Confronting the

CHALLENGES OF CLIMATE CHANGE FOR WATERFOWL AND WETLANDS

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FOREWORD

This paper was prepared with support from the Bipartisan Policy Center and coordinated with the National Sportsman's Advisory Group on Climate Change, a joint venture of twelve sportsman and wildlife organizations that recognize the implications of global climate change for their members and the species and habitats they have successfully conserved for decades. Ducks Unlimited (DU) prepared this white paper summarizing new and traditional conservation approaches to address the impacts of climate change and variability on wetland ecosystems and waterfowl in North America. The content of this paper provides the basis for the Waterfowl Chapter in the book Beyond Season's End: A Path Forward for Fish and Wildlife in the Era of Climate Change published by the Bipartisan Policy Center in 2010. While the specific possible impacts of climate change on landscapes are unknown, a number of predicted scenarios would have far-reaching impacts on both waterfowl and hunters.

DU has a long history of wetland conservation in North America. Working with both private and public landowners, DU has protected, restored and/or managed over 12 million acres of important wildlife habitat. Historically, these landscapes have included the extensive Boreal Forests, vast grasslands of the Prairie Pothole Region, bottomland forests of the Mississippi Alluvial Valley, and Gulf Coast marshes. While these key waterfowl areas continue to be targeted by DU and other agencies and organizations, new conservation challenges from a changing climate are emerging. The potential consequences of climate change are significant, and we continue to take steps to apply climate change science in conservation planning efforts to help ensure the future of waterfowl and hunting traditions for generations to come.

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Ducks Unlimited Inc. is a private, non-profit organization dedicated to conserving wetland habitat for waterfowl and other wildlife and people.

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1. CLIMATE CHANGE IMPACTS ON WATERFOWL AND WETLANDS

1.1 Summary

The effects of climate change now underway have extensive potential to affect waterfowl throughout North America, either directly or indirectly through changing habitat conditions. When considered in combination with other pressures (e.g., habitat fragmentation, pollution, urbanization) the potential effect is even greater. Healthy duck populations and functioning wetlands can serve as barometers of healthy landscapes, highlighting the relationship between sustainable waterfowl populations and landscapes that support people, their quality of life, and their livelihood.

Several aspects of climate change will affect wetlands and the waterfowl that use them. An increase in carbon dioxide (CO2) will trap heat in the atmosphere causing a rise in air, water, and soil temperature -- including in wetlands, lakes, streams, rivers, estuaries, and oceans, which will present challenges to wetland plants and animals (Kusler 2006). Other factors include changes in precipitation and more intense weather events that affect wetland systems through heavy rainfall and erosion. Rising temperatures have reduced snow cover, mountain glaciers, and Arctic sea ice. Sea level rise resulting from thermal expansion of the oceans and freshwater input was 4.7 - 8.6 inches for the 20th century (IPCC 2007). Nighttime temperatures have increased more than daytime temperatures (thereby decreasing the diurnal range) (Karl et al. 1991), and land surface temperatures have warmed more than sea surface temperatures. These changes add to growing pressures from shifting patterns of land use that are diminishing the availability of high-quality waterfowl habitat.

While it is certain that climate plays an important role in the health, functioning, and distribution of wetlands, how climate variations will impact specific habitats and waterfowl is difficult to assess given the multitude of interplaying factors. Further complicating the issue, wetlands are diverse systems that have varying degrees of vulnerability to changes in timing and amount of precipitation, which causes them to manifest impacts differently. While existing global climate models differ in technical details, those differences are only some of the uncertainties in climate predictions and the potential impacts in store for waterfowl. Despite uncertainties in the science and future outcomes of climate change, however, it is clear that the tapestry of water and birds across this continent is likely to change in the years ahead.

2. REGIONAL IMPACTS

2.1 Prairie Pothole Region

The Prairie Pothole Region (PPR) lies in the heart of North America and provides breeding habitat for up to 60% of North America's ducks. The PPR is the core of what was once the largest expanse of grassland in the world, the Great Plains of North America. For breeding waterfowl, the number of wetlands determines the number of ducks that will use an area, while the type and amount of land cover impact productivity (e.g., nest success). Unfortunately, conversion of grassland and wetlands to cropland has dramatically altered the sustainability of this region for breeding waterfowl. For example, more than half of the continent's northern pintail population breeds in the PPR. Conversion of wetlands and grasslands for agriculture has reduced the capacity of this landscape to support pintails with current populations at only 25% of historic peak numbers and 50% of North American Waterfowl Management Plan goals. Pressures from agriculture likely will only increase unless specific efforts are made to protect and restore perennial grass cover. However, climate change scenarios will also have significant impacts on agriculture, and a drier and more variable climate could result in more grassland-based agriculture across the PPR, a trend that is already in place.

Figure 1. More than half of North America's northern pintail population breeds in the Prairie Pothole Region (Photo: Ducks Unlimited).

Importantly, wetlands in the PPR may be significantly affected by relatively minor climatic changes. Over 80% of wetlands on the prairies are less than 2 ½ acres in size; thus, this highly dynamic system and the species that rely on the landscape are particularly sensitive to changes in hydrology. Changes in both precipitation levels and in the timing of precipitation events will change the nature of this landscape for waterfowl with the potential to result in more frequent and longer drought periods which will reduce continental duck populations.

2.2 Boreal Forest

North America's Boreal Forest is part of the largest unspoiled forest and wetland ecosystem remaining on Earth. At 1.5 billion acres, this forest stretches from western Alaska to the Atlantic Ocean, accounting for 25% of the earth's remaining intact forests. On average, 13-15 million ducks use the Western Boreal Forest of Canada and Alaska during spring (http://www.fws.gov/migratorybirds/). Notable declines in scaup (both lesser and greater) to half their historic levels and concerns about sea duck populations (e.g. scoters) present specific challenges for conservation of this relatively pristine landscape. Scaup productivity, for example, already has declined, and hypothesized causes include habitat changes in the Boreal ecosystem, contaminants, parasites, and nutritional condition following migration (summarized in Austin et al. 2000). Climatic changes may result in melting of permafrost, de-watering of many small wetlands, and significant changes in subsurface hydrology. Declines in permafrost ponds, well-documented in both Alaska (Riordan 2006) and Siberia (Smith et al. 2005), present near-term impacts of a changing climate that likely will increase in the future; species like scaup will directly reflect these changes in North America.

Canada's Boreal Forest plays a unique role in the global carbon equation by storing more carbon per hectare than any other ecosystem, making it the world's largest terrestrial carbon storehouse. Boreal forests store 22 percent of all carbon on the Earth's land surface -- nearly twice as much carbon as tropical forests per hectare (Carlson and Roberts 2009). However this large carbon sink is at risk as boreal ecosystems could be among the most affected by global warming because of the greater temperature increases expected, and already experienced, at high latitudes (Environment Canada 1995). Further, as a result of increasing snow and ice melt and the consequent increase in absorbed solar energy, ecological predictions include lengthening ice-free seasons on lakes and rivers, earlier runoff, and melting permafrost (Inkley et al. 2004).

Although relatively pristine, less than 20% of the boreal region is under permanent protection, and concerns for the future of this expansive landscape include agricultural expansion at the southern boundary, petroleum exploration and development, forestry, hydroelectric development, mining, and acid precipitation. Industrial activities adjacent to or directly on networks of interconnected wetlands potentially will negatively impact their hydrology. Uncertainty exists about how climate changes could further accentuate impacts on hydrology, water quality, and ecology of boreal watersheds and wetlands in the context of growing industrial activities. Natural disturbances such as forest fires and insect damage are expected to increase due to climate change resulting in increasing concerns about cumulative effects on terrestrial and aquatic ecosystems.

2.3 Great Lakes - St. Lawrence

Figure 2. Canvasbacks winter regularly on the Lower Great Lakes (Photo: Ducks Unlimited).

The massive Great Lakes - St. Lawrence watershed drains 295,000 square miles and contains the Great Lakes. The region contains 21% of the world's fresh water, sustains an economy for 40 million people, and supports millions of waterfowl throughout their annual cycle. The Great Lakes have more than 10,000 miles of shoreline, more than the Atlantic and Pacific coasts of the United States.

Waterfowl managers face challenges of historic wetland losses exceeding 60%, reduced water quality, invasive species, and a growing human population in the region.

Growing evidence suggests that the climate of the Great Lakes region is already changing: winters are getting shorter, annual average temperatures are growing warmer, and extreme heat events are occurring more frequently (Karl et al. 2009). The duration of lake ice cover is decreasing as air and water temperatures rise. Despite an increase in heavy precipitation events, the climate of the Great Lakes region is predicted to grow warmer and drier during the twenty-first century. Future declines in both inland lakes and the Great Lakes are expected as winter ice coverage decreases, causing increased evaporation (Lofgren 2006a; Lofgren 2006b).

Population declines of breeding black ducks and migrating scaup and canvasbacks, already of concern to waterfowl managers, will continue to be issues. Reduced summer water levels are likely to diminish the recharge of groundwater supplies, causing small streams to dry up and reduce the area of wetlands, resulting in poorer water quality and less habitat for waterfowl. Continued expansion of urban areas and shoreline development will contribute to waterfowl declines and pose further challenges for climate adaptation.

2.4 Upper Mississippi River

Despite an average wetland loss of 65%, and in some regions, more than 90%, the Upper Mississippi River region continues to support the majority of waterfowl migrating to wintering areas in the Mississippi Alluvial Valley and much of the Gulf Coastal Prairie. Mallards, blue-winged teal, wood ducks, and Canada geese are primary waterfowl features of this landscape. The loss and degradation of extensive wetlands associated with the Mississippi, Missouri, and Illinois rivers and their tributaries have resulted in a specific focus on managed federal, state, and private wetlands (Fig. 3). Waterfowl managers concentrate on water and food management on these intensively managed areas to replace the once extensive resources for migratory birds. Continued wetland loss and degradation as well as reduced water quality present significant waterfowl conservation challenges today that will only be exacerbated by a changing climate.

Figure 3. Altered hydrology and untimely growing season flooding at Ted Shanks Conservation Area in Missouri (1970s to 1990s) resulted in loss of bottomland forest and wetland degradation, concerns that will be exaggerated by a changing climate (Photos: D. Humburg).

There is considerable uncertainty about the nature of climate impacts on precipitation in the Mid-continent. Untimely flooding can have single-year effects on the production and availability of waterfowl foods produced by annual plants and agricultural crops in floodplain areas. Moist-soil conditions occur when late spring and early summer drying gradually occurs in wetland basins, and prolific seed-producing annual plant species such as smartweeds (*Polygonum* spp.) and millets (*Echinochloa* spp.) germinate and grow throughout summer (Fredrickson and Taylor 1982). When inundated in the fall through spring by natural or managed flooding, seeds and invertebrates provide important food resources for waterfowl and other wetland wildlife. Growing season floods can greatly reduce or eliminate waterfowl habitat values, and increased frequency of these events could have long-term implications for waterfowl distribution and abundance during migration.

2.5 Mid-Atlantic Coast

Significant waterfowl areas of the Mid-Atlantic Coast, include the Chesapeake Bay, Delaware Bay, New Jersey coast and Long Island. Wintering habitat in this region supports 70% of the continent's American black ducks, and 80% of the Atlantic brant, greater snow geese, and Atlantic Flyway populations of Canada geese. Declines of up to 60% of the black duck population and 70–80% declines in winter use by canvasbacks and redheads are indicative of deteriorating wintering habitat conditions. Historic loss of tidal wetlands, declining water quality, greatly reduced submerged aquatic vegetation beds, and significant declines in shallow water habitats in the watershed are primary contributing factors. Regional growth in human populations and associated demands on the landscape present significant challenges to maintaining or improving water quality and waterfowl habitat in Mid-Atlantic estuaries.

Restoring the function of coastal wetlands is already a daunting challenge for waterfowl managers and will only be exacerbated by impacts associated with climate change. Altered stream flows, increasing salinity, and nutrient loading are processes already affected by the changing condition of associated watersheds. Climate change and associated potential effects on precipitation, runoff, and erosion are changes to system processes that will be further compounded by rising sea levels.

2.6 Pacific Northwest

From Alaska to northern California, the Pacific Northwest (PNW) provides critical estuarine and riverine habitat for breeding, migrating, and wintering waterfowl. The coastal areas of southern British Columbia and Upper Pacific Coast of the U.S. are regions of intense land use that threaten critical habitat for resident and migrating waterfowl such as Pacific brant, wigeon, sea ducks, the largest concentration of harlequin ducks in the United States, trumpeter swans, and a number of other migratory birds. Complex systems, affected by wetland loss, urbanization, agricultural expansion, sedimentation, and reduced water quality, have been disconnected from important hydrologic flow patterns. Eelgrass, a staple of a number of species' diets, has been heavily impacted by these changes and would be further affected by a changing climate.

During the past 100 years, the PNW has become warmer and wetter with the region's average temperature increasing 1.5 degrees F (Mote and Henry 2000). Snowpack has also decreased 11 percent and the dates of peak snow accumulation and snowmelt-derived stream flow have shifted 10 to 30 days earlier during this time period. Some locations in the Cascades, for example, have already seen declines in snow-water equivalent in excess of 70% (Mote et al. 2005). As a result of earlier spring runoff and lower water inflow in the summer months, salinity levels in estuaries could be elevated since they are largely controlled by freshwater fluctuations. In addition, low-lying estuaries also are threatened by projected sea-level rise. The narrow coastal band between shallow estuarine habitats and urban and agricultural development greatly limits the capacity for inland "migration" of coastal habitats. This "ecological right-of-way" is a high priority for current waterfowl habitat strategies and will be even more important in the future.

2.7 Great Basin

Wetlands in the Great Basin are diverse and most are "self-contained" as the watersheds of the regions end in "terminal basins" within the landscape. Chief concerns involve water quality and water availability, and these issues are increasing as threats to wetland condition because of a rapidly expanding human population (Engilis and Reid 1996). Waterfowl disease (primarily avian botulism), invasive species (e.g., carp and cheatgrass), livestock grazing, water diversions, and solar evaporation for acquisition of magnesium and potassium are issues of concern for waterfowl managers who are striving to maintain historic waterfowl populations. Although relatively scarce, wetlands in this region are extremely valuable on an individual basis in support of spectacular fall migrations of waterfowl and other migratory birds, wintering eagles, and breeding diving ducks, mallards, gadwalls, and cinnamon teal.

Waterfowl conservation efforts to protect and enhance remaining wetlands are already challenged by limited budgets and competing land uses. This will, as in other regions, be only exaggerated by a changing climate. Reduced snowpack could be offset to a degree by a shift northward of monsoons bringing increased summer moisture. However, projections indicate a drier scenario overall. In this regard, competition for fresh water will increase as the region is projected to be drier and warmer in the future. Hydrologic functions of wetlands will deteriorate as climate change occurs.

2.8 Southern Great Plains

The Southern Great Plains is an arid region where water is the precious lifeblood of wildlife and people. Stretching from central Texas to Nebraska, this region serves as the primary migratory pathway for several million ducks and geese in the Central Flyway. During spring migration, over 90% of the Mid-continent Population of greater white-fronted geese migrates through this area.

Unfortunately, the important wetland systems in the Southern Great Plains have been dramatically altered by drainage and conversion to agricultural production. As a result, wetland losses have exceeded 90% of those present historically, and migrating waterfowl are further concentrated in a region that had limited historic wetland resources. Large concentrations of waterfowl in a severely restricted wetland landscape are at increased risk of disease outbreaks, which can result in substantial mortality just prior to the breeding season. For example, an outbreak of avian cholera in the Rainwater Basin of Nebraska could result in significant mortality of greater white-fronted geese because most of the Mid-continent Population of these birds stages there. Greater concentration of migrating waterfowl due to wetland losses in a drier, warmer climate would only accentuate the disease concerns.

Wetland losses have equally important impacts on people living in the Southern Great Plains. For example, rampant urban development along the front range of the Rockies has created substantial declines in Platte River flows, which impact water availability for communities and farmers along the river. Obviously, water is a critical and limited resource in the Southern Great Plains, which is projected to be less plentiful in a warmer climate. Although twentieth century temperature records show no consistent trend in the region, some areas are experiencing greater seasonal warming during winter and spring. In addition, areas of the Southern Great Plains have already experienced significantly more high-intensity rainfall, which is also expected to accompany global warming (Joyce et al. 2000). Due to the nature of the region, agriculture and agricultural policies such as the farm bill have great potential for creating more sustainable landscapes.

2.9 Mississippi Alluvial Valley

Primary landscape features in the Mississippi Alluvial Valley (MAV), including forest cover and the significant extent of natural and managed winter flooding, ensure foraging habitat for up to eight million wintering waterfowl. This region is a continentally important wintering area for mallards, wood ducks, and gadwalls, all of which make extensive use of seasonally flooded forested wetlands and cleared lands dedicated to agriculture. Winter distribution (Nichols et al. 1983) and subsequent-year recruitment (Heitmeyer and Fredrickson 1981, Kaminski and Gluesing 1987) of mallards are correlated with winter precipitation and subsequent seasonal flooding across the MAV.

Figure 4. Flooded bottomland hardwood forest conservation and restoration is one strategy for waterfowl adaptation to climate change in the Mississippi Alluvial Valley (Photo: Ducks Unlimited).

Waterfowl conservation emphasis in the MAV has been directed to protection of existing tracts of frequently flooded forest (Fig. 4), restoration of forested wetlands that were converted to agriculture, and enhancement of management capacity on protected acres. Gains from these conservation strategies represent the results of decades of focused conservation planning and delivery. Still, water quality issues are widespread in the MAV, and in some areas water quantity is also becoming an issue. Although there is currently little direct competition between agricultural interests and waterfowl management, this could be an issue in the future, especially in a changing climate.

In a warmer climate, higher temperatures, increased evaporation, and changes in precipitation could heavily influence runoff in MAV states. Lower stream flows and groundwater levels in the summer could affect water availability and increase competition among domestic, industrial, and agricultural water users. Declining groundwater levels are a matter of concern throughout much of Arkansas and Mississippi. Increased rice irrigation and fish farming (although less than in the recent past) in the Delta region have reduced groundwater levels in the Mississippi Alluvial Aquifer. Increased municipal and industrial withdrawals in metropolitan areas have also lowered groundwater levels. Warmer and drier conditions could compound these types of problems due to higher demand and less recharge.

Warmer and drier winters could also affect waterfowl use and hunting opportunities in the MAV. Waterfowl use, winter body condition, and over-winter survival all could decline with climate change and resulting impacts on habitat via less natural flooding and reduced seasonal sheet water. The quality of waterfowl hunting would likely follow these same negative trends.

Conversely, a likely increase in the frequency and intensity of rainfall and subsequent flooding poses long-term threats related to too much water rather than too little. Although unaltered forest systems show a high degree of resilience to climate change (Cleaveland 1995), the majority of contemporary bottomland forests have been affected by numerous human disturbances which have altered hydrology and fragmented forests (Rudis 1995). Changes in flood zones affecting regeneration of bottomland tree species and survival of established stands -- especially if flooding occurs during the growing season -- present long-term challenges. Because of the long-lived nature of forest systems, even infrequent untimely flooding could have lasting effects. Extended growing-season flooding, such as during the mid-1990s in the Midwest, only needs to occur every few decades to have long-term impacts on wetland systems and waterfowl populations.

2.10 Gulf Coastal Prairie

Coastal wetland loss and conversion to open water is the primary threat to waterfowl habitat, especially in Coastal Louisiana. Loss of emergent marsh has occurred with greater subsidence rates, coastal erosion, and a reduced rate of land building from river sediments. The extent of open water is a relatively direct measure of the loss of waterfowl foraging habitat, and recent analysis by the Gulf Coast Joint Venture showed that significant shortages of waterfowl foraging habitat exist in coastal fresh and intermediate marshes in Louisiana and Texas, which threatens peak wintering waterfowl numbers exceeding 15 million. Research shows that winter habitat conditions (food availability) affects body condition and ultimately over-winter survival rates (e.g., for pintails - Anderson 2008). Notably, female pintails have very low over-winter survival rates in the Texas Mid-Coast region, where foraging models suggest a habitat shortfall of about 100,000 acres. A contributing factor is the loss of more than 50% of rice agriculture in coastal southwest Louisiana and Texas. Resident wildlife also has been affected. For example, recent analysis of mottled duck population growth, survival, and reproductive rates suggest declining populations in the region (Johnson 2009). Although causes are not clear, loss of habitat, which could increase with a changing climate, is a key consideration.

Sea-level rise is projected to be greatest in the Gulf Coastal region of North America and represents the most significant physical force of a warming climate and is among the most important policy issues faced along the Gulf. A predicted rise of 1 m or more over the next 100 years would result in dramatic losses of waterfowl habitat. Also, it is not clear if coastal marshes will be permitted to “migrate” inland, or if policies will seek to “harden” the coast (i.e., levees and other features) resulting in wholesale losses of coastal wetland habitats. Without an effort to manage or mitigate habitat lost to increasing sea levels, wintering waterfowl will be forced to relocate to other portions of the wintering grounds -- none of which have excess capacity to support additional duck and goose numbers. Resident wildlife, such as mottled ducks, could be pushed toward threatened or endangered status.

2.11 Central Valley California

The Central Valley of California hosts the greatest concentration of wintering waterfowl on this continent. More than one million northern pintails are recorded in winter surveys, and seven million total wintering waterfowl are supported by the Central Valley when populations are at North American Waterfowl Management Plan goals. Yet this region, where water resources are significantly over-allocated, faces contemporary conservation challenges that a changing climate would only exaggerate.

Historic losses of 95% of the region’s wetlands bring particular focus to the relatively few acres of wetlands that remain. The fragile balance between water needed for a growing human population, agriculture, and ecosystems is nearly untenable today and will be increasingly challenging in the future. Projections of significant declines in mountain snowpack present long-term problems related to water quantity, allocation, and water quality. Although wetter winters are predicted, which would provide seasonal improvements in water availability, warmer and drier growing seasons would affect wetland management and agriculture – notably rice production – in the region. Extremes in winter conditions are also predicted which would include more droughts and more dramatic flooding. More severe flooding could result in significant damage to infrastructure (e.g., levees, water conveyances, etc.). Cross-seasonal impacts of changing temperature and precipitation patterns present a complex suite of waterfowl habitat problems. Protection of existing wetlands and the water sources essential for their ecological functions is the primary adaptation strategy for the Central Valley.

3. WATERFOWL ADAPTATIONS AND RESPONSE

Waterfowl, due to their mobility, are sensitive barometers for landscape change as shifts in breeding, migration, and wintering affiliations reflect near-term and long-term changes in landscape condition. Their migratory behavior and broad seasonal distribution (Fig. 5) are consistent with the scale of the issues and challenges presented by changes in climate and water quality and quantity. Waterfowl reliance on shallow-water habitats makes them a useful focal group for study of wildlife adaptations to climate change, as shifts in duck abundance and distribution serve as early signs of change in wetland conditions.

Predicted impacts of climate change are different across different landscapes. Whether nesting, migrating, or wintering, waterfowl will be affected by changes in landscape condition; however, the impacts will vary by species. Throughout the process of climate change and human efforts to adapt, waterfowl and ecosystems will undoubtedly change as well. These changes, whether in the form of shifts in biomes, changes in abundance or distribution of waterfowl, or changes in the nature of hydrologic processes and disturbance regimes, will provide the measures of how climate is impacting the continent.

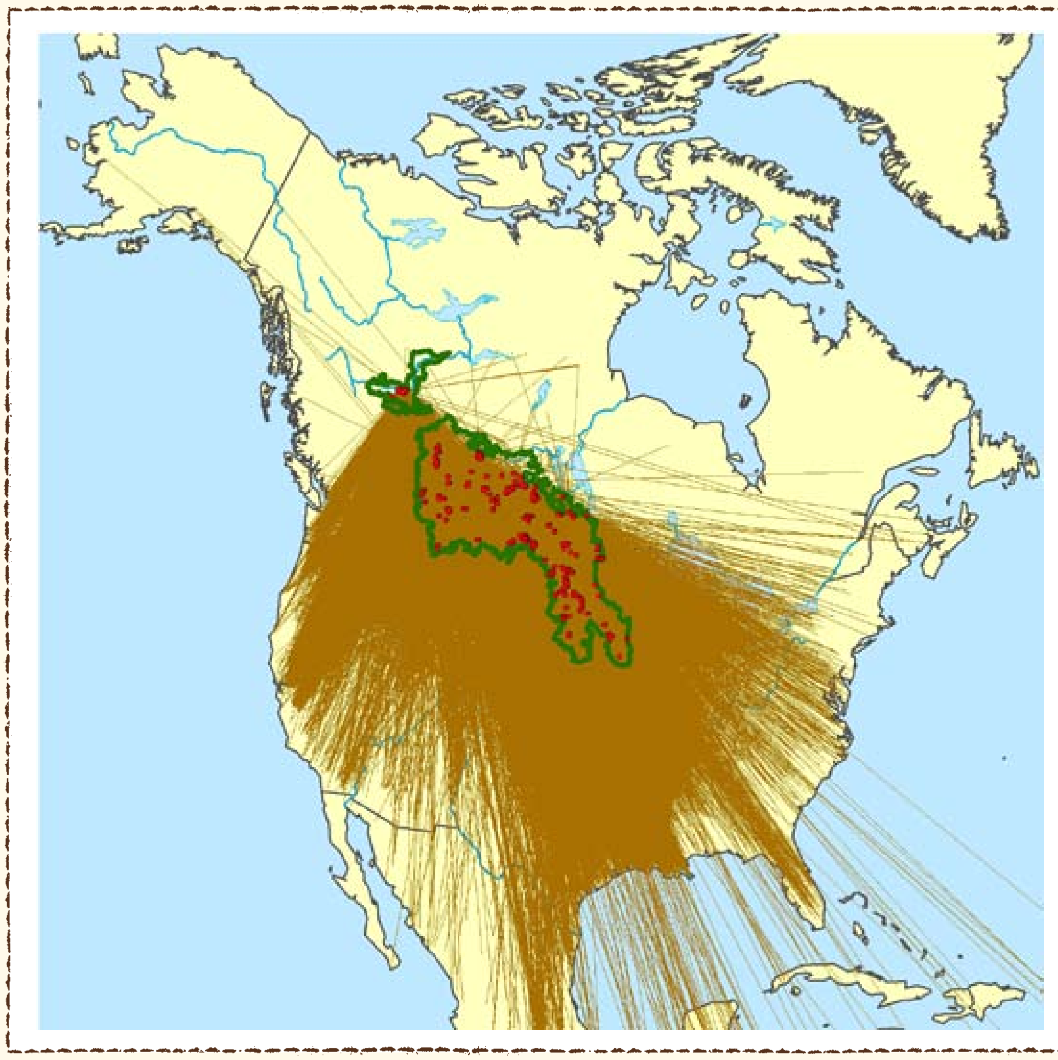


Figure 5. Distribution of band returns of harvested ducks originating in the Prairie Pothole Region (outlined in green). Red dots represent banding sites within the region (Source: U. S. Gelogical Survey).

Short-term variation in waterfowl population estimates are of limited use in assessing climate change impacts. Numbers and distribution change dramatically year to year due to changes in environmental conditions – especially wetland status. Thus, a high degree of uncertainty exists with regard to population responses to climate change, which makes the baseline of long-term population estimates and band recoveries important to maintain in the future. Habitat impacts, however, can be more easily predicted, and the condition and extent of important breeding habitats, such as seasonal prairie wetlands, are known to correlate with breeding-bird abundance, breeding success, and population growth fluctuations in North American waterfowl. For most species, breeding success is the most important factor limiting population growth. A study on mid-continent mallards found that up to 81% of the variation in population growth rates was attributable to key breeding-season events (Hoekman et al. 2002).

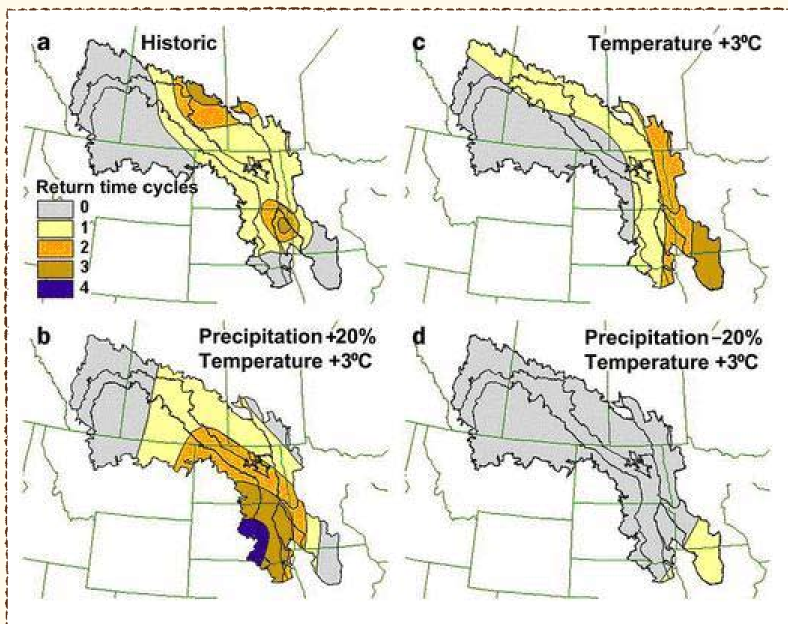
Unfortunately, wetland ecosystems in key breeding areas like the Prairie Pothole Region (PPR) already face significant and widespread human impacts, with global climate change providing an additional challenge. Alterations and destruction of surrounding habitats reduce opportunities for prairie wetland-dependent waterfowl to find new habitat, placing increasing significance on fewer and smaller areas.

Climate change adds temporal and spatial uncertainty to the abundance of resources needed for breeding, migration, and wintering (Figs. 6 and 7). Model simulations developed by Johnson et al. (2005) indicate that the center of the most productive habitat conditions for breeding waterfowl may shift to the east under a drier climate. Optimal habitat could diminish in the center of the PPR (the Dakotas and southeast Saskatechwan) and shift towards the potentially wetter eastern and northern fringes, areas where most wetland systems have been highly altered and drained for agriculture. For waterfowl to adapt to these changing conditions, protecting and restoring the remaining wetlands in these eastern and northern areas of the PPR will be critical; however, the limited potential and cost of wetland conservation in these regions will present considerable challenges.

Overall, the composition and geographic distribution of many ecosystems including wetlands are expected to shift while individual species will respond to these climate-induced changes. This will likely cause a reduction in biological diversity and in the subsequent goods and services that ecosystems provide society (IPCC 2007).

Figure 6.
Geographic patterns of the speed of the wetland cover cycle, simulated for the Prairie Pothole Region under historic (a) and alternative future (b, c, and d) climatic conditions

(Johnson et al. 2005).



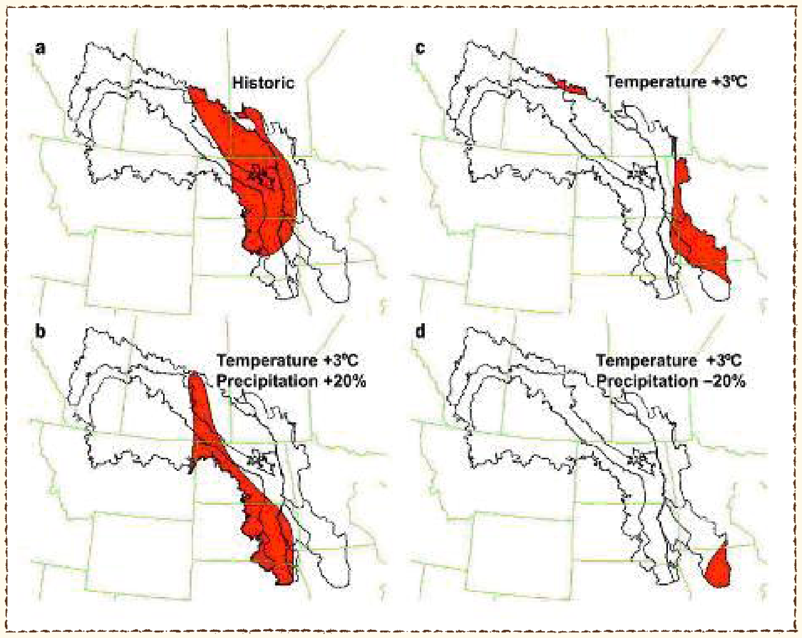


Figure 7.
Simulated occurrence of highly favorable water and cover conditions for waterfowl breeding across the Prairie Pothole Region under historic (a) and alternative (b, c, and d) future climatic conditions

(Johnson et al. 2005).

The most obvious impact of climate change is the potential for waterfowl redistribution in response to warmer seasonal conditions. In addition to changes in breeding habitat conditions and the distribution of breeding waterfowl, climate change may also affect the timing and distance traveled during waterfowl migration. Although this already has been a source of speculation by hunters and biologists, changes in winter distribution were not supported by band recoveries and harvest data (Green and Krementz 2008). In contrast, however, long-term monitoring and modeling of initial changes in bird distribution point to potential changes under climate changes that could be much more evident in the future for many bird species including waterfowl (Matthews et al. 2004).

Warmer average fall and winter temperatures in northern regions would make it unnecessary for waterfowl to fly as far south to find open water conditions and suitable food. Rising winter temperatures make northern latitudes increasingly more hospitable to many species more commonly found farther south during the wintering period. When North America's waterfowl migrate south for the winter, the majority seek ice-free freshwater lakes, riverine habitats, deltas, coastal marshes, and estuaries in the United States and Mexico. Within the United States, many Atlantic Flyway birds travel through the eastern Great Lakes and New England to wintering areas along the Mid-Atlantic coast, including Chesapeake Bay and Delaware Bay. Others move farther south into the Carolinas, Georgia, and Florida. Depending on water conditions, mid-continent species that use the Mississippi and Central flyways largely winter in the Platte River basin, the Mississippi Alluvial Valley, the lower Mississippi River delta, the Playa Lakes region, and coastal marshes along the Gulf of Mexico. In the Pacific Flyway, waterfowl that breed in Alaska and other northwestern regions of the continent opt for wetlands associated with lakes, rivers, bays, and estuaries in Washington, Oregon, California, the western Rocky Mountain states, the Southwest, Mexico, and beyond.

Research by the USDA Forest Service predicts that changes in seasonal temperatures and precipitation due to rising average global temperatures will contribute to a northward shift in the breeding range of mallards and blue-winged teal in the eastern half of North America before the end of this century (Matthews et al. 2007). Climate models developed by the USDA Forest Service

Northern Research Station assessed the current status and potential future conditions of 147 bird species in the eastern United States. The model incorporates Breeding Bird Survey data with 11 environmental variables and distribution patterns of 88 tree species to generate models of current suitable habitat for each species. Three different predictive climate models and two emissions scenarios were then applied. The results (Fig. 8) illustrate the potential changes in suitable habitat under three different General Circulation Models (GCMs) and two different levels of emissions by humans (Hayhoe et al. 2007). The two emissions scenarios used in the model characterize most of the emission futures as outlined by the Intergovernmental Panel on Climate Change's evaluation of emission scenarios (Nakicenovic et al. 2000). Models such as these are useful for natural resource and wildlife managers to assess potential landscape-level climate impacts; however, more information is needed at local and project-level scales to support development of adaptation strategies and to guide implementation.

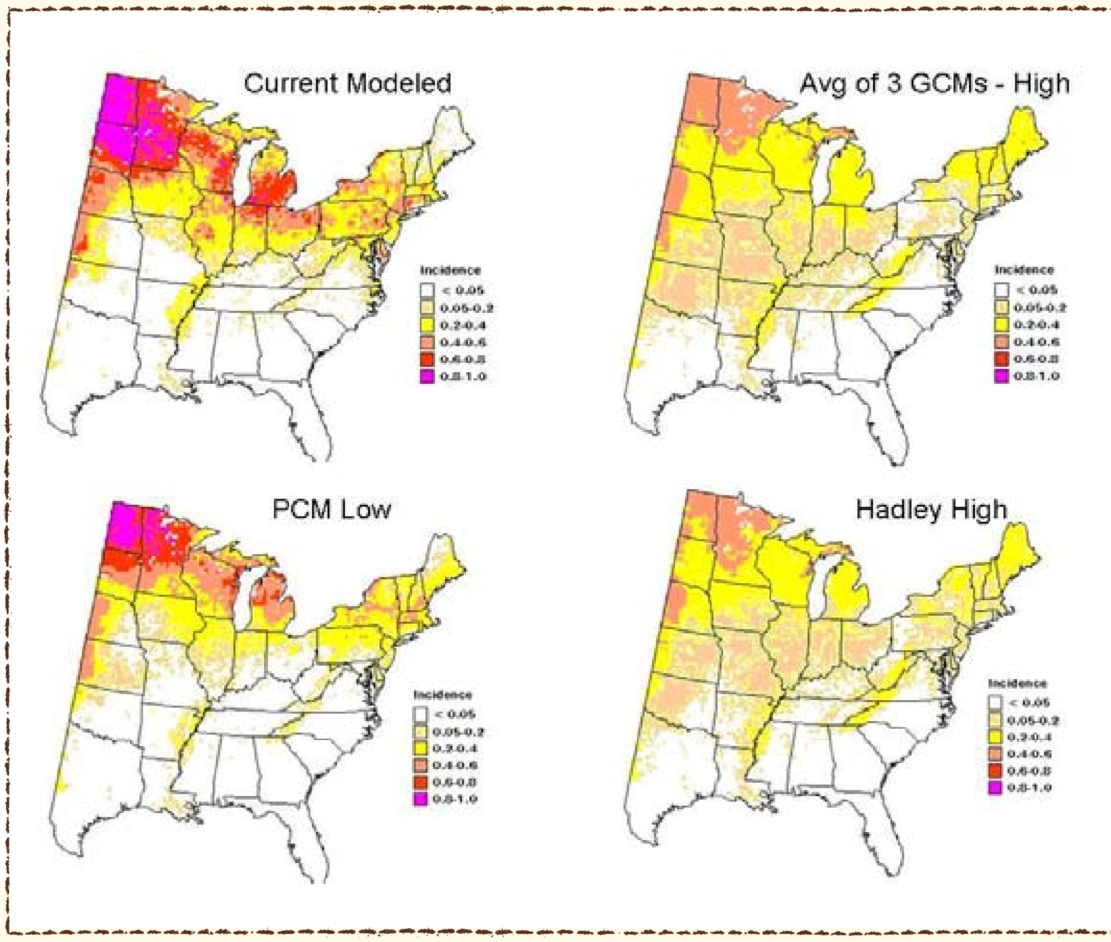


Figure 8. USDA Forest Service model results for mallard habitat using the harshest scenario (Hadley Hi) and the mildest scenario (PCM Lo), as well as the average of all three GCM models for high carbon and low carbon scenarios (Source: USDA Forest Service Northern Research Station).

Response by Waterfowl and Waterfowl Hunters

Waterfowl are migratory and thus can adapt to changes in the distribution of habitat and conditions presented by a changing climate . . . to a degree. However, ducks and geese can only adapt to changes in habitat to the degree that habitat conditions still provide the basic requirements across seasons. Waterfowl hunters will be much less likely to move simply to accommodate their passion for waterfowl hunting. Waterfowl conservation efforts today are not sufficient to keep pace with the rate of habitat loss and alteration or ensure sustained populations of ducks and geese. With continued threats to habitat and populations, waterfowl hunting traditions likely will also face an uncertain future. Changes in climate will present even greater challenges to maintaining these traditions.

The result could be the loss of waterfowl hunting traditions and their impact on regional economies. Waterfowl hunters spent $900 million in 2006 on a variety of goods and services from food, transportation, guns and decoys to hunting dogs, clothing and other incidental expenses (U.S. Fish and Wildlife Service 2009). These expenditures generated more than $2.3 billion in total economic output, which resulted in $157 million in federal and state tax revenues, supported more than 27,000 jobs, and generated more than $8.5 million in employment income.

Impacts on waterfowl hunters are expected in each of the regions where climate impacts on waterfowl and wetlands are projected to occur. Loss of hunting opportunity in landscapes severely affected by climate change should be considered, as should the effects of such changes on places linked to these same populations of birds. Independent of population status, some landscapes may change in a manner that affects hunting opportunity. In other words, less habitat for birds would also mean less habitat for hunters. As an example, relatively conservative projections of a one-meter rise in sea level over the next century along the Gulf Coastal Prairie would significantly affect this region of rich waterfowling traditions (Fig. 9). Waterfowl hunters spend an average of one-half million days afield annually in parishes and counties that would be susceptible to rising sea levels along the Gulf Coast. From a biological perspective, waterfowl traditionally using this important wintering region are derived from breeding landscapes throughout the continent. Wintering and breeding waterfowl as well as waterfowl hunters all would be affected by sea-level changes due to a changing climate.

Certainly, large scale impacts on waterfowl hunting are possible if there is reduced duck production in the prairie and boreal regions as a result of climate change. Lower fall flights would affect hunters all across the continent. Loss of hunting opportunity also could occur if waterfowl are redistributed due to changes in weather, habitat conditions, or interactions between the two. Likewise, increases in hunting opportunity are likely in regions traditionally used during migration but become southern terminuses in the future.

There is considerable annual variation in hunting activity due to near-term dynamics of weather, food, and water conditions. However, if variation in these covariates is statistically controlled, analyses of hunter numbers and harvest may be used as additional measures of climate impacts.

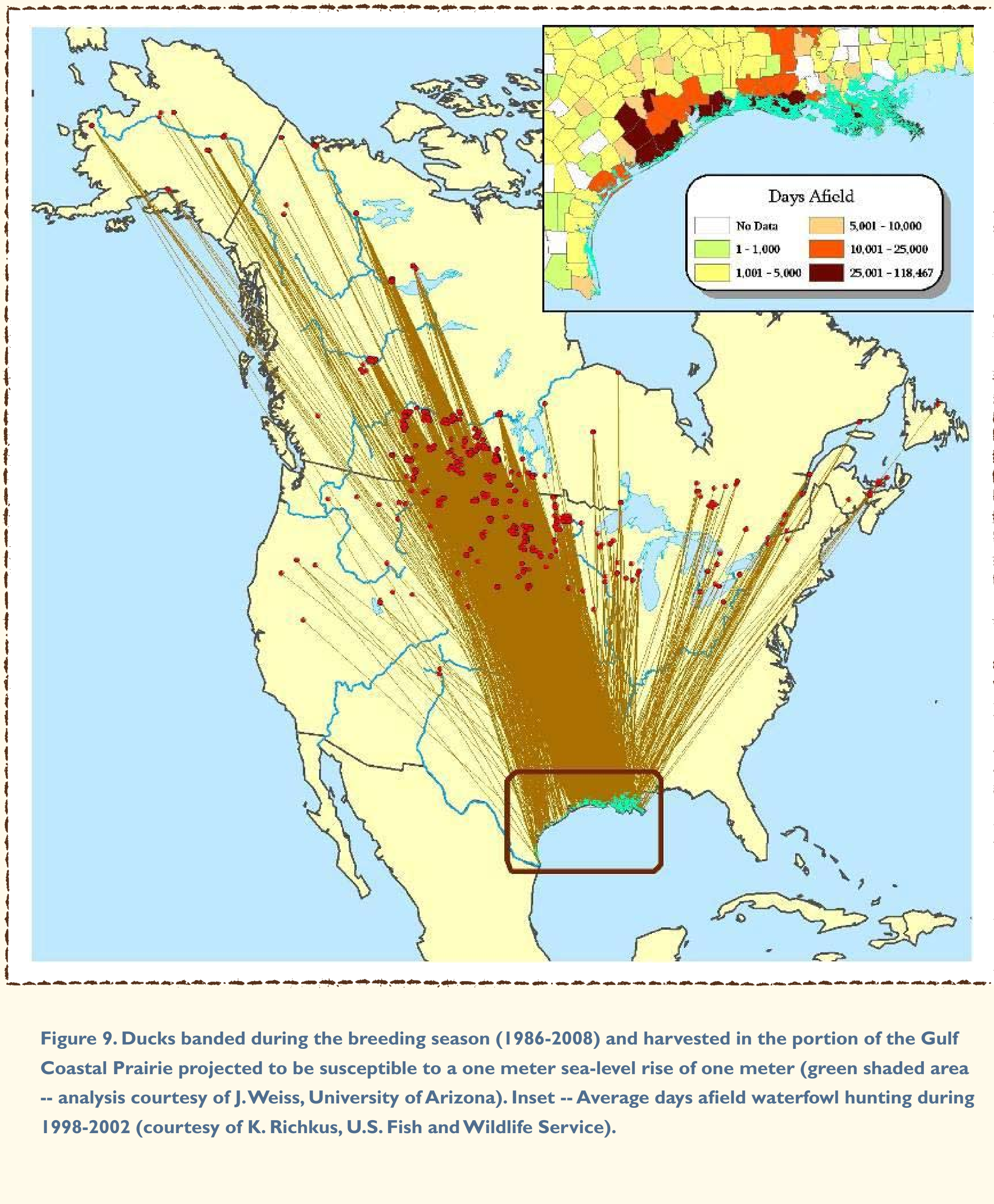


Figure 9. Ducks banded during the breeding season (1986-2008) and harvested in the portion of the Gulf Coastal Prairie projected to be susceptible to a one meter sea-level rise of one meter (green shaded area -- analysis courtesy of J. Weiss, University of Arizona). Inset -- Average days afield waterfowl hunting during 1998-2002 (courtesy of K. Richkus, U.S. Fish and Wildlife Service).

4. LIMITATIONS OF EXISTING STATE AND FEDERAL EFFORTS TO ADDRESS CLIMATE CHANGE

Address Climate Change

North America's migratory waterfowl and the habitats they require provide ecological, social, and economic benefits that include food, ecosystem stability, recreation, jobs, income, and much more. Recognition of the importance of waterfowl and wetlands has led to state and federal policies and conservation programs intended to restore and protect waterfowl populations and their habitats through protection, restoration, and management. However, conservation efforts today are not sufficient to ensure sustained waterfowl populations or hunting traditions. Losses of wetlands important to waterfowl continue at the rate of over 80,000 acres per year (Dahl 2006), and 70% of the historical extent of grasslands across the Great Plains has been lost (Samson et al. 2004) with at least 150,000 acres of continued loss every 10 years in the Missouri Coteau alone (Stephens et al. 2008). Added to continuing land use pressures, changes in climate will present even greater challenges in the future and require additional conservation-focused programs and funding.

National-scale policies that reduce greenhouse gas (GHG) emissions and increase carbon sequestration will be necessary to reduce the threat from climate change to wetlands and associated habitats used by North America's waterfowl. Yet, in the absence of national climate policies, states have implemented various policies and strategies that reduce GHG emissions, develop clean energy resources, promote energy efficiency, and investigate solutions for natural resource adaptation. In some instances, state-specific Climate Action Plans have been developed to help wildlife and natural resources adapt to climate change. Habitat acquisition (including easements), restoration, and management for wildlife have concurrent benefits for climate by increasing the extent of landscapes essential to sequestering carbon. Without comprehensive and large scale policies, however, state and regional efforts will continue to provide fragmented solutions insufficient to address climate change at effective scales.

Protecting and Restoring Grasslands: The U.S. Department of Agriculture (USDA) Conservation Reserve Program (CRP) is one of the nation's largest and most effective means of establishing extensive grasslands. However, revenue opportunities for landowners associated with higher commodity prices, increased land rents, and the production of energy crops are raising concerns that millions of acres of restored grassland may be converted as CRP contracts expire and landowners put the acreage back into production. Despite all the proven benefits of CRP, the 2008 Farm Bill reduced the authorized acreage of 39.2 million acres by more than 18%. The "Sodsaver" program, developed to discourage native prairie destruction, was changed by Congress to make participation optional at the discretion of the governors in five prairie states, but no state chose to participate. An estimated 3.3 million acres of native prairie are projected to be lost in the next five years due to this provision being voluntary instead of mandatory. Landowners will continue to receive taxpayer-subsidized crop insurance after breaking native prairie. When coupled with a new "permanent disaster assistance program," there are now powerful incentives to destroy prairie and put marginal land into crop production. To help reverse this trend, federal climate and energy legislation should employ strategies with dual wildlife adaptation and carbon sequestration benefits.

Protecting and Restoring Wetlands: Federal laws protecting water and wetland resources play a critical role affecting the future of waterfowl habitats. The Clean Water Act (CWA) was passed in 1972 (the Federal Water Pollution Control Act) to restore and maintain "the chemical, physical and biological integrity of the Nation's waters". After almost three decades, the U.S. Supreme Court ruled in Solid Waste Agency of Northern Cook County v. United States Army Corps of Engineers that certain wetlands and other isolated waters could not be protected under the CWA based solely on migratory bird use. Further, the Court ruled in Rapanos v. United States and Carabell v. United States Army Corps of Engineers in 2006 that many wetlands required a "significant nexus" to navigable waters to be covered under the CWA. U.S. Army Corps of Engineers and Environmental Protection Agency regulatory guidance since that ruling has severely reduced protection of wetlands important to waterfowl.

Legislative solutions by Congresswill be required to fully restore the level of CWA protections that existed prior to 2001 and eliminate judicial uncertainty regarding the intent of Congress. Without these changes and without long-term stewardship of wetlands, issues related to climate change, water quality, and wetland-dependent wildlife will escalate drastically.

At a continental level, the North American Waterfowl Management Plan (NAWMP), adopted in 1986, has provided the collaborative framework for waterfowl conservation. Regional joint ventures that have implemented on-the-ground strategies for waterfowl conservation under the NAWMP are well suited to implement strategies in response to climate change. The North American Wetlands Conservation Act (NAWCA), enacted in 1989, provides federal cost-share funding to support the NAWMP. NAWCA was reauthorized in 2006, and the appropriation authorization was increased to $75 million for FY 2007 through FY 2012 – although appropriations must occur for this to be realized. This source of federal funding is highly efficient in that every $1 of federal money allotted to NAWCA must be matched by $1 or more from non-federal sources; in reality, match funds are usually more than tripled. Future appropriations for NAWCA must keep pace with the threats to wetlands.

Waterfowl Conservation and Climate Change: Policies and programs to enhance habitat for waterfowl appear to have had positive impacts on these and other wetland-dependent species. The “State of the Birds Report” released in spring 2009, documented general increases in wetland bird status; however, 24% of the 163 species that breed in freshwater wetlands remain species of conservation concern. Gains made in the last three decades could be reversed and species of concern could be lost entirely without needed legislation and continued increases in funding for wetlands and associated upland habitats. Without incentives for private landowners to engage in landscape-scale solutions, however, waterfowl-directed programs alone will not be sufficient to ensure healthy duck and goose populations in the future. Further, the challenges presented by climate change make it imperative that waterfowl managers identify and prioritize places and programs that address landscapes most vulnerable to future climatic change.

5. ADAPTATION PROJECTS FOR WATERFOWL

Waterfowl are more sensitive than many taxa to potential shifts in climate change due to their strong dependence on wetlands that will be profoundly affected by climate (Butler 2003). While many natural resource managers anticipate that climate change will alter wetland habitats, each landscape is unique in the features important to waterfowl of various species. The nature of habitat loss affects the types of policy and conservation or adaptation solutions that will be required. However, surprisingly few on-the-ground projects have been implemented specifically for the purpose of helping waterfowl and other wildlife adapt to climate change. The uncertainty surrounding the extent and potential impacts of climate change is part of the reason, requiring a flexible management approach that can be continually revised and adapted.

Depending on the characteristics of the resource challenge, projects may help promote resilience or resistance to climate change, while other cases facilitate change as entire ecosystems disassemble. Therefore, examples of projects or strategies that will help waterfowl adapt to climate change are often traditional conservation approaches, but with a broadened sense of purpose.

Structured decision making and, more specifically, adaptive management (Williams et al. 2007) requires agreement about management objectives usually derived through the involvement of many stakeholders. A framework of management alternatives, assumptions, trade offs, and key uncertainties captures the state of knowledge and predicted outcomes. Monitoring to assess the outcomes of management, provides for an explicit feedback process that is used to inform future management decisions. Through an iterative process of decision making, monitoring, and periodic reassessment of management goals, managers and policy makers can learn from their actions and improve long-term management.

In the context of climate change discussions, "adaptation strategies," "adaptive management," and wildlife adaptations to climate change have been confused. In this respect, "adaptation strategies" should be viewed as the actions taken by managers, policy makers, and society in general to position humans and ecosystems to be able to thrive as climate changes. As these strategies are implemented, a structured decision making/adaptive management framework would provide the basis for assessment and amendment favoring effective strategies over time.

5.1 Habitat Buffers for Coastal Migration

Sea-level rise will adversely affect coastal wintering and migratory stopover sites for many waterfowl species. For example, half of all tidal flats and brackish marshes along the Oregon and Washington coasts may be lost to rising seas in the next 90 years. Coastal marsh can be conserved if the sea is allowed to migrate inland, as has happened in the geologic past. Unfortunately, much of the coast is now reinforced with hard sea walls or earthen levees that prevent such movement (Fig. 10). Adaptation projects and programs that focus

Figure 10. Coastal development and infrastructure may prevent or inhibit the inland migration of coastal habitats (Photo: Ducks Unlimited).

on preserving coastal farmland today can ensure conservation options for the future. Adaptation funding for conservation in the form of farmland easements in these coastal areas can help prevent development and preserve corridors for the inland migration of coastal wetlands critical to waterfowl in regions like the Pacific Coast (Fig. 11).

Figure 11. Preserving coastal buffers provides a "right-of-way" for the inland migration of coastal habitats as sea levels rise (Photo: Ducks Unlimited).

5.2 Restoration of Hydrological Processes

The water resources used by North America's waterfowl face many challenges, including climate change. The rate at which observed climate variability impacts have affected water supplies critical to waterfowl habitats and the potential for significant future changes give clear indications of the importance of adaptation projects focused on water resource management. Several water management approaches should be considered to facilitate adaptation under climate change, including allocation and infrastructure changes.

In some important waterfowl regions, like coastal Louisiana, disruption of the natural hydrologic and geomorphic processes has caused significant losses of wetlands. For example, over 750,000 acres of the Mississippi River deltaic marshes of southeastern Louisiana have been converted to open water during the last 70-80 years. Historically, the Mississippi River flooded these marshes at least annually, depositing huge amounts of sediment and delivering a rich supply of nutrients that nourished and built marshes. Today, dams on the upper reaches of the Mississippi and its tributaries have caused an estimated 50% reduction in the sediment reaching coastal Louisiana. Additionally, a large flood protection levee system prevents most seasonal flooding, and hence, delivery of sediment to rebuild and sustain marsh. These coastal marshes have always undergone natural subsidence as the highly organic soils consolidated over time. Today, subsidence continues, but the levee system prevents new sediments from building marsh. Hence, it is clear that if we are to retain Louisiana coastal wetlands at a scale that is meaningful to continental populations of waterfowl and other wildlife, restoration of the natural hydrological processes must occur at a scale that either sustains or increases the present amount of coastal wetlands. This would be true even without the added challenges of climate-change induced sea level rise. However, restoration of the processes that created these wetlands may be the only means of mitigating the potential effects that sea-level rise may have on this system.

5.3 Conservation of Pothole Wetlands

The millions of glacially formed, depressional wetlands embedded in the prairie pothole landscape are key to maintaining populations of North America's waterfowl and ensuring their adaptation to a changing climate (Fig. 12). These wetlands provide habitat for up to 60% of the continent's breeding ducks, and unless these wetlands are protected and restored, waterfowl will face a bleak future. Adaptation projects that secure perpetual conservation easements on the remaining pothole wetlands and surrounding native prairie grasslands can help protect this unique and irreplaceable breeding habitat. Additionally, efforts to restore pothole wetlands that have been drained for agriculture can help decrease habitat fragmentation that cause declines in nest success. Further, depressional wetlands in agricultural landscapes are degraded by sediments and contaminants accumulated from their watersheds. Establishment of vegetative buffers can reduce transport of sediments into pothole wetlands and provide waterfowl with secure cover.

Figure 12. Over two-thirds of the grasslands in the Missouri Coteau in the Prairie Pothole Region have been converted to cropland and many wetlands have been drained. These changes in grasslands and wetlands have important implications for duck populations and hunting seasons (Photo: Ducks Unlimited).

5.4 Habitat Conservation Via Environmental Markets

No matter where we live, the ecosystems used by waterfowl provide many important goods and services. These habitats provide multiple benefits to society, including improved flood control, clean water, recreational opportunities, and climate adaptation. As a whole, these benefits are often referred to as "ecological goods and services," the processes by which the environment produces resources that we often take for granted. Existing and future environmental regulation may provide financial support for adaptation projects that are designed to mitigate habitat loss or preserve existing habitats through emerging environmental markets for carbon, water quality and biodiversity.

Ecosystem markets are a system of buying and selling ecosystem services that have been converted into recognizable units of trade such as "credits." The regulatory frameworks that drive and sustain these markets and the protocols for transacting various credits continue to evolve in the United States (Bayon et al. 2007). For example, voluntary and regulatory legislative strategies to moderate global climate change focus on reducing the dominant source of greenhouse gas emissions to the atmosphere-combustion of fossil fuels that release carbon dioxide. Regulated ecosystem markets currently exist for wetland mitigation banking based on the Clean Water Act and habitat banking driven by the Endangered Species Act. Adequate regulation and policies could create substantial opportunity for ecosystem markets to supplement public and private conservation program funding, thereby expanding acres conserved or protected for the benefit of waterfowl and people.

5.5 Waterfowl Habitat Conservation Via Carbon Projects

Many regions important to waterfowl are also carbon sinks that could provide an additional economic value to landowners who undertake certain land management practices on their properties. The scientific findings on observed and anticipated climate change strongly suggest that all major sources of greenhouse gas emissions, including emissions from land use, need to be addressed to minimize climate change impacts to people and wildlife. Conversion of habitats such as native grasslands in the Prairie Pothole Region not only has severe consequences for breeding waterfowl but also contributes to the 20-25% of global GHG emissions attributed to land-use change.

Restoring and protecting grasslands and bottomland hardwood forest on agricultural lands can offset greenhouse gas emissions through carbon sequestration. Biological carbon sequestration occurs when carbon dioxide is absorbed from the atmosphere and stored in vegetation and soil. Carbon storage rates in grasslands, forests, and other landscapes in the United States are declining. Without additional economic incentives to alter land management practices, carbon storage in these landscapes is expected to continue to decline. Carbon project financing from a national carbon offset program could create important incentives to increase carbon storage, reduce emissions from terrestrial sources, and at the same time provide important habitat for waterfowl and other wildlife.

Industries such as large utility, oil, and chemical companies have started to invest in carbon sequestration to prepare for future regulations that may cap carbon emissions. Voluntary carbon trading in the United States nearly doubled between 2007 and 2008, with trading of 123.4 million tons of carbon dioxide equivalent worldwide resulting in a total market value of $705 million (Hamilton et al. 2009). Market analysts predict global voluntary trading will reach $4 billion in the next five years. With adequate public policy addressing climate change and emissions reductions, this market could provide alternative sources of funding for waterfowl adaptation projects, while providing compensation to landowners who restore or protect waterfowl habitat on their property.

6. ADAPTATION CASE STUDY: MARKET BASED-CONSERVATION OF NATIVE PRAIRIE GRASSLANDS

6.1 Project Background

Geographic and Biological Setting:

Temperate grasslands are the Earth's most threatened biome. The Prairie Pothole Region (PPR) is a 300,000-square-mile landscape that was once covered in grasslands and dotted with millions of small wetlands known as prairie potholes. The native prairie in the PPR is a haven of biodiversity, composed of hundreds of grass and forb species that provide nesting or stopover habitat for the majority of the continent's migratory bird species and harbor numerous unique, nonmigratory species. Each spring, millions of ducks including pintails, mallards, gadwalls, blue-winged teal, shovelers, and canvasbacks nest in the grasslands adjoining the potholes. Many other waterfowl such as lesser scaup, wigeon, green-winged teal, Canada geese, and snow geese use the area as a staging ground in their migration north to the boreal forests and tundra.

Grasslands not only support exceptional biodiversity, they also sustain local communities through grass-based agriculture, including livestock and hay production. Grasslands also provide a suite of ecological goods and services including groundwater recharge, attenuation of flood events, enhancement of water quality, and reduced sedimentation and carbon sequestration and storage.

Figure 13. Native Prairie grasslands store vast amounts of carbon in their soils and contain high species diversity (Photo: Ducks Unlimited).

Unfortunately, in eastern portions of the northern Great Plains, less than 1% of presettlement native prairie remains. Record high commodity prices from rising food demands and a new U.S. Farm Bill with weakened conservation provisions are encouraging the plowing of every available acre. Within the PPR, the Missouri Coteau covers approximately 17 million acres in Canada and the United States. It is known as North America's "duck factory" because of its critical importance to waterfowl production. Unfortunately, over two-thirds of the grasslands in the Missouri Coteau have been converted to cropland and many wetlands have been drained. These changes in grasslands and wetlands across the PPR have important implications for duck populations and hunting seasons. All the science suggests that the combination of fewer wetlands and more cropland will cause duck populations to decline.

In addition, when this 10,000-year-old native prairie is plowed, vast amounts of organic carbon are oxidized and released into the atmosphere as carbon dioxide (CO2), adding significantly to greenhouse gas concentrations that contribute to global warming and climate change. Because of the high species diversity, significant carbon storage, and relatively large amounts of native habitat still present but under imminent threat, the Missouri Coteau area has been identified as a priority area for protection by several conservation organizations.

Generalized Management Situation:

During the past century, conditions for waterfowl in this area have deteriorated as wetlands have been drained and filled and grasslands plowed and planted for agricultural crop production. Ironically, climate concern has helped "heat up" the biofuels sector -- corn and cellulosic ethanol -- putting further pressure on food prices that were already being ratcheted up by rising petroleum prices and natural disasters. New farm technologies allow production on previously untillable land, and new crop varieties allow the production of crops historically unsuitable to the region. All of these factors are putting upward pressure on cropland rents while programs and economic activities that historically supported grassland conservation have become uncompetitive and under funded when compared to other land use options.

Counterproductive federal agricultural policies are also having an impact. The Conservation Reserve Program (CRP), which rewards farmers for converting highly erodible cropland to grass, is now less able to compete with the agricultural land market as the 10- to 15-year contracts expire. Almost 420,000 acres of North Dakota CRP grassland — more than 12 percent of the state's total — were converted back to cropland in 2007 alone. Over 1.7 million acres of CRP land in North Dakota is set to expire over the next few years, over 60% of the state's total. The expected expiration of 5.6 million acres of CRP in the Northern Great Plains over the next few years could result in the release of 78 million metric tons of CO_2, which is equivalent to putting 15 million new cars on the road for a year.

The ability of federal agencies to conserve land in North Dakota is challenged as well; a backlash against federal land acquisition resulted in legislative veto power over the expenditure of federal duck stamp money to purchase habitat in the state. In light of these challenges, environmental markets for products like carbon offset credits driven by sound policy could offer new opportunities for conservation and climate adaptation.

Grasslands, like forests, store large amounts of carbon. Unlike forests, however, grasslands store most of their carbon underground in the soils as a result of the growth and decay of root matter and the incorporation of aboveground stems and leaves. In the Northern Great Plains, native grasslands that have existed for 10,000 years contain 27-38 metric tons of carbon (C) per acre, carbon that remains stored unless the ground is plowed and converted to cropland. However, once converted, about 20-50% of the stored carbon is lost to the atmosphere as CO_2. Soil organic carbon can be restored by planting grass on former cropland. In the Northern Great Plains, sequestration rates of 0.4 metric tons C/acre/year can result from grassland restoration. And while forests can sequester three to six times that amount, the vastness of the grassland region makes it an important mitigation opportunity that also provides vital adaptation benefits to populations of waterfowl and people who depend on the resource. The approach of native prairie protection and restoration is also scalable up to the approximately 19.6 million acres of native grasslands remaining in the eastern Dakotas portion of the PPR, of which over 18 million remain unprotected.

Because of the ecological value of native prairie to waterfowl, the importance of the carbon reservoir, and the rate at which native grassland is being converted, Ducks Unlimited has developed a method to produce carbon offset credits based on avoided loss of grassland-soil organic carbon in the Missouri Coteau.

Goals and Objectives:

The overarching goal of the project is to protect and preserve approximately 26,000 acres of critical waterfowl breeding habitat on existing native prairie grasslands in the Missouri Coteau region of North Dakota by combining traditional conservation easements with carbon market-based financing. The project is designed to support a broader conservation goal of 300,000 acres of native prairie for Ducks Unlimited's Rescue the Duck Factory campaign. The campaign goal will cost approximately $110 million and will avoid the release of over 9 million tons of CO_2 . This project demonstrates how combining a traditional practice (conservation easements) with a contemporary funding approach (carbon markets) can create powerful and cost-effective results. The project will achieve three critical goals: helping waterfowl adapt to climate change, reducing a source of greenhouse gas, and providing a new funding source for the conservation effort.

Voluntary and regulatory carbon markets recognize terrestrial carbon sequestration, natural processes through which plants extract carbon dioxide from the atmosphere, as a method for reducing greenhouse gas emissions. In addition, landscape scale waterfowl habitat conservation can be achieved through the creation of carbon credits that result from either avoiding the loss (conversion) of native prairie or from restoring grass on former cropland for the purpose of reducing greenhouse gas emissions.

The Avoided Grassland Conversion carbon project method developed by Ducks Unlimited is the first terrestrial carbon sequestration project in North America to achieve certification and a gold rating under the Climate, Community, and Biodiversity Standard (CCBS). The project will not only help maintain waterfowl populations by securing threatened breeding habitat but also contribute towards reducing the 20% of global CO_2 emissions resulting from land conversion.

There is abundant opportunity for this landscape-level adaptation strategy to be scaled up to the expanse of unprotected grasslands. Future climate legislation that recognizes avoided grassland conversion as a valid carbon sequestration and offset strategy would facilitate significant private investment in conservation. In 2003, there were 405 million acres of rangeland in the conterminous U.S. that was not federally owned. Including pasture and CRP (restored grass), there was 553 million acres of grassland in the U.S. With carbon market-based financing, it would be possible for Ducks Unlimited to protect up to 50,000 acres per year. By comparison, 74,000 acres were converted in Montana, South Dakota, and North Dakota in 2006 alone.

Conservation Outcomes:

Implementation of perpetual conservation easements on the project properties will prohibit conversion of native grasslands to crop-based agriculture. This will avoid the release of CO_2 into the atmosphere through the oxidation of soil organic carbon and protect critical waterfowl breeding habitat currently under significant threat. Landowners receive payments for conservation easements and transfer of greenhouse gas rights on their properties. The purchased easements are donated to the U.S. Fish and Wildlife Service and incorporated into the National Wildlife Refuge System. If the goal of protecting all 26,000 acres is achieved, the project will help mitigate climate change by preventing the release of approximately 795,000 metric tons of carbon dioxide over 99 years and will also protect biodiversity, waterfowl habitat, and community values in the region.

Implementation Challenges:

While there is increasing consensus about the importance of incorporating assessments of ecosystem services in resource management decisions, measuring the values of these services provided by different waterfowl habitats has proven difficult. A standardized method for calculating carbon sequestration and storage benefits for terrestrial carbon projects is important for a future market. Within a national carbon offset program, grassland preservation and restoration must be recognized as an important way to slow or mitigate climate change, analogous to avoided deforestation and re-forestation in terms of desirable environmental benefits. In addition, grassland carbon projects should be coupled with perpetual conservation easements that ensure grasslands will remain intact forever for the maximum benefit for waterfowl and permanent carbon storage. Purchased easements have proven to be popular with landowners and effective in sustaining grasslands, but require significant upfront capital investment in exchange for marketable carbon credits that are generated and sold gradually over long periods of time. Cooperation between policymakers, scientists, and the financial sector is needed to ensure proper development of the carbon market and the accounting rules for terrestrial carbon offsets.

6.2 Case Study Cost Analysis

Carbon project financing based on a market driven by a national carbon offset program would create important incentives for landowners to undertake land management practices that increase carbon storage and reduce emissions while conserving critical habitat for waterfowl. Currently, over 850 landowners in North Dakota are on the waiting list for conservation easements with the U.S. Fish and Wildlife Service (FWS). Unfortunately, the FWS does not have adequate funding to meet this demand so market-based conservation financing could potentially offer a solution. Preserving with conservation easements the approximately 397,500 acres of grassland owned by the landowners on the waiting list would cost approximately $121 million.

6.3 Project Tasks, Timelines, and Costs

Example tasks, costs, and timeline for developing a carbon program in the PPR with a 5,000-acre native prairie grassland conservation goal are outlined below. These estimates will vary depending on easement costs as well as the outcome of future climate legislation, which may or may not result in a regulated carbon market.

TASKS	NARRATIVE	COST
	YEAR ONE	
Develop a carbon project design document (PDD) for validation by an approved third party verifier	Assess project's methods. Prepare documentation used to evaluate its qualifications as an emissions reduction activity within a particular greenhouse gas reduction program or standard. The PDD addresses project components including project location technology used carbon measurement methods project participants explanation of co-benefits monitoring plan	$30,000 - $50,000

Enroll landowners	Pay staff and administrative costs for aggregating suitable native prairie grassland tracts averaging 300 acres each and enrolling landowners at a cost of $10 to $15 per acre X 5,000 acres	$50,000 - $75,000
	YEAR TWO	
Pay landowners for easements	$100-$250 per acre X 5000 acres	$500,000 - $1,250,000
Purchase greenhouse gas rights	Difficult to determine due to limited availability of market price signals; estimated purchase price of greenhouse gas rights based on the Chicago Climate Exchange and other competing landuse practices: $20-$30 per acre X 5,000 acres	$100,000 - $150,000
	YEAR THREE	
Monitor easements for compliance	Initiate annual monitoring of perpetual conservation easements to ensure compliance with stipulated land management practices. Cost is assumed by the agency holding the easement (U.S. Fish and Wildlife Service).	Not applicable
Verify carbon credits	Measure and verify carbon credits. Because the carbon value of grasslands is stored underground, monitoring might be achieved via aerial surveys, satellite or other forms of remote sensing. Frequency and cost of third-party credit verification vary by program. Credit buyer assumes verification costs for this project.	Not applicable
	YEAR FOUR	
Sell carbon credits	Potential annual revenue based on the aggregated properties producing approximately 1513 metric tons of CO2 credits per year at $6 per metric ton. Policy and accounting rules could develop that increase incentives or facilitate the sale of forward streams of credits for terrestrial carbon projects using perpetual conservation easements. Upfront revenue potential could then approach $900,000 for all carbon offsets produced over the 99-year project.	Annual revenue: $9,078

	TOTALS	
	Total project implementation costs	$650,000 - $1,475,000
	Potential revenues from carbon credit sales: $9,000 annually x 99 years	$891,000
	Depending on actual expenses and credit sales, net cost or earnings of conserving and protecting 5,000 acres of Prairie Pothole Region waterfowl grassland habitat for 99 years	Costs up to $1,475,000 or earnings up to $250,000

7. CONCLUSION

Because traditional conservation strategies are part of the solution for assisting waterfowl adaptation to climate change, protecting existing investments in landscapes important to waterfowl should be a policy priority. Other national policies currently being considered will help reduce carbon dioxide levels and other atmospheric emissions. Conservation partners and policymakers must continue to develop ways in which landowners can receive financial incentives for protecting waterfowl habitat and for preserving carbon stores on their property. Since prairie wetlands and grasslands provide both benefits, future government policies could supply significant new support for conserving these vital waterfowl breeding habitats.

The mutual benefits of conserving habitat for waterfowl and reducing carbon dioxide levels in the atmosphere are not limited to the prairies. Conservation of boreal forest landscapes, bottomland hardwood forests and coastal wetlands could also help reduce carbon dioxide emissions and atmospheric levels while providing vital habitat for waterfowl and other wildlife. This could lead to even greater support for waterfowl habitat conservation — a vital factor in sustaining duck populations and to the very future of waterfowling

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