ranges overlap (Figure 1.4). Hooded Mergansers are included in the merganser category, but few are counted because they are difficult to detect in the wooded habitats where they occur during the breeding season. The midcontinent and Alaska region of the WBPHS shows an increasing trend from the early 1970s to mid-1980s, with relatively stable populations since then (Figure 1.8). In the east, the WBPHS shows no trend since 1996 (Figure 1.8).

Common Merganser

Common Mergansers breed in forested areas across North America from interior Alaska to Newfoundland, south to the New England and upper Great Lake states, and most of the northwestern states. The species winters widely across the western, central, and northeast United States, mostly in freshwater environments. CBC data show a steadily increasing trend for Common Mergansers continentally since 1974 (Niven et al. 2004, National Audubon Society 2011). The Eastern Waterfowl Survey shows highly variable numbers with no obvious trend from 1990 to 2012 (Figure 1.10). In the Strait of Georgia, British Columbia, shore-based winter waterbird surveys indicated no trend in Common Mergansers over the 1999–2011 period (Crewe et al. 2012).

Red-breasted Merganser

Red-breasted Mergansers (*M. serrator*) breed across the subarctic and arctic regions of Alaska and Canada, and as far south as the Great Lakes in eastern North America, and winter primarily along the Atlantic and Pacific coasts and Great Lakes. Based on CBC data, Red-breasted Mergansers have been stable since 1974 on a continental scale (Niven et al. 2004, National Audubon Society 2011). Numbers of Red-breasted Mergansers in the Eastern Waterfowl Survey are highly variable with no obvious trend from 1990 to 2012 (Figure 1.10). Shore-based winter waterbird surveys in the Strait of Georgia, British Columbia, indicated no trend in Red-breasted Mergansers over the 1999–2011 period (Crewe et al. 2012).

Hooded Merganser

Hooded Mergansers have two largely disjunct breeding regions in North America; one includes nearly all of the eastern US and southeastern Canadian provinces, with another segment centered in the Pacific northwestern states and British Columbia. Primary wintering areas include the southeastern United States and coastal areas from Texas to the New England states, as well as coastal British Columbia and Pacific northwestern states. CBC data suggest that Hooded Mergansers have steadily increased in both eastern and western North America since 1974 (National Audubon Society 2011). In Eastern Canada, the Eastern Waterfowl Survey shows increasing numbers from 1990 to 2012 (Figure 1.10).

DISCUSSION

Existing waterfowl surveys provide limited information to estimate abundance, relative densities, and population trends for many species of sea ducks. There is an urgent need for surveys that will provide accurate indices of population size for long-term monitoring and robust detection of trends for all sea ducks. To be most useful, new surveys must cover appropriate geographical areas, be properly timed, and address the particular methodological challenges of enumerating sea ducks.

The full extent of breeding, wintering, molting, and staging areas remains to be described for many species, and current monitoring efforts focus on reconnaissance surveys to fill geographic gaps in our knowledge of seasonal distribution (Sea Duck Joint Venture 2013). Information from these surveys can be complemented by data from birds outfitted with satellite transmitters, which provide valuable insights on areas missed by reconnaissance work, the timing of breeding and migration, annual site fidelity, and the identity of regionally distinct subpopulations (Sea Duck Joint Venture 2012). Such information will allow waterfowl managers to design appropriately scaled and timed surveys for sea ducks and possibly identify areas that could provide indices representative of larger continental populations.

Effective sea duck surveys must address the particular challenges that sea ducks pose during enumeration. Three groups of sea ducks are especially prone to misidentification: scoters (Black, Surf, and White-winged), goldeneyes (Common and Barrow's), and the two large merganser species (Common and Red-breasted). These species are often identified only to genus, and even species-specific counts may not reflect the true composition of the community if the probability of correct identification varies among species. There are also identification problems among the black and white species that include goldeneyes, mergansers, Buffleheads, and sometimes also scaup and Ring-necked Ducks (*Aythya collaris*). Species misidentification and identification to genera complicate detection estimation and can lead to biased population estimates.

Sea ducks are also regularly found in large mixed species flocks during the nonbreeding season (Silverman et al. 2013) and are observed in multispecies groups more commonly than other waterfowl during breeding surveys (S. G. Gilliland, pers. comm.). Large aggregations introduce counting errors and the potential for bias (Bordage et al. 1998), which may be compounded when similar species co-occur.

One approach to addressing these challenges is to ensure observers are well trained in sea duck identification and practiced in counting large groups. Rigorous presurvey training and the dissemination of an appropriate aerial field guide and other training materials would reduce errors and help to standardize survey counts. When possible, presurvey training should include simultaneous aerial photography and visual observations to provide feedback to observers and help correct misidentification problems and adjust count biases. High-definition photography could also be employed on surveys as a means of sampling for species composition and for enumerating birds in large flocks. Aerial photography can also aid in the development of detection corrections, possibly including availability bias. More work using double-observer and distance sampling methods will also improve our ability to estimate detection probabilities and understand the factors that affect detection.

Despite the limitations of many surveys for monitoring sea ducks, some general trends across species are notable. In particular, some species that exhibited declines throughout the 1980s and 1990s (scoters, Long-tailed Ducks, some eider populations) appear to have stabilized or increased in recent years, albeit below historic levels. While this is encouraging, the factors driving population dynamics are still unknown for most species. Recent research suggests that sea ducks may be responding to changes in the ocean environment (Zipkin et al. 2010, Flint 2013), with survey counts correlating with major decadal shifts in the Pacific marine environment (Flint 2013). Notably, many of the species we classify as stable to increasing in recent years, including Spectacled Eiders, western King Eiders, Pacific Common Eiders, Pacific Black Scoters, and Long-tailed Ducks, are the more marine-dependent species of Mergini and inhabit the North Pacific and Bering Sea (Table 1.1).

A decade ago, available evidence suggested that 10 of 15 species of sea ducks in North America were declining (Sea Duck Joint Venture Management Board 2008). The situation appears more optimistic today. Population trajectories appear to be stable or increasing for 11 of the 22 sea duck populations recognized by the Sea Duck Joint Venture, and only 2 populations appear to be declining (Table 1.1). Data are insufficient or lacking for the other nine populations. That said, characterizations of trends for several populations are based on data that are less than robust, and some species are currently at levels below numbers observed in the most recent two to four decades.

There is growing interest in using population indices to better assess and inform harvest management and to focus habitat conservation efforts on areas of greatest importance to sea ducks (see Chapter 14, this volume). Accurate estimates of sea duck population trends would improve managers' ability to make decisions about these and other conservation priorities. Until management agencies in the United States and Canada devote greater resources to monitoring sea ducks, conservation efforts will be hampered by the lack of reliable data. Monitoring surveys also need to be complimented by other data sources. Additional sea duck banding, where practical, along with continued studies involving satellite telemetry, genetics (Sonsthagen et al. 2011; Chapter 2, this volume), and stable isotope techniques (Mehl et al. 2004, 2005), should be encouraged to better delineate populations and support the development of robust monitoring programs. Considering the increasing impact of humans on northern sea duck habitats, including expansion of resource development in boreal forest and arctic marine areas, increased shipping of materials including oil, and large-scale oceanic changes due to global warming (Caldeira and Wickett 2003; Descamps et al. 2011, 2012; Benoit 2012; Chapter 14, this

TABLE 1.1

Summary of contemporary (10–20 Years) population status and trends for North American sea ducks.

Species	Recent trend	Status relative to historical levels	Confidence in trend
Bufflehead	Stable to increasing	Above	High
Hooded Merganser	Stable to increasing	Above	High
Common Goldeneye	Stable to increasing	Above	Medium
Common Merganser	Stable to increasing	Above	Medium
Red-breasted Merganser	Stable to increasing	Above	Medium
Spectacled Eider	Stable to increasing	Below	High
Pacific Black Scoter	Stable to increasing	Below	Medium
Western King Eider	Stable to increasing	Below	Low
Long-tailed Duck	Stable to increasing	Below	Low
Eastern Harlequin Duck	Stable to increasing	Unknown	High
Eastern Barrow's Goldeneye	Stable	Unknown	Low
Steller's Eider	Decline	Below	Medium
American Common Eider	Decline	Below	Low
Surf Scoter	Unknown	Below	
White-winged Scoter	Unknown	Below	
Eastern King Eider	Unknown	Unknown	
Hudson Bay Common Eider	Unknown	Unknown	
Northern Common Eider	Unknown	Unknown	
Pacific Common Eider	Unknown	Unknown	
Atlantic Black Scoter	Unknown	Unknown	
Western Harlequin Duck	Unknown	Unknown	
Pacific Barrow's Goldeneye	Unknown	Unknown	

volume), it is becoming ever more important to accurately determine sea duck abundance and distribution and establish long-term monitoring programs, particularly for boreal and arctic species including eiders, scoters, and Long-tailed Ducks.

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CHAPTER TWO

Phylogenetics, Phylogeography, and Population Genetics of North American Sea Ducks (Tribe: Mergini)*

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Abstract. Many environments occupied by North American sea ducks are remote and difficult to access, and as a result, detailed information about life history characteristics that drive population dynamics within and across species is limited. Nevertheless, progress on this front during the past several decades has benefited by the application of genetic technologies, and for several species, these technologies have allowed for concomitant tracking of population trends and genetic diversity, delineation of populations, assessment of gene flow among metapopulations, and understanding of migratory connectivity between breeding and wintering grounds. This chapter provides an overview of phylogenetic, phylogeographic, and population genetics studies of North American sea duck species, many of which have sought to understand the major and minor genetic divisions within and among sea duck species, and most of which have been conducted with the understanding that the maintenance of genetic variation in wild sea duck populations is fundamental to the group's long-term persistence.

Key Words: fossil, genetic, glacial refugia, molecular ecology, phylogenetic, phylogeography, taxonomy, systematics.

The maintenance of genetic variation in wild populations of Arctic, subarctic, and temperate species, including sea ducks, is fundamental to the long-term persistence of regional biodiversity. Variability provides opportunities for species to respond to novel challenges, such as changing environmental conditions and emerging pathogens. When individual species decline in abundance and their geographic distributions contract, genetic variability can also erode. However, we have not yet developed a clear understanding of how genetic variability is spatially and temporally distributed, particularly in Arctic and subarctic regions of North America, which provides breeding and in some cases wintering habitat for 15 extant sea duck species. Further, we lack understanding about how genetic variation, and therefore evolutionary potential, is generated and maintained for most high-latitude species. The advent of new technologies and analytical approaches now provides opportunities to generate more comprehensive views of genetic variation and can provide the necessary foundation for diverse theoretical and applied endeavors,

* Talbot, S. L., S. A. Sonsthagen, J. M. Pearce, and K. T. Scribner. 2015. Phylogenetics, phylogeography, and population genetics of North American sea ducks (Tribe: Mergini). Pp. 29–61 in J.-P. L. Savard, D. V. Derksen, D. Esler, and J. M. Eadie (editors). Ecology and conservation of North American sea ducks. Studies in Avian Biology (no. 46), CRC Press, Boca Raton, FL.

BOX 2.1

Systematics integrates across all other subdisciplines within the biological sciences by charting the evolutionary record necessary to discover, categorize, and interpret biodiversity. Without this foundation, we cannot ask pertinent questions related to species and their evolutionary responses. Excluding the more charismatic species, our knowledge of the systematics of the vast majority of Arctic and subarctic organisms, including sea ducks, remains meager. Within systematics, two particular disciplines are closely interlinked: *phylogenetics* (the study of evolutionary relationships) and *taxonomy* (the generation of a standard nomenclature). Concurrently, knowledge emerging from these two disciplines contributes to the broader issues of viability, sustainability, and availability of critical biotic diversity. Therefore, systematics is an integral feature informing the management and conservation of Arctic species (Kutz et al. 2009), including sea ducks.

Phylogenetics is the study of the evolutionary relationships among various groups of organisms, based on evolutionary similarities and differences in existing characteristics. Above the level of populations, phylogenetics becomes a history of speciation, with species regarded as independent lineages. Phylogenetic trees reconstruct history and constrain explanations about the emergence and distribution of biodiversity. *Taxonomy* is the theory and practice of classifying organisms (Mayr 1969). While early taxonomic studies relied almost exclusively on morphological variation, in recent decades, diversity has been queried using genetics techniques, which have provided increasingly refined views of geographic variation. Classification systems provided by taxonomy are foundational for efficient funding prioritization as well as rigorous project design. A poorly developed taxonomic framework can have serious negative conservation consequences (Mace 2004). When a taxonomic framework accurately reflects evolutionary relationships among organisms, the taxonomy provides more than a universally accepted name or common language for scientists and managers. By presenting the species' history, systematic and taxonomic research generates direct connections linking ecology, evolution, and biogeography, affording a predictive framework within which to investigate and identify emerging risks such as hybridization and disease (Schrag and Wiener 1995, Brooks and Hoberg 2006, Seehausen et al. 2007).

ranging in this case from recovering the history of diversification and extinction of sea ducks to developing robust projections for the long-term persistence of sea ducks in North America.

This chapter provides an overview of the systematic studies of North American sea ducks, including phylogenetic, phylogeographic, and population genetics relationships. We emphasize that an understanding of how genetic diversity is shaped in deeper evolutionary time is essential to predicting future responses and persistence of sea ducks in high-latitude habitats (Box 2.1).

SYSTEMATICS, TAXONOMY, AND PHYLOGENETIC RELATIONSHIPS IN MERGINI

The fossil record of waterfowl is more complete than many other avian families (Olson and Feduccia 1980, Box 2.2), leading to paleontological reconstructions that placed a major radiation of the waterfowl within the last 60 million years (Delacour and Mayr 1945, Olson and Feduccia 1980). Delacour and Mayr (1945) considered the sea ducks, tribe Mergini, to have emerged after tribe Oxyurini, the Stiff-tailed Ducks, sharing most common ancestry with members of the tribe Cairinini (or Cairininae), the perching ducks (Figure 2.1), although taxonomists disagree over the classification within Cairinini (Johnsgard 2010). Given the largely northern hemisphere origin of Mergini, Howard (1964) and Weller (1964) proposed a northern hemisphere origin for the tribe.

Sea ducks are generally considered to comprise up to 20 extant species worldwide (Delacour and Mayr 1945, Johnsgard 1975, Livezey 1995), largely distributed across northern hemisphere habitats, including six mergansers (*Lophodytes cucullatus*, *Mergellus albellus*, *Mergus merganser*, *M. serrator*, *M. squamatus*, and *M. octosetaceus*, the sole species

BOX 2.2

Paleontology. New paleontological findings continue to provide insight into the evolution of sea ducks and factors contributing to their population demography and, sometimes, extinction. For example, the goose-sized, flightless sea duck, *Chendytes lawi*, thought to be most closely related to the eiders (*Somateria*; Mosimann and Martin 1975) and once common off the California coast, was once thought to have gone extinct at the Pleistocene/Holocene transition. However, its survival well into the Holocene was verified in 1976 when bones attributed to *C. lawi*, Carbon dated (^{14}C) to between 5,400 and 3,800 ybp, were found in archaeological sites north of Santa Cruz (Morejohn 1976). Morejohn (1976) speculated the species bred on offshore islands, providing immunity to predation by humans, and this was confirmed by Guthrie (1992), who reported immature individuals and egg shells found in late Pleistocene sites on San Miguel Island, one of the Channel Islands. Morejohn (1976) and others (Jones et al. 2008) suggest that *C. lawi* became extinct between 3,000 and 2,200 ybp. Extinction corresponded to the development of watercraft by native Californians that increased efficiency in accessing remote islands, islets, and offshore rocks used as breeding colonies by the birds (Steadman and Martin 1984). Jones et al. (2008) proposed that *C. lawi* was hunted by humans for at least 8,000 years before it was driven to extinction.

distributed only in the southern hemisphere), five or six scoters (*Melanitta nigra*, *M. americana*, *M. perspicillata*, *M. fusca*, *M. deglandi*, and *M. stejnegeri*), four eiders (*Somateria mollissima*, *S. spectabilis*, *S. fischeri*, and *Polysticta stelleri*), two goldeneyes and Bufflehead (*Bucephala clangula*, *B. islandica*, and *B. albeola*), the Harlequin Duck (*Histrionicus histrionicus*), and the Long-tailed Duck (*Clangula hyemalis*). Some researchers (Livezey 1995) elevate some or all of the four to seven subspecies of Common Eider (*S. mollissima mollissima*, *S. m. faeroeensis*, *S. m. islandica*, *S. m. borealis*, *S. m. sedentaria*, *S. m. dresseri*, and *S. m. v-nigrum*) into

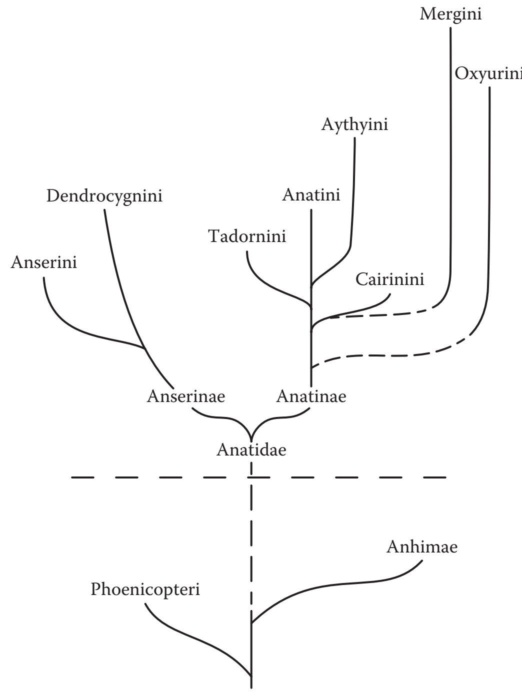

Figure 2.1. Hypothesized relationships among subfamilies and tribes of the Anatidae. (After Delacour and Mayr 1945.)

a species complex, *S. mollissima*-gp. Likewise, the Palearctic *M. nigra* and the Nearctic *M. americana* are sometimes grouped into a single Black Scoter complex (*Melanitta nigra*-gp.) and *M. fusca* and *M. deglandi* into a White-winged Scoter complex (*M. fusca*-gp.). The recently extinct Mergini include the enigmatic Labrador Duck (*Camptorhynchus labradorius*) and the Auckland Islands Merganser (*Mergus australis*), both of which went extinct sometime during the nineteenth- and twentieth-century transition (Hahn 1963). Of the extant species, 15 occupy habitats in North America.

Morphology and Behavior

In the 10th edition of *Systema Naturae*, Linnaeus (1758) divided the class Aves into six orders—Accipitres, Picae, Anseres, Grallae (Scolopaces in previous editions), Gallinae, and Passeres, based largely on morphological characteristics, heavily emphasizing bill and foot characteristics. His third order, Anseres, comprised 11 genera largely made up of web-footed, short-legged waterbirds: *Anas*, *Mergus*, *Procellaria*, *Diomedea*, *Pelecanus*, *Phaeton*, *Alca*, *Colymbus*, *Larus*, *Sterna*, and *Rynchops*. In the Linnaean arrangement, waterfowl comprised *Anas* (within which 39 species were recognized) and *Mergus* (within which 5 species were recognized). Waterfowl (*Anas* and *Mergus*) were not segregated into distinct subcategories. Within *Anas*, which included 13 sea ducks, four groups were identified according to certain morphological characters: (1) bill gibbous (with bulbous protuberances at the base), (2) bill equal at base, (3) certain feathers recurved, or (4) crested. Under Linnaeus' schema, White-winged Scoter (*M. fusca*), Black Scoter (*M. nigra*), and King Eider (*S. spectabilis*) are placed in the first group within *Anas* and Surf Scoter (*M. perspicillata*) and Common Eider in the second group. *Mergus* included only mergansers. Contemporaneous eighteenth-century and subsequent nineteenth-century taxonomic treatments of waterfowl provided diverse groupings of sea ducks (Illiger 1811, Cuvier 1817, Vigors 1825) often retaining the mergansers within a group separated from the remainder of the sea duck species. Cuvier (1817) grouped the Macreuses (scoters), Garrots (goldeneyes, Harlequin and Long-tailed Ducks), eiders, and Milloiuns (pochards) into a duck subgenus. Recognizing that variations in the trachea and syrinx of avian species, which are greatly simplified in waterfowl (Johnsgard 1961), can provide a means to judge taxonomic relationships, Yarrell (1827) examined tracheal characteristics and linked the true ducks (including species within the genera *Tadorna* [shelducks] and *Anas* [gadwalls, shovelers, Garganey, teal]) to the Harlequin Duck, Long-tailed Duck, and goldeneyes via eiders and scoters. Yarrell (1827) also noted similarities between the mergansers and goldeneyes based on sternum and stomach as well as trachea.

Twentieth-century taxonomists continued to revise earlier taxonomies. In their revision of the classification of Anatidae, Delacour and Mayr (1945) erected the tribe Mergini, separating the pochards (*Netta* and *Aythya*) from the remaining diving ducks and merging the mergansers (*Mergus*, *Mergellus*, and *Lophodytes*) and the goldeneyes (*Bucephala*) with the other sea ducks into a monophyletic group (Figure 2.1). Mergini was characterized by the following life history and ecological characteristics: (1) a sea-dwelling habit and feeding primarily on animal food obtained during diving; (2) strong, hooked bills; (3) moderately heavy wing loading and rapid flight; (4) brightly colored eclipse plumage in males, with metallic coloration generally restricted to the head region; (5) sexual maturity at 2–3 years of age; (6) elaborate displays in males; (7) largely northern distribution; and (8) bold gray and white patterning with distinctive capped head appearance in downy young. Delacour and Mayr (1945) considered perching ducks (Cairinini) to be Mergini's closest relatives, based on similarities in nesting habits and tail morphology, although Johnsgard (1960a) noted differences between the Cairinini and Mergini with respect to behavior, characteristics of downy young, and ability to hybridize.

Although previous to their treatment, eiders were placed with scoters, goldeneyes, and other diving ducks, Delacour and Mayr (1945) gave only provisional assignment of eiders to Mergini, citing differences in eider tracheal anatomy and appearance of downy young. In-depth studies of tracheal anatomy, however, led Humphrey (1955, 1958) to conclude that Mergini comprises two unrelated groups of birds, of which some members independently evolved similar diving adaptations. His research suggested that the eiders and Harlequin Duck shared common, uniform features in tracheal anatomy, whereas the remainder of the tribe possessed variable tracheas, ranging from rudimentary (scoters) to more complex shapes with membranaceous fenestrae (the remainder of the tribe). Humphrey (1955, 1958) supported the placement of eiders into a separate tribe (Somateriini) more closely allied to the Anatini than the remainder of Mergini, largely based on tracheal structure of male eiders, plumage patterns of females, coloration of downy young, food habits, and foraging behavior of eider ducks. Subsequent studies of female courtship and copulatory behavior in 11 of the 18 existing species of Mergini led Myres (1959) to reject Humphrey's hypothesis of a close relationship between eiders and the Anatini. To date, however, investigators have largely agreed with the *Bucephala*–*Mergus* assemblage and the composition of the tribe Mergini (Livezey 1995), but within-tribe relationships continue to be debated. For example, relationships between eiders and the rest of Mergini (Humphrey 1955, 1958; Delacour 1969; Cramp and Simmons 1977), and the placement of Harlequin Duck and Smew (*M. albellus*) within the tribe, remained unresolved. There is also disagreement regarding the separation of Mergini from other diving ducks (Phillips 1925, 1926; Peters 1931; Livezey 1995) and the perching ducks (Cairinini, Delacour and Mayr 1945, Johnsgard 1960b).

Livezey (1995) performed cladistics analysis of 137 morphological characters (skeletal, tracheal, and natal and definitive plumage) across 25 sea duck lineages to assess phylogenetic relationships within Mergini. To polarize characters and assess intertribal relationships, he also included data from several species of Anatini, Oxyurini, and Aythyini. His analyses are as follows: (1) Eiders (*Polysticta* and *Somateria*) are placed into a monophyletic group that is sister to all other Mergini and (2) *Somateria* is placed as monophyletic, with Spectacled Eider, *S. fischeri*, as the basal taxon of the congeners and Steller's Eider, *P. stelleri*, as basal in the eider clade. Among the non-eider clades, (3) Harlequin Ducks are placed closest to the eider group, followed (in order of descending relationship from eiders) by *Melanitta* and the extinct *Camptorhynchus*, *Clangula*, *Bucephala* and *Mergellus*, *Lophodytes*, and *Mergus*; (4) Black Scoters (here, *M. nigra* and *M. americana*) comprise the sister group of the other scoters; (5) Buffleheads (*B. albeola*) are the sister group to the goldeneyes, and (6) *Lophodytes* (Hooded Merganser, *L. cucullata*) is the sister group to the *Mergus*; and (7) Smew are placed with the goldeneyes. Livezey (1995) suggested that among attributes characterizing sea ducks, the clearest patterns include primary preference for nest site (selection for terrestrial nest sites considered a primitive character, with preference for nest cavities in goldeneyes and mergansers considered a derived character), frequency of semicolonial nesting, and method of diving, followed by variation in clutch size and relative clutch mass, sexual size dimorphism, and frequency of interspecific brood parasitism. Moderate phylogenetic constraint was observed in the attributes of sexual dichromatism and migratory habit.

Molecular

Phylogenetic studies of sea ducks based on molecular data are still few and typically do not include all species comprising Mergini. The composition of integumental lipids suggested moderate distance between Common Eider and other genera comprising Mergini (Jacob and Glaser 1975, Jacob 1982), and feather proteins differentiated eiders from the rest of the Mergini (Brush 1976). Analyses of 13 proteins suggested a separation of *Bucephala* from *Melanitta* and *Clangula* (Patton and Avise 1986), but analyses of 25 presumptive protein loci of 40 waterfowl species, including 12 species of sea duck, separated Black Scoters from the other *Melanitta* (White-winged and Surf Scoter) and grouped them with the Long-tailed Duck in an ancestral position relative to the remainder of Mergini (Oates and Principato 1994). The Wagner distance phenogram also placed *Histrionicus* with *Lophodytes* (Oates and Principato 1994). DNA hybridization studies conducted in the late 1980s (Madsen et al. 1988, Sibley and Ahlquist 1990, Sibley and Monroe 1990) precluded insights into intratribe relationships, as only a single member of Mergini (*Melanitta*) was included. Donne-Goussé et al. (2002) analyzed sequence data from the mitochondrial genome in 45 waterfowl species representing 24 waterfowl genera to infer phylogenetic relationships among Anseriformes and included six sea duck species (Black Scoter, Smew, Hooded Merganser, Red-breasted Merganser [*M. serrator*], Long-tailed Duck, and Common Eider). Their analyses placed these representatives of Mergini, as well as, surprisingly, *Callonetta leucophrys* (Ringed Teal; sometimes placed with the dabbling ducks but of unresolved phylogenetic relationship; Bulgarella et al. 2010), within a single clade that was sister to a clade comprising Cairinini, Anatini, and Aythyini. The mergansers, including *Mergellus*, were placed in a monophyletic clade, and *Somateria* was placed close to *Clangula* within the Mergini clade.

Gonzalez et al. (2009) included 12 species of sea duck in a phylogenetic analysis of Anatidae, based on mitochondrial DNA (mtDNA) cytochrome *b* and ND2 genes; their analysis also placed Mergini in a single clade, sister to the Aythyini and Anatini, with Cairinini (represented by *Aix sponsa*, *A. galericulata*, and *Cairina moschata*) sister to Tadornini. *Clangula* is placed as the basal species in the monophyletic clade Mergini. The two eider species analyzed (Common and King Eiders) were placed within a single clade sister to a clade comprising scoters, goldeneyes, and mergansers. *Callonetta* did not group with Mergini in this analysis. Solovyeva and Pearce (2011) and Liu et al. (2012) also used mtDNA control region and cytochrome *b* sequences to examine phylogenetic relationships among several mergansers. Solovyeva and Pearce (2011) analyzed data from Common Mergansers (*M. merganser*) from North America and Europe/Russia and Hooded, Red-breasted, and Scaly-sided Mergansers; their analyses placed Red-breasted and Hooded Mergansers in a single clade. This classification differed from Liu et al. (2012), who placed Common

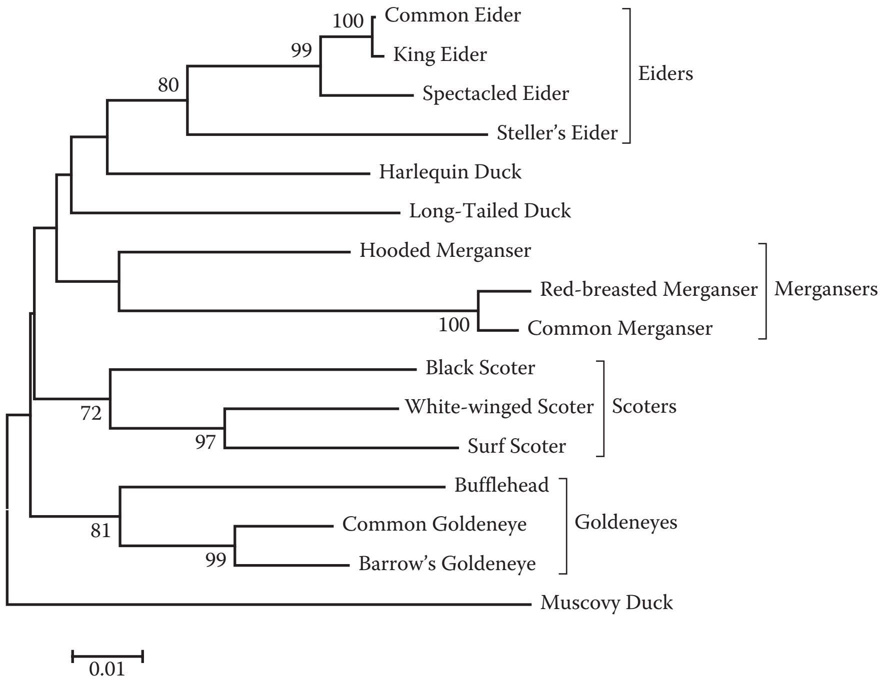

Figure 2.2. Phylogenetic reconstruction of all 15 North American sea duck species assayed from 549 bp of mtDNA cytochrome *b* sequence, using a minimum evolution distance approach. Bootstrap support values are provided at relevant nodes (>70% support).

and Red-breasted Mergansers in a single clade, sister to a clade comprising Smew and Hooded Mergansers, concluding that both *Lophodytes* and *Mergellus* belong within *Mergus*.

In an effort to provide a more comprehensive evaluation of the evolutionary relationships among the 15 extant North American sea duck species, we obtained sequence data from 549 base pairs of the mtDNA cytochrome *b* gene and used the distance approach to generate a phylogenetic tree, following methods similar to those outlined in Pearce et al. (2004). Unfortunately, the phylogenetic reconstructions failed to resolve intragenera relationships, with most nodes receiving <70% bootstrap support (Figure 2.2). *Somateria* eiders comprised a single clade that was sister to Steller's Eider. Buffleheads were basal to Common (*B. clangula*) and Barrow's Goldeneyes (*B. islandica*), and Black Scoter was basal to White-winged and Surf Scoters. The scoters and mergansers both formed monophyletic clades. However, the relationships of the Harlequin Duck and Long-tailed Duck, relative to the other sea duck species, remain unresolved. Additional data are needed to provide sufficient resolution to infer higher-level phylogenetic relationships within Mergini. We suggest that future assessments that query the mitochondrial genome apply whole mitogenomic data to the question of Mergini phylogeny to provide greater resolution. Further, whole genomic (or reduced representational genomic) next-generation sequencing technologies, which simultaneously generate whole mitogenomes, are becoming increasingly affordable for nonmodel organisms (Miller et al. 2012), and application of these technologies to generate a wide range of markers (mtDNA, autosomal, and sex linked) to phylogenetic investigations of sea ducks will likely clarify a number of these unresolved relationships.

PHYLOGEOGRAPHY OF NORTH AMERICAN SEA DUCKS

General Genetic Patterns

The application of comparative population genetic approaches to the examination of multiple and widespread species can be used to determine whether each taxon has been similarly influenced by historical isolating mechanisms

BOX 2.3

Phylogeography. Phylogeography, the assessment of the spatial distribution of genealogical lineages within species (Avise 2000, Knowles 2009, Hickerson et al. 2010), bridges phylogenetic (macroevolution) and population genetic (microevolution) analyses (see Box 2.1). Phylogeography employs our ability to generate DNA data from individuals across multiple species and ranges, allowing us to acquire fundamental insights about evolutionary origins, concordant genetic patterns of different species within a single ecosystem, location of refugia, historical demography, biogeographic barriers, temporal niche conservatism, and evolutionarily significant units (ESUs). Deep knowledge of such biotic and abiotic attributes will ultimately facilitate better predictions about the range of future responses of species, such as sea ducks.

(Avise 2000). Recent comparative population genetic studies of avian species have led to several general conclusions: (1) sympatric taxa distributed across similar regions exhibit a range of phylogeographic patterns (Zink et al. 2001, Qu et al. 2010, Humphries and Winker 2011) and (2) levels of population genetic structure are not necessarily correlated with taxonomic similarity; that is, closely related taxa do not always share similar phylogeographic patterns or levels of genetic diversity and gene flow among populations (Gómez-Diaz et al. 2006, Friesen et al. 2007). Thus, comparisons among species can aid in the identification of isolating barriers (Klicka et al. 2011) and their demographic impacts on populations (Hewitt 2000, Hansson et al. 2008). Genetic information can also be used to infer aspects of species biology, such as flexibility of life history traits, and thus the response to past and future changes in climate (Qu et al. 2010). Studies that investigate phylogeographic relationships using both mitochondrial and nuclear markers, which differ in mode and tempo of inheritance, can also uncover sex-biased life history characteristics, such as dispersal and philopatry (Scribner et al. 2001, Sonsthagen et al. 2011, Peters et al. 2012).

Assessments of neutral genetic variation within North American sea duck species, based on data from both the mtDNA and neutral nuclear markers, have been reported for all the eiders (Scribner et al. 2001; Pearce et al. 2004, 2005b; McKinnon et al. 2006; Sonsthagen et al. 2007, 2009, 2010, 2011, 2013), Harlequin Duck (Lanctot et al. 1999), Long-tailed Duck (Humphries and Winker 2011), and mergansers (Pearce 2008; Pearce et al. 2008, 2009b; Fishman 2010; Solovyeva and Pearce 2011; Peters et al. 2012). Additionally, genetic assessments have been made based on a single mtDNA locus for Red-breasted Mergansers (Pearce et al. 2009a), Buffleheads and goldeneyes (Pearce et al. 2014). No comprehensive molecular-based comparative phylogeographic studies including all North American species within Mergini have been published. Nevertheless, three general patterns have emerged from these single-species or group studies.

Genetic analyses of Steller's, Spectacled, and King Eiders (Scribner et al. 2001; Pearce et al. 2004, 2005b) occupying ice-dominated western and eastern Beringian habitats and in some cases high-latitude habitats in Canada reflect a signal of high variability but low to absent population structuring, particularly at the nuclear genome (Figure 2.2). This pattern is observed also in other highly migratory high-latitude vertebrate species (Dalén et al. 2005; Sonsthagen et al. 2012a; E. Peacock et al., U.S. Geological Survey, unpubl. data), in Beringian scoters (S. L. Talbot and J. M. Pearce, U.S. Geological Survey, unpubl. data) and Long-tailed Ducks (Humphries and Winker 2011; R. E. Wilson et al., U.S. Geological Survey, unpubl. data). Exceptions to this general observation include Common Eiders, which show high levels of population structuring relative to the other eiders (Tiedemann et al. 2004, Sonsthagen et al. 2011).

A second pattern, largely associated with high-latitude boreal nesting sea ducks, is a disjunct North American distribution observed for lineages within some species, including Harlequin Ducks (Scribner et al. 1998) and possibly White-winged Scoters (S. L. Talbot, unpubl. data). This east–west disjunct has been observed in other avian species, including forest obligate accipiters (Hull and Girman 2005, Sonsthagen et al. 2012b, Bayard de Volo et al. 2013). In the Sharp-shinned Hawk (*Accipiter striatus*), this pattern has been attributed to westward expansion following the expansion

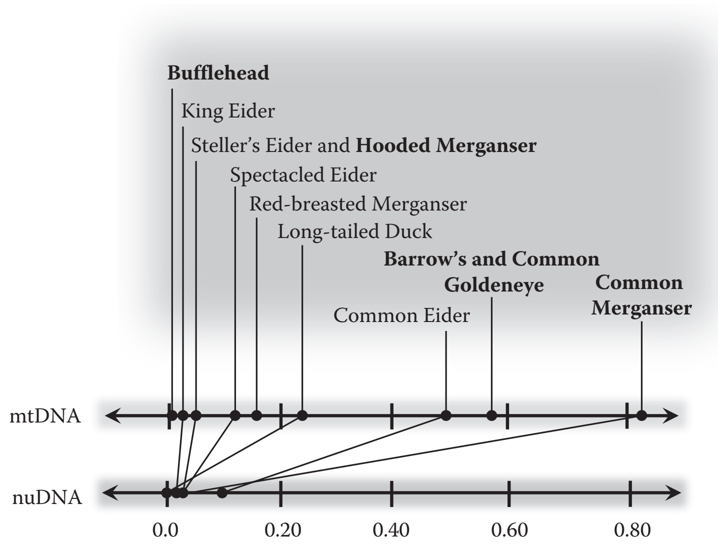

Figure 2.3. Estimates of genetic differentiation for 11 sea duck species, as measured by F_{ST} from large geographic scale studies in North America. Cavity-nesting species are shown in bold. For six species, both mitochondrial (mt) and nuclear (nu) DNA results are shown to illustrate the lower levels of population differentiation observed with nuDNA markers in sea duck species. From left to right, species names represent results from Bufflehead (Pearce et al. 2014), King Eider (Pearce et al. 2004), Steller's Eider (Pearce et al. 2005b), Hooded Merganser (Pearce et al. 2008), Spectacled Eider (Scribner et al. 2001), Red-breasted Merganser (Pearce et al. 2009b), Long-tailed Duck (R. E. Wilson et al., U.S. Geological Survey, unpubl. data), Common Eider (Sonsthagen et al. 2011), Barrow's Goldeneye (Pearce et al. 2014), Common Goldeneye (Pearce et al. 2014), and Common Merganser (Pearce et al. 2009a, b). Studies with $F_{ST} > 0.2$ represent cases of significant population structuring (Category II from Avise 2000). For mtDNA, values are based on control region sequences except for King Eider and Steller's Eider, which are from cytochrome *b*. (Adapted from Pearce et al. 2014.)

of forest during the Holocene Thermal Optimum (or Hypsithermal; Hull and Girman 2005), although this explanation does not explain the pattern in at least one sea duck species, the Harlequin Duck (S. L. Talbot et al., unpubl. data).

A third pattern is associated with cavity nesters. Larger-bodied, cavity-nesting waterfowl species apparently exhibit greater levels of population differentiation than smaller-bodied congeners (Pearce et al. 2014; Figure 2.3). Seven sea ducks are either obligate or semi-obligate cavity-nesting species and all are secondary cavity nesters, relying upon naturally occurring cavities from tree decay and breakage or on excavator species that create holes into trees. Nest-box studies of cavity-nesting sea ducks (Gauthier 1990, 1993; Eadie et al. 1995, 2000) have documented high levels of nest (breeding) site fidelity, a possible indicator of population structure if accompanied by philopatric behavior. However, patterns of fidelity may be driven by variables other than cavity availability, such as competition, food requirements, brood habitat, and body size (Boyd et al. 2009). For example, despite high levels of breeding site fidelity, Pearce et al. (2008) found little evidence for population genetic structure in Hooded Mergansers, which likely are not limited by nest cavity availability (Denton et al. 2012). In contrast, another cavity-nesting sea duck, the Common Merganser, exhibited a high degree of population genetic structure across North America (Figure 2.3). These findings led to the hypothesis that population structure among cavity-nesting ducks could be influenced by body size and cavity competition (Pearce et al. 2009b). Among cavity-nesting species of waterfowl, Common Mergansers have the largest body size, requiring larger cavities that may be rare in some forested landscapes (Vaillancourt et al. 2009). As a result, Common Mergansers may exhibit greater fidelity and population structure than smaller-bodied congeners such as the Hooded Merganser. Thus, there may be a positive relationship between body size and level of population structure among cavity-nesting waterfowl due to the greater abundance of smaller cavities and rarity of large cavities. Consistent with this prediction was the finding that Buffleheads, the smallest cavity-nesting species, exhibited the lowest level of population differentiation relative to intermediate-sized Barrow's and Common Goldeneyes (Pearce et al. 2014).

Impact of Historical Climate Change on Genetic Structure

It is increasingly evident that environmental processes associated with Quaternary cycling have resulted in predictable sequences of diversification relative to geography (Avise 2000, Hewitt 2004). While species at lower latitudes experienced fragmentation and local population contraction/expansion through climate cycles, they did not drastically shift ranges. On the other hand, temperate and high-latitude species, including sea ducks, likely experienced range shifts that resulted in more shallow coalescent times due to recent speciation or a loss of historical diversity as glacial cycles wiped the genetic slate clean (Hewitt 1996). In general, vagile species may exhibit broad regional differentiation (Sonsthagen et al. 2012a), although some widespread vagile species, such as Common Eiders, still exhibit relatively fine-scaled phylogeographic structure (Sonsthagen et al. 2007, 2009, 2011, 2013). It is now well established that fluctuating climatic conditions associated with these Pleistocene glacial cycles (Hewitt 2004) greatly influenced the distribution of species in northern latitudes and their genetic diversity. Over 20 Pleistocene glacial cycles have been recorded (Williams et al. 1998), each resulting in major range shifts and fluctuations in population demography of northern latitude species. During glacial stadials, many high-latitude species apparently retracted to southern refugia, recolonizing northward following the retreat of the Laurentide and Cordilleran ice sheets in North America (Avise 2000), and the Fennoscandian ice sheet following climate amelioration in Europe (Hewitt 2001, Schmitt 2007). Nevertheless, much of Eastern Europe, Siberia, and North America remained virtually ice-free throughout these cycles, potentially providing refugia for tundra-obligate species (Hope et al. 2011), or ice-obligate species that occupy adjacent terrestrial habitats for a portion of their annual cycle. Beringia was a large refugium during glacial advances, and multiple species apparently recolonized the Arctic from Beringia after the ice sheets receded (Hultén 1937). However, Beringia was itself recolonized by species expanding out of glacial refugia, mostly from the south (Stewart et al. 2010), and thus this region, which spans eastern Russia, Alaska, and western Canada to the MacKenzie Highlands, may have played a central role in the diversification of populations of Arctic biota (Rand 1954, MacPherson 1965). The Bering Isthmus that connected Eurasia and North America during glacial periods facilitated transcontinental migration of plants and animals, homogenizing lineages there. Separation of Eurasia and North America by the Bering Strait is not generally reflected in genetic analyses, suggesting that this recurring barrier to terrestrial species dispersal (most recently formed 11,000 years ago) has imposed only minor influence on genetic structure or divergence within many free-living terrestrial organisms (Galbreath and Cook 2004).

There is also considerable evidence for additional high Arctic glacial refugia in North America, with divergent lineages and high genetic diversity observed in populations of a number of taxa occupying the high Canadian Arctic and Greenland (Tremblay and Schoen 1999, Abbott et al. 2000, Fedorov and Stenseth 2002, Waltari and Cook 2005). Refugia typically harbor divergent DNA lineages within species that reflect their long-term isolation (Fedorov et al. 2003), and expansion of populations from glacial refugia has left predictable genetic patterns in recently colonized regions (Lessa et al. 2003). Genetic data analyzed under the principles of the coalescent theory have enabled researchers to investigate historical species distribution and demography, aiding in the identification and location of glacial refugia (Lessa et al. 2003, Waltari and Cook 2005, Sonsthagen et al. 2011).

Based on current distribution of waterfowl species, Ploeger (1968) postulated the relative importance of these ice-free areas as potential refugia for Arctic waterfowl (Anatidae) during the last Pleistocene glacial period. Proposed high Arctic refugia that harbored migratory North American species include Beringia, the Canadian Arctic Archipelago, northern Greenland, Spitsbergen Bank near Svalbard, and northwest Norway. Proposed temperate refugia included Newfoundland, western Greenland, Iceland, and Western Europe. Convergence in genetic signatures of population expansion across multiple Arctic species has provided insights into