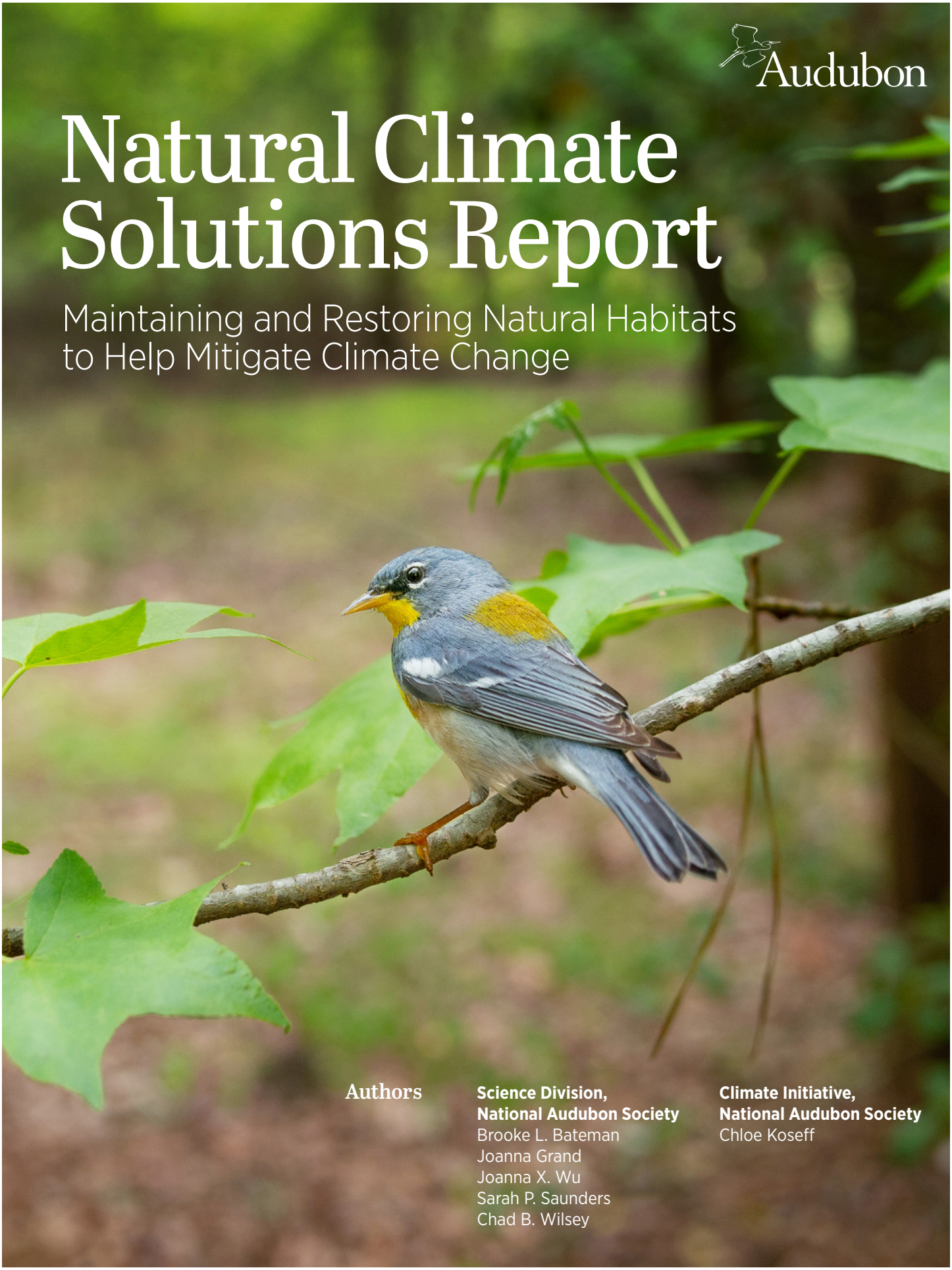

Audubon

Natural Climate Solutions Report

Maintaining and Restoring Natural Habitats to Help Mitigate Climate Change

Authors

Science Division, National Audubon Society
Brooke L. Bateman
Joanna Grand
Joanna X. Wu
Sarah P. Saunders
Chad B. Wilsey

Climate Initiative, National Audubon Society
Chloe Koseff

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Greater Sage-Grouse in Carbon County, Wyoming

A Letter from Dr. Gray

Elizabeth Gray, Ph.D.
Interim CEO
National Audubon Society

IN 2019 AUDUBON'S *SURVIVAL BY DEGREES* report sounded a stark warning: Without meaningful action to mitigate the impacts of climate change, two-thirds of North American bird species are at risk of extinction. This Natural Climate Solutions Report provides a scientific framework to help us address this existential threat. As a scientist, I appreciate the rigor and sophistication of our science team's analysis; as a conservationist, I'm energized by what it tells us about how, together, we can safeguard our environment and secure a resilient future for birds and for people.

Audubon's science team focused on one of the most powerful tools in the climate mitigation toolkit: the natural ability of ecosystems to store carbon. By keeping more carbon in the ground and capturing it in plants, we can reduce carbon dioxide, a potent greenhouse gas, in our atmosphere. What's needed is a unifying way to identify, prioritize, and capitalize on the best opportunities to maximize the impact of this important natural climate solution.

Audubon's science team focused on one of the most powerful tools in the climate mitigation toolkit: the natural ability of ecosystems to store carbon.

That's where birds—and this report—come in. We looked at forest, grassland, aridland, coastal and interior wetland, tundra, and urban and suburban ecosystems. In each, we found significant overlap between critical bird habitat areas and areas of high carbon value—both current carbon stores and active or potential carbon sinks for sequestering atmospheric carbon. The bottom line: what's good for birds is also good for climate change mitigation.

In addition, as the first study of high carbon value areas to factor in projected climate impacts on birds, this report gives Audubon and our conservation partners a future-focused lens for prioritizing and advancing natural climate solutions that benefit both birds and people.

The following are some key findings and recommendations from our analysis:

- Ongoing conservation and restoration of the priority areas identified in our report is estimated to deliver up to 23% of the US commitment to draw down greenhouse gas emissions in the 2016 Paris Agreement.
- The majority (67%) of these priority areas are on private lands. This points to the vital role of landowner and community engagement in land management and stewardship.
- Forests store more carbon than any other ecosystem, due to both the value of trees as carbon sinks and the amount of forested land. Our report identifies 538 million acres of priority forest. With upwards of 60% of this land in private ownership, landowner engagement in programs such as Audubon's Healthy Forests Initiative has a critical role to play, along with protection of public lands like Alaska's 16.7 million-acre Tongass National Forest. Conservation and restoration of our priority forest areas is essential for the survival of many climate-vulnerable bird species, including the Wood Thrush.
- Coastal wetlands store the highest amount of carbon per acre and represent a significant opportunity for increased carbon sequestration through restoration; they are also important to multiple bird species, including threatened shorebirds like the Piping Plover. Our analysis identified 24.7 million acres of priority coastal wetland habitats. More than 65% of these priority areas are privately owned, underscoring the importance of policies that incentivize and support natural climate solutions that build resilience for coastal communities and wildlife.
- Grassland birds are among our most vulnerable species, and grassland ecosystems store a very significant share of the earth's terrestrial carbon. Looking ahead, grassland ecosystems represent both opportunity and risk. Without active conservation and restoration, some current carbon sinks are in danger of becoming carbon sources. More than 81% of the 576 million acres of priority grasslands identified in our report are privately owned, making programs that engage landowners, like Audubon's Conservation Ranching program, and public policies that provide incentives for conservation both essential for advancing natural climate solutions.
- Urban and suburban areas present opportunities to restore natural ecosystems and create carbon sinks, while also protecting biodiversity, increasing environmental equity, and delivering health and quality of life benefits for communities.

Tongass National Forest

Survival by Degrees was a rallying call for Audubon's bipartisan network of members, donors, and people who love birds, inspiring them to speak out about climate change—in communities, statehouses, and on Capitol Hill. That same passion for birds, together with the important findings in the following report, will help us find common ground and build momentum for the sound, science-based policy decisions and on-the-ground conservation action we need now to safeguard the future for birds and all of us who share the planet with them.

I welcome your feedback and questions on this report.

Conservation and restoration of our priority areas is essential for the survival of many climate-vulnerable bird species.

Richardson Bay, California

Why we care about Natural Climate Solutions

HABITAT LOSS AND CLIMATE CHANGE ARE two of the most pervasive and detrimental threats to biodiversity globally.[1–3] In the last few decades alone, we have lost 3 billion birds in North America, and many of these declines have been attributed to land conversion and other human-induced changes impacting habitats.[4] Conversion of natural ecosystems also accelerates climate change by contributing up to 20% of the world's greenhouse gas (GHG) emissions through released carbon into the atmosphere.[5] This number is expected to increase as climate change continues and warming leads to accelerated carbon loss.[5] Climate change also contributes to species' declines.[6] Audubon's *Survival by Degrees* report, released in October 2019, indicated that future climate change will put two-thirds of birds in North America at risk due to projected range losses. Of the 604 species analyzed, none were projected to remain untouched by either climate-driven range loss or extreme weather, sea level rise, or other climate change-related threats.[7–9] A critical next step is to identify opportunities for birds to adapt to changing climate conditions via maintenance and restoration of areas that are important for birds today and under future climate change, which we refer to as Climate Strongholds.

With proactive conservation efforts, Climate Strongholds can serve as resilient habitats for birds in a changing climate.

We need solutions to protect biodiversity well into the future that both stabilize climate change below the 2°C climate tipping point[8] and restore degraded ecosystems. Natural Climate Solutions (NCS) are part of the solution set. NCS maintain, through conservation and/or sustainable management, and restore natural ecosystems, which in turn act as effective carbon stores and sinks that can actively pull carbon dioxide from the atmosphere and convert it into carbon that gets stored within plants and soils. In the United States (US), NCS have the potential to mitigate nearly a quarter of net annual GHG emissions[10] without infringing on requirements for human food and fiber.[10] Restoring or maintaining natural ecosystems also provides co-benefits to people and biodiversity, including clean and abundant drinking water from healthy watersheds; increased productivity from healthy soils; flood control from functioning wetlands; and temperature moderation and high-quality wildlife habitats from healthy forests. Implementing NCS, such as reforestation and wetland restoration, is primarily a climate mitigation strategy; however, to the extent that these actions can improve ecosystem function, NCS have additional climate adaptation potential. Maintaining existing intact ecosystems and preventing their conversion or implementing sustainable management practices keeps carbon stores contained within the system and allows species to adapt to a changing climate by providing necessary resources. By restoring ecosystems that have already been converted, we can generate carbon sinks that sequester carbon from the atmosphere, while also providing new, natural habitats for wildlife.

In this report, we identify: (1) areas of high carbon storage (i.e. carbon already stored in an ecosystem in plants and soils) and active carbon sinks (i.e. areas that remove more carbon from the atmosphere than they emit, thus lowering the concentration of carbon dioxide in the atmosphere) that align with areas that are important for birds today and will continue to be under future climate change scenarios (i.e., Climate Strongholds[1]), and (2) potential carbon sinks (i.e., areas that have the potential to sequester more carbon if anthropogenic disturbance is minimized) that align with Vulnerable Climate Strongholds at risk of conversion. We focus on carbon because carbon dioxide is the primary GHG that NCS have the potential to mitigate. Our analyses cover several ecosystems in the US: forests, grasslands and rangelands, aridlands, coastal wetlands, interior wetlands, urban and suburban systems, as well as Alaskan forests, coastal and interior wetlands, and tundra and alpine systems. This report focuses on the potential of natural ecosystems; however, environmental justice and equity, as well as Indigenous land stewardship, must also be addressed when implementing land conservation and management actions. Environmental justice in conservation planning will be integral to a forthcoming Natural Climate Solutions, Part II report.

For each of the ecosystems, we report the following:

PRIORITY AREAS TO MAINTAIN
Climate Strongholds for birds that align with high carbon stores or active carbon sinks. These areas are recommended for maintaining current ecosystem function via conservation or management within a NCS framework.

PRIORITY AREAS TO RESTORE
Vulnerable Climate Strongholds for birds that align with potential carbon sinks. These areas are recommended for restoration or improved management efforts within a NCS framework. Note that we do not present priority areas to restore for Alaska, given data limitations and the relatively low human footprint.

To better understand opportunities for NCS, we also summarize carbon storage, active and maximum potential carbon sequestration rates, as well as land ownership and designated land protection status (i.e., GAP status;[11]) in priority areas. Further, we tally the number of bird species—including climate-vulnerable species, species at risk from climate change-related threats, and Audubon priority birds—that could benefit from maintenance and restoration through NCS in these priority areas.

We need solutions that both stabilize climate change below the 2°C climate tipping point and restore degraded ecosystems.

Forests

Black-throated Blue Warbler

Wood Thrush

Pygmy Nuthatch

Important habitat for birds

In the US, forests are home to the greatest diversity of breeding bird species.[12,13] Forests provide key habitats for birds throughout their annual life cycles, with up to one-third of migratory birds depending on forests at some point during the year.[14] Forests are also home to some of our most climate-vulnerable groups of species, with forest-dwelling bird taxa projected to have nearly 80% of species at risk from climate change-related range loss, and 55% facing multiple coincident climate-related threats.[8,9]

Climate change mitigation potential

Globally, temperate forests act as net carbon sinks, sequestering carbon from the atmosphere to be stored for decades or even centuries. Forests store about 45% of the world's terrestrial carbon[15] and could store up to 25% of the atmospheric carbon needed to avoid the 2°C climate tipping point.[5] In the US, forests also have the largest climate mitigation potential of all ecosystems.[10] Halting forest loss and conversion is an essential climate change mitigation strategy, as it protects carbon currently stored in those systems; any carbon lost to conversion would not be recoverable in the timeframe needed to address climate change.[16,17] Of all NCS, reforestation is the single largest mitigation opportunity, and also benefits biodiversity, air filtration, soil enrichment, water filtration, and flood control.[10]

Bird species that co-benefit

Restoring native forests reduces the effects of habitat fragmentation and degradation, benefitting several vulnerable bird species, including Wood Thrush (*Hylocichla mustelina*), which has declined by 60% over the last 50 years.[4,18] Reforestation also creates early successional forest, a critical habitat type for many birds like American Woodcock (*Scolopax minor*), a game species which is declining across parts of its range.[19] Conserving and maintaining old-growth forests across the US not only benefits birds like the Spotted Owl (*Strix occidentalis*) and Black-throated Blue Warbler (*Setophaga caerulescens*) that depend on these interior, undisturbed forests, but these habitats also mitigate climate change by acting as buffers from rising temperatures through microclimate moderation effects[20]. NCS that support birds and carbon storage/sequestration in forested ecosystems are shown in Table 1.

American Woodcock^+
Black-throated Blue Warbler^
Brown-headed Nuthatch*^+
Cerulean Warbler*^+
Florida Scrub-Jay*^+
Hermit Warbler^+
Northern Parula^+
Pygmy Nuthatch^
Spotted Owl^
Swainson's Warbler*
Wilson's Warbler^+
Wood Thrush^+

*Audubon priority birds
^Climate-vulnerable species
+Species at risk to climate-related threats

Table 1.

Natural Climate Solution	Description
Forest protection	Establish large-scale incentives and regulatory mechanisms to address deforestation
Avoided forest conversion	Improve production on existing agricultural lands to avoid unsustainable forest conversion
Natural forest management	End logging in old-growth forests, extend harvest cycles, and adopt reduced-impact logging practices
Reforestation	Active planting of native trees and long-term habitat management
Wildfire management	Prescribe low-intensity fires in fire-prone systems and fire control practices (e.g., fire breaks at forest edges) to avoid unintended fires

Results

- More than 313M acres of forests represent priority areas to maintain and more than 224M acres of degraded forests represent priority areas to restore (Figures 1a and 2a). Note that 20% of priority restoration areas were not forested prior to European colonization and should be assessed for forest restoration potential locally.
- Total forest carbon storage is higher than any other ecosystem—priority forests to maintain comprise 34% and priority forests to restore comprise 38% of total carbon storage within their respective priority areas across all ecosystems (Figure 23).
- Forests actively sequester more carbon per acre than any other ecosystem, regardless of priority area type (Figure 22).
- At least 59% of priority areas to maintain and 70% of priority areas to restore are located on privately-owned land (Figures 1b and 2b). Of those that are protected, the majority are GAP Status 3, a multi-use designation (see GAP status definitions; Figures 1c and 2c). See Supplementary Information for ownership and protection acreages.
- Forests provide habitat for up to 211 bird species regionally in priority areas to maintain (including 50 Audubon priority species and up to 86 species identified as climate-vulnerable[8]) and up to 202 bird species in priority areas to restore (including 50 Audubon priority species and up to 86 climate-vulnerable species).

CONSERVATION AND MANAGEMENT OPPORTUNITIES

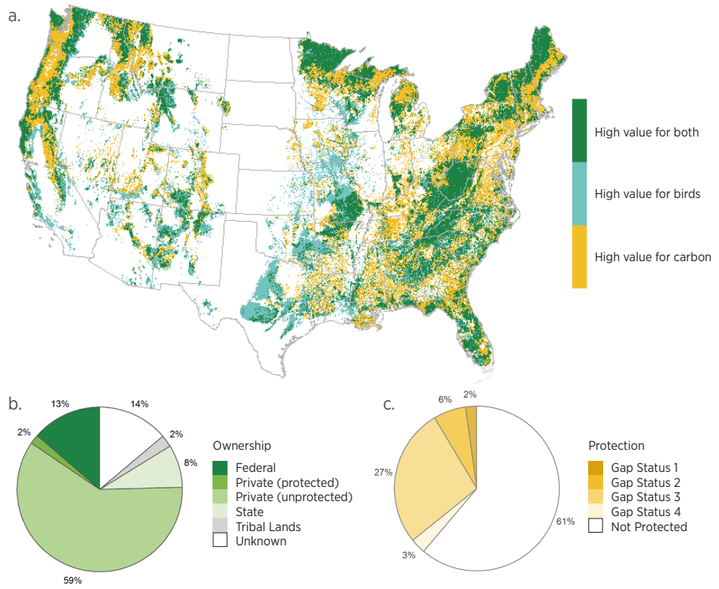


Figure 1. (a) Priority areas to maintain for forests: areas of high value for carbon (yellow; top 40% of carbon storage and active sequestration values), birds (blue; top 40% of climate stronghold ranks), and overlap (green). (b) Proportions of priority areas to maintain under various ownership designations (designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 1 (high) – 4 (low); white = unprotected (i.e., without mandate)).

RESTORATION OPPORTUNITIES

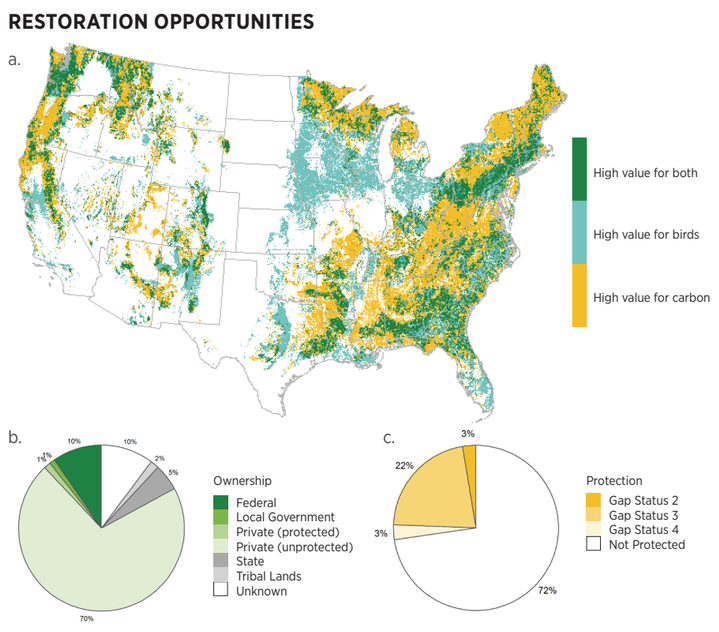
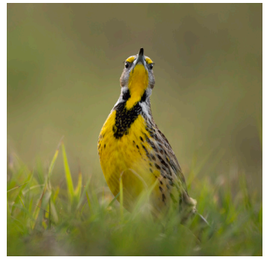


Figure 2. (a) Priority areas to restore for forests: areas of vulnerable strongholds for birds that are disturbance prone and align with areas that are potential carbon sinks. Areas of high value for carbon (yellow; top 40% of maximum potential sequestration values), birds (blue; top 40% of vulnerable stronghold ranks), and the overlap (green). (b) Proportions of priority areas to restore under various ownership designations (b; designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 2 (moderate) – 4 (low); Gap status 1 = 0%; white = unprotected (i.e., without mandate)).

Grasslands & Rangelands

Grasshopper Sparrow

Burrowing Owl



Eastern Meadowlark

Important habitat for birds

More than 80% of North American grasslands have been converted to agriculture or other land uses,[21] and grassland bird populations have been drastically declining over the past 50 years.[22,23] Nearly 70% of grassland species are vulnerable to extinction due to climate change.[7,8,24] Because most natural grasslands have been converted to cropland or pasture, grassland birds are now largely dependent on habitats that are managed for agricultural production.[25] Rangelands are increasingly important for grassland birds because they are not managed as intensively as cropland or pasture, and with proper grazing and management, can provide critical habitat for a diverse group of grassland birds.[26]

Climate change mitigation potential

Grasslands store approximately one-third of the terrestrial soil organic carbon pool.[27] Grassland carbon sinks result when increased carbon dioxide and nitrogen deposition[28] in the soil creates a positive feedback loop that increases soil fertility and causes plants to grow faster.[29] Thus, grassland restoration efforts targeted at reducing or preventing soil degradation and increasing carbon stocks can have significant climate change mitigation benefits.[27] In some regions, grasslands will store more carbon for a longer period of time than forests, as climate change reduces the resilience of trees to drought and fire, favoring grasses and other kinds of herbaceous vegetation.[30]

Bird species that co-benefit

Two grassland species that may substantially co-benefit from avoided grassland conversion and restoration are Eastern Meadowlark (*Sturnella magna*) and Grasshopper Sparrow (*Ammodramus savannarum*). Both species have experienced alarming declines due to loss and degradation of native grassland habitats, with 3 out of 4 Eastern Meadowlarks lost since 1970[4] and Grasshopper Sparrow population declines of up to 72% over the same period.[13] A diverse group of bird species depends on grasslands and rangelands for breeding and overwintering; thus, maintenance of these habitat types is likely to co-benefit additional species, including shorebirds, prairie chickens, and owls. NCS that support birds and carbon storage/sequestration in grassland and rangeland ecosystems are shown in Table 2.

Bobolink^
Burrowing Owl+
Eastern Meadowlark^+
Grasshopper Sparrow+
Lesser Prairie-Chicken*^
Long-billed Curlew*^+
Tricolored Blackbird*^+
Upland Sandpiper*
Western Meadowlark*

*Audubon priority birds
^Climate-vulnerable species
+Species at risk to climate-related threats

Table 2.

Natural Climate Solution	Description
Avoided native grassland conversion	Enhance efforts to intensify sustainable agriculture to help meet food demands while avoiding grassland loss
Regenerative grazing	Implement rotational grazing and bunched grazing to increase carbon storage and profits for ranchers, and reduce soil erosion
Restore native grassland	Restore native grasslands, control erosion, promote healthy watersheds, improve nutrient cycling, and where appropriate, use livestock as a management tool
Conservation ranching	Incentivize sustainable grassland and rangeland stewardship practices through a certification label on beef products

http://naturalclimatesolutions.org

Results

- More than 333M acres of grasslands and rangelands represent priority areas to maintain, and more than 243M acres of degraded grasslands represent priority areas to restore (Figures 3a and 4a). Note that 21% of priority restoration areas were not grassland prior to European colonization and should be assessed for restoration potential locally. Our grassland/rangeland designation also included areas of pasture and hay because these habitats can support grassland species when restored or managed appropriately; in some cases, these areas include irrigation-dependent habitats (e.g. alfalfa). Management or restoration of these agriculture-associated grassland habitats for birds should be assessed locally.

- Total carbon storage is high in grasslands and rangelands. Priority grasslands and rangelands to maintain and restore comprise 19% and 27%of total carbon storage within their respective priority areas across all ecosystems (Figure 23). However, in periods of high disturbance, grasslands may also act as the largest carbon sources per acre (not shown), losing more carbon to the atmosphere than any other ecosystem.

- Grasslands and rangelands have relatively high carbon sink potential, regardless of priority area type (Figure 22c).

- At least 81% of priority areas to maintain and 91% of priority areas to restore are located on privately-owned land (Figures 3b and 4b), making market-based initiatives like Audubon's Conservation Ranching Program particularly important in these ecosystems. Of those that are protected, the majority are GAP Status 3, a multi-use designation (see GAP status definitions; Figures 3c and 4c). See Supplementary Information for ownership and protection acreages.

- Grasslands and rangelands provide habitat for up to 216 bird species regionally in priority areas to maintain (including 50 Audubon priority species and up to 85 species identified as climate-vulnerable[8]) and up to 217 bird species regionally in priority areas to restore (including 49 Audubon priority species and up to 79 climate-vulnerable species).

CONSERVATION AND MANAGEMENT OPPORTUNITIES

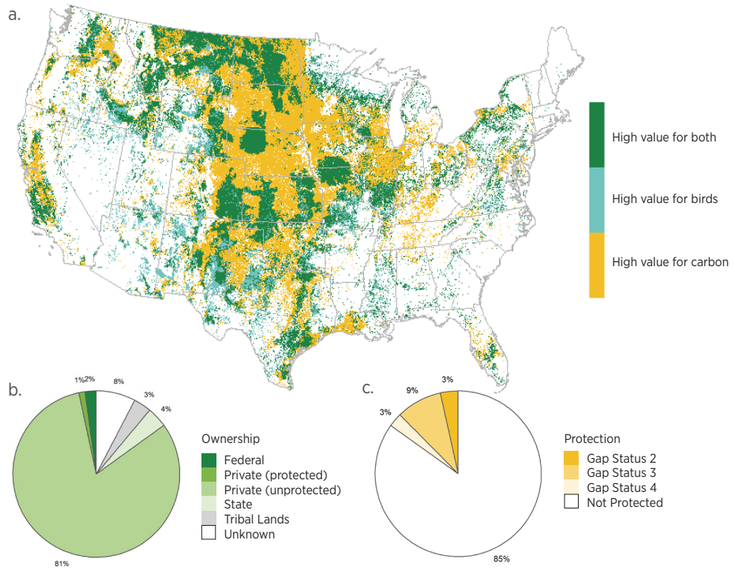


Figure 3. (a) Priority areas to maintain for grasslands and rangelands: areas of high value for carbon (yellow; top 40% of carbon storage and active sequestration values), birds (blue; top 40% of climate stronghold ranks), and overlap (green). (b) Proportions of priority areas to maintain under various ownership designations (designations associated with <1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 2 (moderate) – 4 (low); Gap status 1 = 0%; white = unprotected (i.e., without mandate)).

RESTORATION OPPORTUNITIES

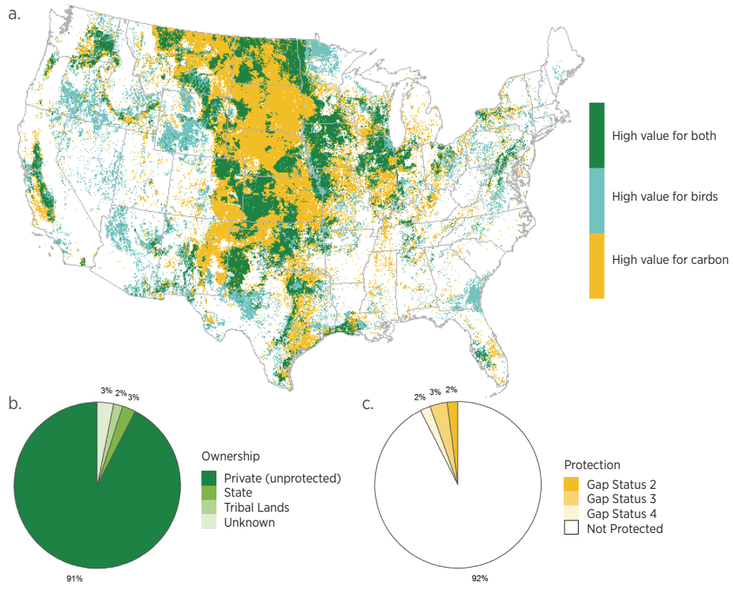
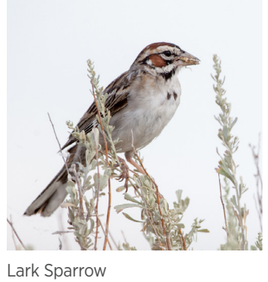


Figure 4. (a) Priority areas to restore for grasslands and rangelands: areas of vulnerable strongholds for birds that are disturbance prone and align with areas that are potential carbon sinks. Areas of high value for carbon (yellow; top 40% of maximum potential sequestration values), birds (blue; top 40% of vulnerable stronghold ranks), and the overlap (green). (b) Proportions of priority areas to restore under various ownership designations (designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 2 (moderate) – 4 (low); Gap status 1 = 0%; white = unprotected (i.e., without mandate)).

Aridlands

Greater Sage-Grouse

Sage Thrasher



Lark Sparrow

Important habitat for birds

Aridlands (western regions dominated by scrub or chaparral) provide breeding and wintering habitat for many bird species, as well as migratory stopover habitat for forest-dwelling species.[31] Arid shrub-steppe ecosystems like sagebrush have declined by up to 50% from their original range,[32] and the loss of these habitats puts aridland birds that depend on these systems at risk.[33] Since 1968, populations of 17 aridland bird species have dropped by 46%.[34] Long-term habitat degradation from unsustainable land use, invasions of non-native grasses, and encroachment by trees and shrubs have played significant roles in the decline of aridland birds.

Climate change mitigation potential

Globally, aridlands cover approximately 40% of land area and account for roughly 8% of terrestrial carbon stocks.[35] Due to their vast global extent, their cumulative potential for carbon sequestration is significant.[36] They are characterized by water scarcity and high temperatures—conditions that are not ideal for plant productivity or carbon sequestration, and are vulnerable to degradation and desertification from unsustainable agricultural practices which contribute to carbon loss. Yet despite their relatively low carbon sequestration capacity, there is evidence of significant carbon storage in certain arid and semiarid ecosystems, such as the Mojave Desert.[37] Other aridlands, such as cold desert and sagebrush shrubland, also act as carbon sinks in their natural states.[38,39]

Bird species that co-benefit

Restoring degraded aridlands to a more functional state would not only increase carbon sequestration, but would also increase air and water quality, wildfire abatement, wildlife habitat, biodiversity, and aesthetic and recreational values. Several climate-vulnerable bird species depend on aridland sagebrush habitat, including the Sage Thrasher (*Oreoscoptes montanus*), which has declined by up to 52% over the last 50 years,[13,34] and the Greater Sage-Grouse (*Centrocercus urophasianus*), which has experienced an 80% decline over the same period.[40] NCS that support birds and carbon storage/sequestration in aridland ecosystems are shown in Table 3.

Bendire's Thrasher+
Greater Sage-Grouse*^
Lark Sparrow+
LeConte's Thrasher^
Long-billed Curlew*^+
Sage Thrasher^
Sagebrush Sparrow^+

*Audubon priority species
^Climate-vulnerable species
+Species at risk to climate-related threats

Table 3.

Natural Climate Solution	Description
Restore degraded shrublands	Plant native, drought-resistant plants to regenerate soils and form long-term carbon sinks
Reduce cheatgrass invasions	Identify and use competitive native perennial plants for rehabilitation from cheatgrass invasion
Regenerative grazing	Implement rotational grazing and bunched grazing to increase carbon storage and reduce soil erosion
Conservation ranching	Where it is an appropriate management technique, provide incentives for sustainable aridland stewardship practices through a certification label on beef products

http://naturalclimatesolutions.org

Results

- More than 87M acres of aridlands represent priority areas to maintain, and more than 82M acres of degraded aridlands represent priority areas to restore (Figures 5a and 6a). Note that 12% of restoration priority areas were not aridlands/shrublands prior to European colonization and should be assessed for aridland restoration potential locally.
- Total carbon storage is relatively low in aridland habitats. Priority aridlands to maintain and restore comprise 2% and 4% of total carbon storage within their respective priority areas across all ecosystems (Figure 23).
- Aridlands have relatively high carbon sink potential per acre, regardless of priority area type (Figure 22c). However, aridlands may also be substantial carbon sources (not shown), with roughly twice as much carbon loss as other ecosystems during high disturbance periods.
- At least 37% of priority areas to maintain and 41% of priority areas to restore are located on privately-owned land (Figures 5b and 6b), making market-based initiatives like Audubon's Conservation Ranching Program particularly important in these ecosystems. Of those that are protected, the majority are GAP Status 3, a multi-use designation (see GAP status definitions; Figures 5c and 6c). See Supplementary Information for ownership and protection acreages.
- Aridlands and shrublands provide habitat for up to 212 bird species regionally in priority areas to maintain (including 33 Audubon priority species and up to 78 species identified as climate-vulnerable[8]) and up to 211 bird species in priority areas to restore (including 34 Audubon priority species and up to 76 climate-vulnerable species).

CONSERVATION AND MANAGEMENT OPPORTUNITIES

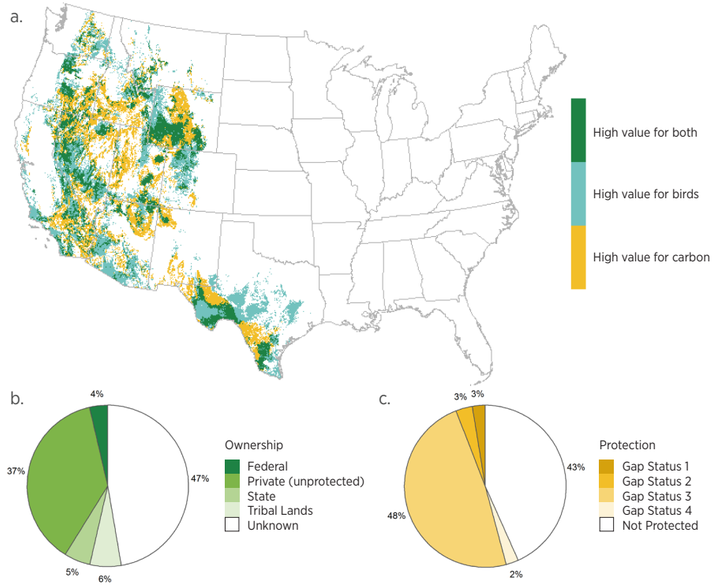


Figure 5. (a) Priority areas to maintain for aridlands: areas of high value for carbon (yellow; top 40% of carbon storage and active sequestration values), birds (blue; top 40% of climate stronghold ranks), and overlap (green). (b) Proportions of priority areas to maintain under various ownership designations (designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 1 (high) – 4 (low); white = unprotected (i.e., without mandate)).

RESTORATION OPPORTUNITIES

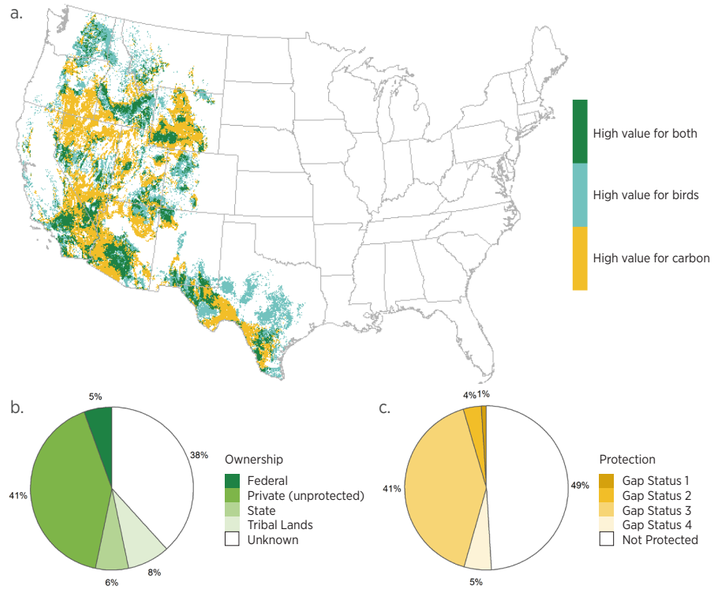


Figure 6. (a) Priority areas to restore for aridlands: areas of vulnerable strongholds for birds that are disturbance prone and align with areas that are potential carbon sinks. Areas of high value for carbon (yellow; top 40% of maximum potential sequestration values), birds (blue; top 40% of vulnerable stronghold ranks), and the overlap (green). (b) Proportions of priority areas to restore under various ownership designations (designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 1 (high) – 4 (low); white = unprotected (i.e., without mandate)).

Coastal Wetlands

Least Tern

Sanderling

Ruddy Turnstone

Important habitat for birds

Coastal wetlands, or wetlands adjacent to marine waterbodies, provide critical habitat for many bird species, including waterbirds, waterfowl, shorebirds, and marshbirds. These highly productive wetlands support large numbers of birds, many of which are migratory and obtain essential nutrients from aquatic prey during their journeys. Despite their significance, we continue to lose 80,000 acres of coastal wetlands in the US each year, primarily due to development, drainage, erosion, and sea level rise.[41] If current trends continue, a further 30–40% of coastal wetland habitats (e.g., tidal marshes, mudflats, seagrasses, mangroves) could be lost in the next 100 years.[42] Similarly, coastal birds are experiencing multiple, coincident climate change-related threats, including loss of habitat to sea level rise and continued urbanization.[9]

Climate change mitigation potential

Coastal wetlands play an important role in global carbon cycles[43] because they sequester "blue carbon" (i.e., carbon sequestered by oceans and wetlands), trap organic carbon from multiple sources, and delay the decay of organic materials (which releases carbon) for longer periods. Vegetated coastal habitats such as seagrasses, tidal marshes, and mangroves occupy only 0.2% of the ocean surface, but account for nearly 50% of the total carbon burial in ocean sediments.[44] Globally, coastal wetlands bury about the same amount of carbon belowground as terrestrial forests do in soil annually, even though they represent less than 3% of the area of forests.[44] Conversion to agriculture, drainage for coastal development, and other forms of degradation of coastal wetlands can release between 165 and 1124 million tons of carbon dioxide into the atmosphere every year,[42] which has the potential to convert these blue carbon ecosystems from carbon sinks to carbon sources.[42,45]

Bird species that co-benefit

Climate-vulnerable shorebird species like Sanderling (*Calidris alba*), Western Sandpiper (*Calidris mauri*), and Ruddy Turnstone (*Arenaria interpres*) are susceptible to habitat degradation and have declined due to loss of coastal habitats throughout their ranges. Generally, coastal birds are the most climate-vulnerable bird group in North America and face multiple, coincident threats like sea level rise, flooding, and heat waves alongside urban expansion.[9] Marshbird species like Clapper Rail (*Rallus crepitans*) and Ridgway's Rail (*Rallus obsoletus*) are also experiencing precipitous declines because of coastal wetland loss. Restoration of wetland habitats will help mitigate climate change and provide critical breeding and wintering areas for wetland-reliant species. NCS that support birds and carbon storage/sequestration in coastal wetland ecosystems are shown in Table 4.

Table 4.

Natural Climate Solution	Description
Restore coastal wetlands	Plant native plants, restore natural hydrology (e.g., via water control structures or improved drainage), and improve nutrient management practices; facilitate adaptation potential of salt marshes for sea level rise through raising marsh profile or providing passage for marsh migration, restoration of seagrass beds
Avoided coastal wetland conversion	Establish new protected areas, expand the Coastal Barrier Resource System, improve land tenure, and enforce land-use laws
Reduce anthropogenic nutrient inputs	Improve agricultural practices and treatment of municipal wastewater, improve habitat upstream through re-vegetation to reduce sediment inputs, and better control runoff from storm sewers
Living shorelines	Use plants or other natural elements for stabilization to reduce soil erosion, reduce flooding, and improve coastal resilience

American Oystercatcher*+
Black Skimmer*+
Clapper Rail*^+
Least Tern*
Long-billed Curlew*^+
Piping Plover*^+
Ridgway's Rail*+
Ruddy Turnstone^
Saltmarsh Sparrow*^+
Sanderling^
Western Sandpiper*^+

*Audubon priority species
^Climate-vulnerable species
+Species at risk to climate-related threats

Results

- More than 10.6M acres of coastal wetland habitats represent priority areas to maintain, and more than 14.1M acres of degraded coastal wetlands represent priority areas to restore (Figures 7a and 8a).
- Total carbon storage is relatively low in coastal wetlands due to their limited area. Priority wetland areas to maintain and restore comprise 2% and 4% of total carbon storage within their respective priority areas across all ecosystems (Figure 23).
- Despite their limited area, coastal wetlands store the highest amount of carbon per acre in priority areas to maintain (Figure 22a) and also have the highest potential carbon sequestration per acre, regardless of priority area type (Figure 22c).
- At least 65% of priority areas to maintain and 83% of priority areas to restore are located on privately-owned land (Figures 7b and 8b). Of those that are protected, the majority are GAP Status 2 (see GAP status definitions; Figures 7c and 8c). See Supplementary Information for ownership and protection acreages.
- Coastal wetland areas provide habitat for up to 213 bird species regionally in priority areas to maintain (including 45 Audubon priority species and up to 78 species identified as climate-vulnerable[8]) and up to 218 bird species regionally in priority areas to restore (including 45 Audubon priority species and up to 78 climate-vulnerable species).

CONSERVATION AND MANAGEMENT OPPORTUNITIES

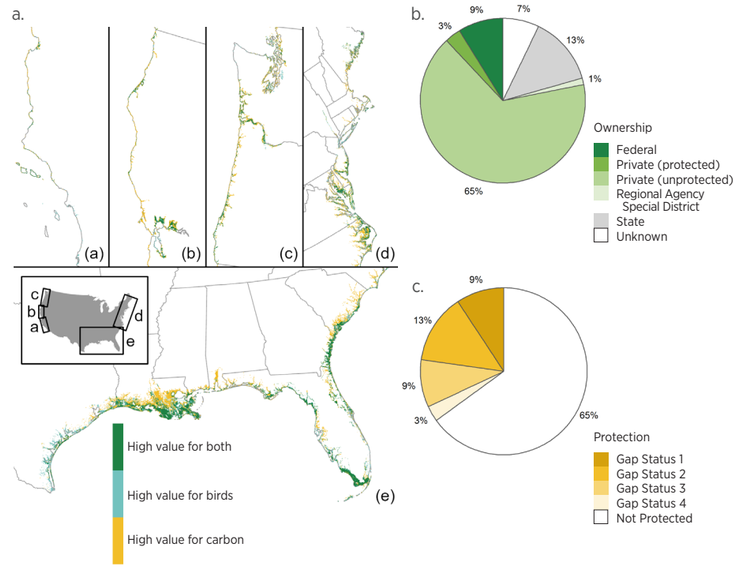


Figure 7. Priority areas to maintain for coastal wetland habitats (marshes, beaches, and mudflats): areas of high value for carbon (yellow; top 40% of carbon storage and active sequestration values), birds (blue; top 40% of climate stronghold ranks), and overlap (green). (b) Proportions of priority areas to maintain under various ownership designations (designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 1 (high) – 4 (low); white = unprotected (i.e., without mandate)).

RESTORATION OPPORTUNITIES

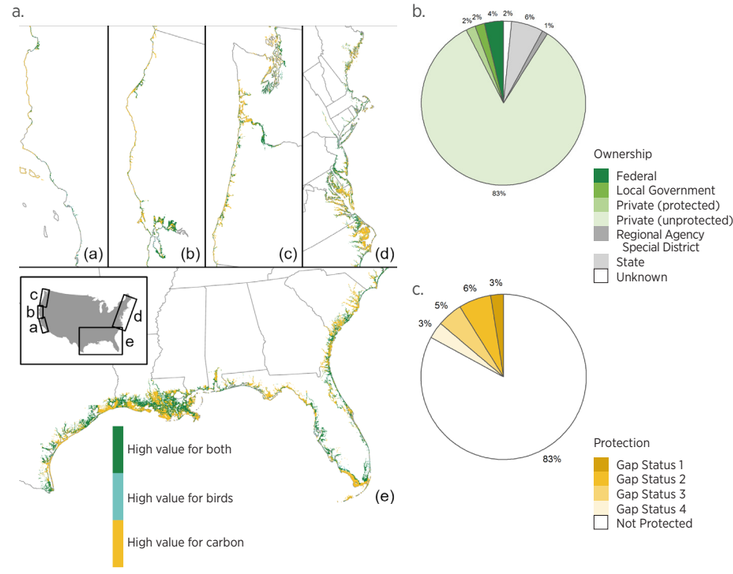


Figure 8. (a) Priority areas to restore for coastal wetland habitats (marshes, beaches, and mudflats): areas of vulnerable strongholds for birds that are disturbance prone and align with areas that are potential carbon sinks. Areas of high value for carbon (yellow; top 40% of potential sequestration values), birds (blue; top 40% of vulnerable stronghold ranks), and the overlap (green). (b) Proportions of priority areas to restore under various ownership designations (designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 1 (high) – 4 (low); white = unprotected (i.e., without mandate)).

Interior Wetlands

Green-winged Teal

Snowy Egret

Sora

Important habitat for birds

Interior freshwater wetlands include peatlands (bogs and fens), mineral wetlands (marshes, tundra), and seasonal or permanent floodplains. Although not freshwater, interior saline lakes (e.g., Salton Sea, Great Salt Lake) and their associated freshwater wetlands also serve as important habitats for birds in the western US, providing critical resources for many species traveling across arid western landscapes. Many birds, such as waterfowl, woodpeckers, hawks, wading birds, and songbirds depend on the energy-rich resources wetlands provide for breeding and refueling during migration. In fact, one-third of all bird species depend on food resources in interior wetlands during migratory periods. Further, roughly half of all North American bird species nest and/or forage in wetlands. Despite their significance, the US has experienced substantial wetland loss and degradation (e.g., harmful algal blooms) from water diversions, pollution, and nutrient loading (e.g., fertilizer application), among other causes, since the 1950s. These threats have led to significant population declines of many wetland-dependent bird species.[46] Wetland bird taxa are vulnerable to climate change, with nearly 80% of waterbird species at risk.[47]

Climate change mitigation potential

Carbon storage in wetlands accumulates primarily in the soil over centuries to millennia, making wetlands an effective long-term approach to mitigating climate change.[50] Freshwater wetlands can be significant carbon sinks due to their high productivity and waterlogged conditions; however, there are many different types of freshwater wetlands and some sequester more carbon than others.[47] Their anaerobic soil conditions prevent the decomposition of dead biomass and retain sequestered carbon within the soil, but also make freshwater wetlands the largest natural source of methane emissions. Recent research suggests that most wetlands are net carbon sinks after accounting for methane's decay rate.[48] Saline lakes may also act as net carbon sinks under high pH conditions. Hydrologic interactions of wetlands within the broader landscape should be considered when implementing NCS, given that such interactions can impact mitigation capacity, sustainability, and cost-efficiency.[49]

Bird species that co-benefit

Removing invasive species (e.g., *Phragmites*, hybrid cattail) in freshwater wetland habitats will create high-quality habitat for declining marshbird species such as Common Gallinule (*Gallinula galeata*) and Sora (*Porzana carolina*). In peatlands, restoration and avoided conversion offer mitigation benefits while increasing habitat for peatland birds like the climate-vulnerable Sedge Wren (*Cistothorus platensis*) and Golden-winged Warbler (*Vermivora chrysoptera*). Protecting and restoring flows to saline lakes will help mitigate degradation of limited Eared Grebe (*Podiceps nigricollis*) habitat. NCS that support birds and carbon storage/sequestration in freshwater wetlands are shown in Table 5.

Table 5.

Natural Climate Solution	Description
Interior freshwater wetland restoration	Restore the natural flows and seasonal variability, often using water control structures, of water and soil saturation that provide co-benefits to biodiversity
Protection or avoided conversion/destruction of wetlands	Ensure that existing local, state and federal wetland protections and regulations are followed
Reduce anthropogenic nutrient inputs	Improve agricultural practices and treatment of municipal wastewater, and control runoff from storm sewers
Invasive plant removal	Remove invasive species like *Phragmites* and manage hybrid cattail to help restore interspersion of emergent vegetation, improve water quality, and improve habitat for declining marshbird species

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Common Gallinule+
Eared Grebe*^+
Golden-winged Warbler*^
Green-winged Teal^
Louisiana Waterthrush*^+
Sandhill Crane*^
Sedge Wren^
Semipalmated Sandpiper*^+
Snowy Egret
Sora^+
Whimbrel^+

*Audubon priority species
^Climate-vulnerable species
+Species at risk to climate-related threats

Results

- More than 87M acres of interior wetlands represent priority areas to maintain, and more than 106M acres of degraded freshwater wetlands represent priority areas to restore (Figures 9a and 10a).
- Carbon storage is relatively high in interior wetlands. Priority areas to maintain and restore comprise 11% and 20% of total carbon storage within their respective priority areas across all ecosystems (Figure 23).
- Interior wetlands have relatively high maximum potential carbon sink value per acre, regardless of priority area type (Figure 22c).
- At least 64% of priority areas to maintain and 76% of priority areas to restore are located on private land (Figures 9b and 10b). Of those that are protected, the majority are GAP Status 3 (see GAP status definitions; Figures 9c and 10c). See Supplementary Information for ownership and protection acreages.
- Interior wetlands provide habitat for up to 210 bird species regionally in priority areas to maintain (including 50 Audubon priority species and up to 84 species identified as climate-vulnerable[8]) and up to 218 bird species regionally in priority areas to restore (including 50 Audubon priority species and up to 78 climate-vulnerable species).

CONSERVATION AND MANAGEMENT OPPORTUNITIES

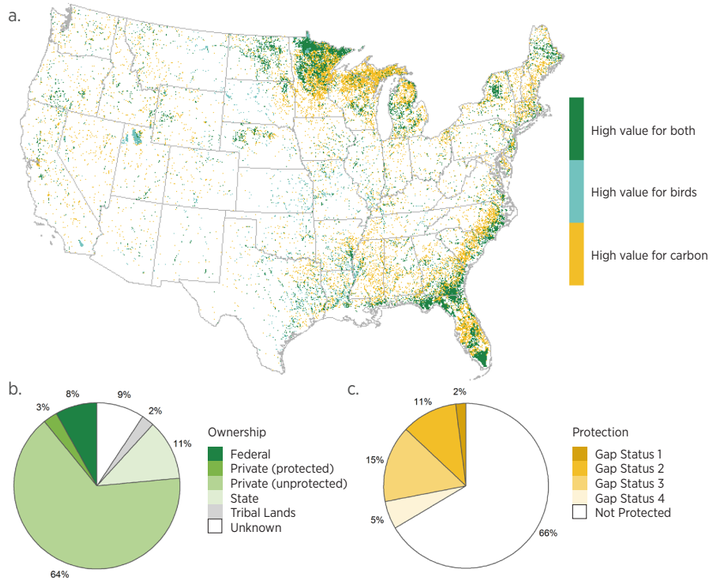

Figure 9. (a) Priority areas to maintain for interior wetlands: areas of high value for carbon (yellow; top 40% of carbon storage and active sequestration values), birds (blue; top 40% of climate stronghold ranks), and overlap (green). (b) Proportions of priority areas to maintain under various ownership designations (designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 1 (high) – 4 (low); white = unprotected (i.e., without mandate)).

RESTORATION OPPORTUNITIES

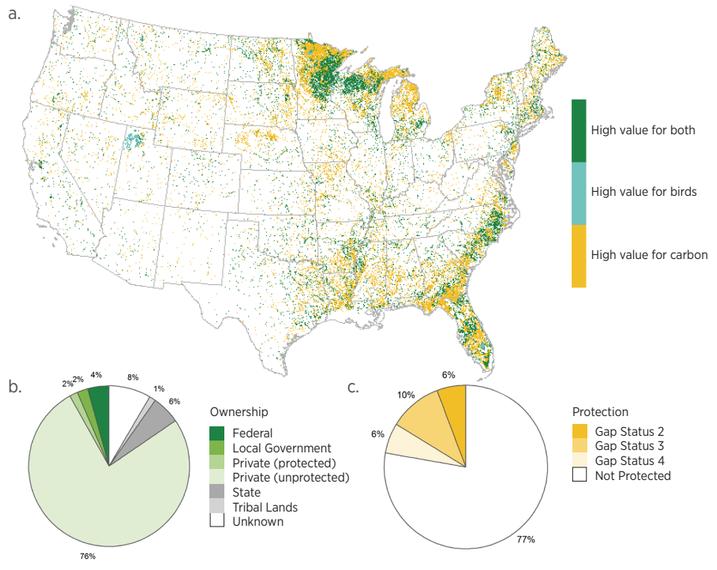

Figure 10. (a) Priority areas to restore for interior wetlands: areas of vulnerable strongholds for birds that are disturbance prone and align with areas that are potential carbon sinks. Areas of high value for carbon (yellow; top 40% of maximum potential sequestration values), birds (blue; top 40% of vulnerable stronghold ranks), and the overlap (green). (b) Proportions of priority areas to restore under various ownership designations (designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 2 (moderate) – 4 (low); Gap status 1 = 0%, white = unprotected (i.e., without mandate)).

Urban/Suburban

American Goldfinch

Blue Jay

Song Sparrow

Important habitat for birds

Although urbanized environments are largely a result of conversion from natural habitats, many bird species have become adapted to urban environments because of the increased access to food resources (e.g., backyard bird feeders) and, in some cases, greater protection from natural predators. While highly dense areas provide little habitat for birds, suburban and natural green areas can promote an even greater diversity of habitats than unmodified landscapes, thus potentially supporting a greater variety and abundance of birds.[51]

Climate change mitigation potential

Urban and suburban areas can emit more carbon than they sequester, but they vary greatly in their range of carbon sequestration rates and should be considered a carbon storage opportunity because there is potential for urban and suburban areas to become active carbon sinks. For example, forest stands in US cities have relatively high carbon storage capacity compared to non-urban forest stands because tree density is lower in urban-associated environments, allowing trees to grow bigger and faster, thus sequestering more carbon per tree,[52] particularly in suburban and rural areas.[53] Urban trees also increase cooling and therefore decrease associated electricity needs.

Bird species that co-benefit

Promisingly, urban green areas that are important for birds are also the best areas for carbon storage. While ecological innovations of private and public areas need to be compatible with landowner interests, if executed well, they can simultaneously provide habitats for birds and native plants and natural climate solutions. Urban green spaces also provide valuable stopover habitat for birds during spring and fall migrations,[54] and efforts to further improve the safety of urban environments for migratory birds (e.g., reducing light pollution and bird-building collisions) will benefit the birds that pass through these areas. In addition, maintaining a diversity of habitat types (e.g., wetlands, scrub, trees), increasing the size of green spaces, and planting native plants are critical in supporting greater bird diversity and abundance in urbanized environments.[51] NCS that support birds and carbon storage/sequestration in urban and suburban environments are shown in Table 6.

American Goldfinch^+
American Robin^
Blue Jay
Common Grackle+
Mourning Dove+
Northern Cardinal+
Northern Mockingbird+
Song Sparrow^

^Climate-vulnerable species
+ Species at risk to climate-related threats

Table 6.

Natural Climate Solution	Description
Urban green spaces	Revitalize urban green spaces to create wildlife habitat, provide recreational value, and promote carbon sequestration
Natural infrastructure	Add green features to infrastructure (e.g., green roofs, alley & street trees, green playgrounds) to improve carbon storage in urban areas
Blue infrastructure	Add blue infrastructure (e.g., rain gardens, wetland corridors) to provide sustainable drainage systems, improve water quality, and reduce street runoff
Native plant gardens	Plant native plants, which are effective at storing carbon while simultaneously providing vital habitat for birds and pollinators like butterflies, moths, and bees
Composting	Compost improves the soil's ability to stabilize carbon and increases plant growth, thereby pulling more carbon from the atmosphere; composting also reduces methane emissions

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Results

- More than 38M acres of urban and suburban systems represent priority areas to maintain, and more than 55M acres of degraded urban and suburban systems represent priority areas to restore (Figures 11a and 12a).
- Carbon storage is relatively low in urban and suburban environments. Priority areas to maintain and restore in urban and suburban systems comprise 3% and 7% of total carbon storage within their respective priority areas across all ecosystems (Figure 23).
- Priority areas to maintain and restore in urban and suburban systems vary widely in their sequestration potential because they include a mosaic of natural habitats and ecosystem types. These areas overlap with the priorities to maintain and restore, respectively, in other ecosystems in this report, including forests (17%, 20%), grasslands (13%, 9%), aridlands (1%, 3%), coastal wetlands (2%, 2%), and interior wetlands (14%, 13%).
- Only 9% of priority areas to maintain and 8% of priority areas to restore are located on protected land. Of these, the majority are GAP Status 4 (see GAP status definitions; Figures 11c and 12c). See Supplementary Information for ownership and protection acreages.
- Urban and suburban areas are utilized by up to 212 bird species regionally in priority areas to maintain (including 50 Audubon priority species and up to 82 species identified as climate-vulnerable[8]) and up to 213 bird species regionally in priority areas to restore (including 50 Audubon priority species and up to 81 climate-vulnerable species).

CONSERVATION AND MANAGEMENT OPPORTUNITIES

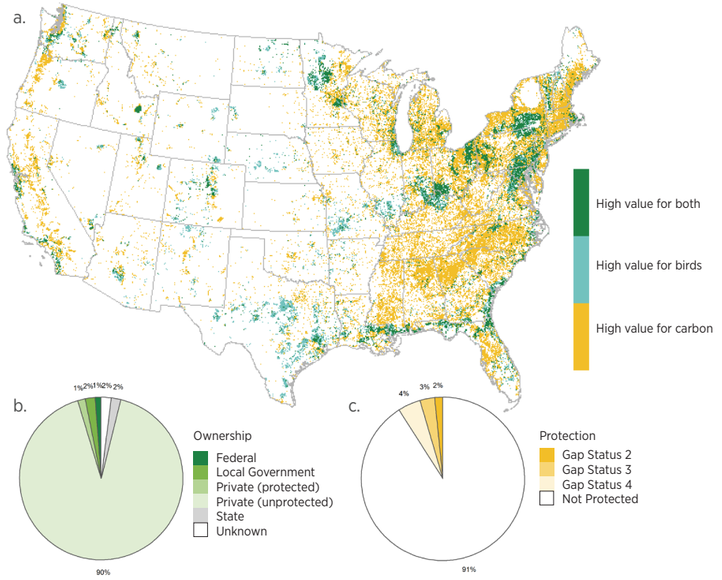


Figure 11. Priority areas to maintain for urban and suburban areas: areas of high value for carbon (yellow; top 40% of carbon storage and active sequestration values), birds (blue; top 20% of climate stronghold ranks), and overlap (green). (b) Proportions of priority areas to maintain under various ownership designations (designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 2 (moderate) – 4 (low); Gap status 1 = 0%; white = unprotected (i.e., without mandate)).

RESTORATION OPPORTUNITIES

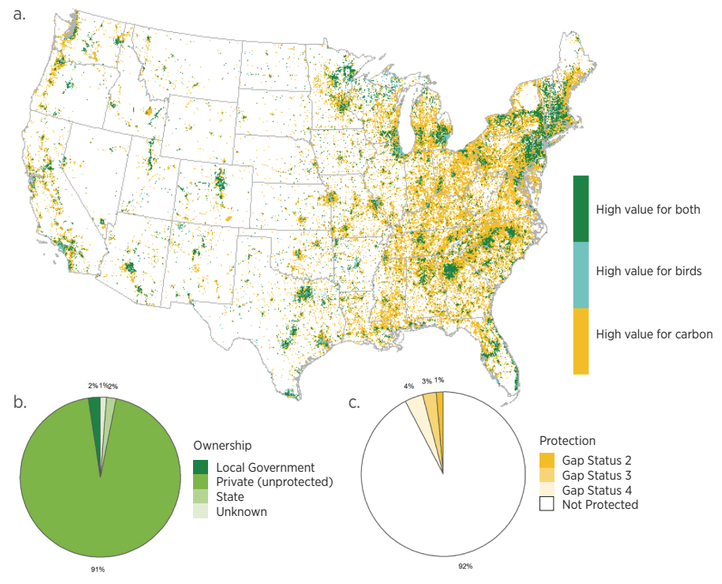


Figure 12. Priority areas to restore for urban and suburban areas: Areas of vulnerable strongholds for birds that are disturbance prone and align with areas that are potential carbon sinks. Areas of high value for carbon (yellow; top 40% of maximum potential sequestration values), birds (blue; top 20% of vulnerable stronghold ranks), and the overlap (green). (b) Proportions of priority areas to restore under various ownership designations (designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 2 (moderate) – 4 (low); Gap status 1 = 0%, white = unprotected (i.e., without mandate)).

Alaska: Forests, Coasts, Wetlands, and Tundra

Varied Thrush

American Golden Plover

Red-throated Loon

Important habitats for birds

Alaska is the largest state in the US, and boasts a diversity of habitats supporting over 500 bird species. Vast interior wetlands cover 43% of the state, along with 47,000 miles of coastline, which hosts 75 million seabirds and 10 million waterfowl.[55] Alaskan forests also host up to 40% of the birds found in North America at any given time.[56] Alaska's Arctic lowland and alpine tundra ecosystems, which are treeless landscapes that transform into high-productivity areas under the extended daylengths in summer, provide critical breeding habitat for migratory bird species from all six continents. In a changing climate, Alaska will become even more integral to species coping with rising temperatures and shifting precipitation patterns.

Climate change mitigation potential

Although Alaska makes up only 18% of the total land area in the US, it contains roughly 53% of the total carbon storage thanks to its forests, coastal and interior wetlands, and tundra habitats.[57] Despite the greater vulnerability of Alaska's carbon storage to climate change, the state is anticipated to continue to act as a carbon sink and sequester carbon through the end of the century as growing seasons lengthen. Forested areas in Alaska, which presently represent 8% of the carbon mitigation nationally,[58] will increase in carbon sequestration ability by 8-27%. Specifically, the Tongass National Forest is the US carbon champion, representing 44% of carbon mitigation capacity across the entire national forest system.[58,59] However, 91% of Alaska's carbon stocks reside in the soils and permafrost of the northern wetlands and Boreal forests, which could shrink up to 25% by the end of the century without climate stabilization.[60]

Bird species that co-benefit

Alaska has more coastline than any other US state, representing ample opportunities to protect and maintain coastal wetland habitats that will co-benefit birds and carbon sequestration. Alaska's forests will also continue to be important for carbon storage and sequestration, as well as for species that depend on Boreal forest habitats like the climate-vulnerable Boreal Chickadee (*Poecile hudsonicus*). Tundra ecosystems in places like the Arctic National Wildlife Refuge, which hosts up to 200 bird species, currently store two times the amount of carbon that is held in the atmosphere[61] and also provide key breeding areas for declining bird species like the Red-throated Loon (*Gavia stellata*). NCS that support birds and carbon storage/sequestration in Alaskan lowland and tundra ecosystems are shown in Table 7. For forests, wetlands and coastal NCS, please see the previous sections.

Table 7.

Natural Climate Solution	Description
Tundra protection	Protect large intact tundra ecosystems like the Arctic National Wildlife Refuge
Rewilding*	Repopulate native herbivores to promote grasses and suppress shrubs and trees to protect permafrost and reduce thawing
Indigenous land management	Consider Indigenous knowledge and practice in land practices; improving Indigenous communities' tenure security can lead to better land protection, management and climate resilience[62]

**NCS that is forthcoming, but may need more research before implementation.*

Forests
Boreal Chickadee*^+
Gray-crowned Rosy-Finch*^
Varied Thrush*^
White-crowned Sparrow*^ +
Greater White-fronted Goose*^+
Red-throated Loon*^+
Western Sandpiper*^+~

Wetlands/coasts
Barrow's Goldeneye* ^+
Black Oystercatcher*+~

Tundra/alpine
American Golden-Plover*^+
Lapland Longspur*^+
Pacific Golden-Plover*^+

*Audubon Alaska watchlist species
^Climate-vulnerable species
+ Species at risk to climate-related threats

Results

- More than 145M acres of Alaskan ecosystems (forests, coasts, wetlands, and tundra) represent priority areas to maintain (Figure 13a).
- Alaskan ecosystems act as important carbon stores. Priority areas to maintain in Alaska comprise 29% of total carbon storage within maintain priority areas across all ecosystems (Figure 23).
- Alaskan ecosystems in priority areas to maintain store the second largest amount of carbon per acre (Figure 22a), as nearly half of the total area is comprised of forests.
- At least 81% of Alaska's priority areas to maintain are located on protected land (Figure 13b), the majority of which are divided between GAP Statuses 1, 3, and 4 (see GAP status definitions; Figures 13c). See Supplementary Information for ownership and protection acreages.
- Alaska provides habitat for up to 163 bird species regionally in priority areas to maintain (including 13 Audubon priority species and up to 109 species identified as climate-vulnerable[8]).

CONSERVATION AND MANAGEMENT OPPORTUNITIES

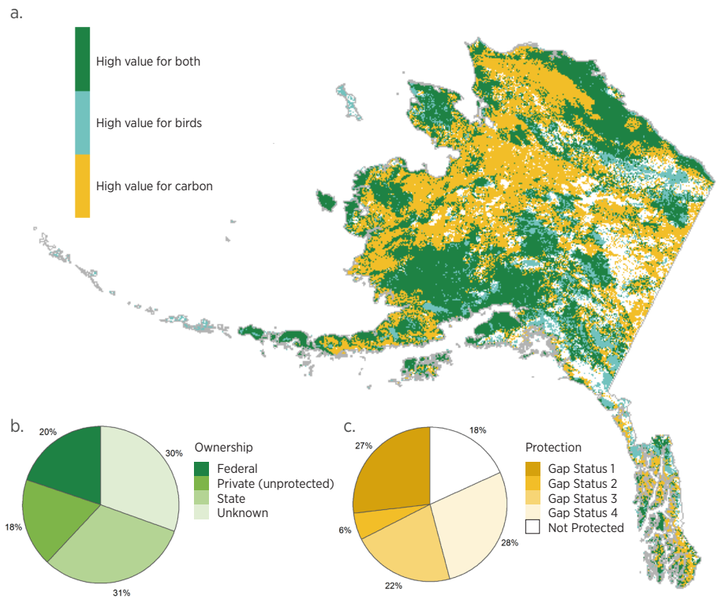


Figure 13. Priority areas to maintain for Alaskan habitats: areas of high value for carbon (yellow; top 40% of carbon storage and active sequestration values), birds (blue; top 40% of climate stronghold ranks), and overlap (green). (b) Proportions of priority areas to maintain under various ownership designations (designations associated with < 1% of priority areas were excluded) and (c) proportions of priority areas to maintain under varying levels of protection (Gap status 1 (high) – 4 (low); white = unprotected (i.e., without mandate)).

ALASKA LAND OWNERSHIP

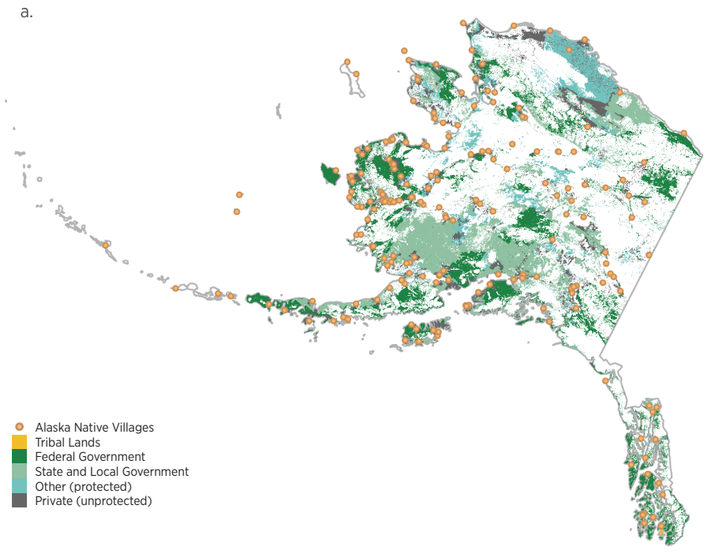


Figure 14. Land ownership for priorities to maintain across all ecosystems in Alaska. Ownership categories were pooled for ease of interpretation. Alaska lands are the traditional territories of 231 federally recognized tribes.

Additional Factors

EACH ECOSYSTEM HAS NATURAL OR ANTHROPOGENIC PROCESSES THAT CAN LEAD TO SIGNIFICANT ECOSYSTEM change and impact the effectiveness of NCS. These include natural disturbances, such as wildfire, and human-induced disturbances, such as sea level rise, that can threaten biodiversity and ecosystem function. These changes can be intermittent, permitting natural or management-driven recovery, or persistent, causing irreversible alterations. For each ecosystem, we highlight one of these additional factors occurring within our priority areas to maintain or restore to further guide implementation of NCS.

Forests

Wildfire is a natural disturbance process that releases carbon sequestered in forested ecosystems. Post-fire habitat and plant regeneration can lead to increased carbon sequestration. However, there has been an increase in climate change-fueled megafires that are outside the range of normal fire regimes, and can prevent natural regeneration, particularly in western forests. Management and/or restoration within these wildfire disturbance areas (Figure 14) should therefore be assessed under local fire management planning and federal/state-level fire response efforts to determine what actions, if any, are needed to promote healthy, resilient forest systems. At least 7% of priority forest areas to restore experience severe wildfire disturbance (Figure 15).

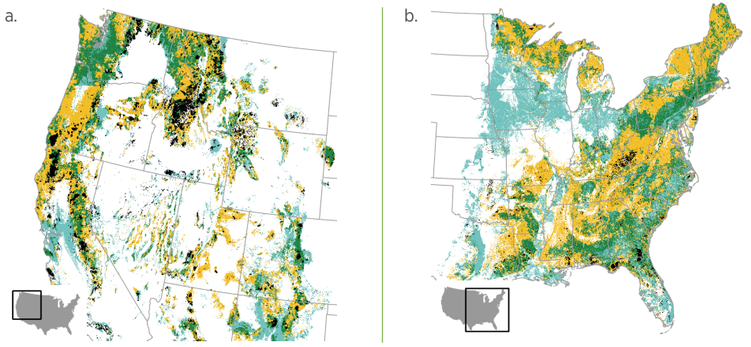


Figure 15. Priority forests to restore with locations of historic fires (1975-2015) in black for a) western forests and b) eastern forests.

Grasslands and Rangelands

One of the largest threats to western rangelands is invasive cheatgrass (*Bromus tectorum*) and other non-native annual grasses.[63] Cheatgrass outcompetes native perennials, as it has the ability to germinate in both fall and spring, and has a high tolerance for grazing and frequent fire.[64] Management and/or restoration within areas of severe cheatgrass invasion (Figure 15) should be carefully assessed to determine whether management efforts are viable. Only about 4% of priority areas to maintain in grasslands and rangelands are severely threatened by cheatgrass, providing ample opportunities to prevent future invasion (Figure 15).

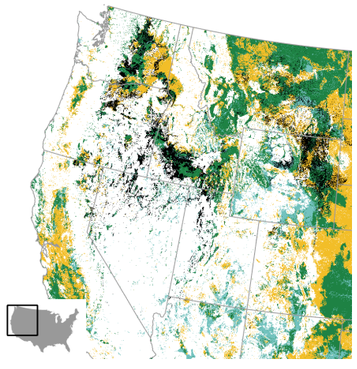


Figure 16. Priority areas to maintain in grasslands and rangelands that also have high cheatgrass invasion (>10% per square kilometer) indicated in black. Efforts to remove cheatgrass in these areas will be needed to maintain suitable habitat and ecosystem function, and locations should be assessed for management viability.

Aridlands

Invasive grasses, such as cheatgrass, are also major contributors to carbon loss in shrub-steppe ecosystems[65] and increases the risk of wildfire. (Figure 17). As in grasslands and rangelands, management and/or restoration within areas of severe cheatgrass invasion should be carefully assessed to determine whether restoration efforts are viable. Only about 17% of priority areas to maintain in aridlands are severely threatened by cheatgrass, providing ample opportunities to prevent future invasion (Figure 17).

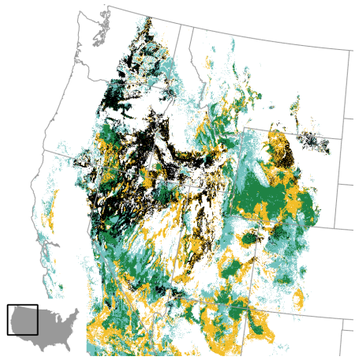


Figure 17. Priority aridlands to maintain with high cheatgrass invasion (>10% per square kilometer) in black. Efforts to remove cheatgrass in these areas will be needed to maintain suitable habitat and ecosystem function and locations should be assessed for management viability.

Coastal Wetlands

Sea level rise is a persistent threat to coastal ecosystems, leading to loss of habitat from inundation and transitions to different habitat types (Figure 17). Sea level rise also threatens coastal communities via flooding, which can impact the quality of our drinking water and the ability to grow crops. Priority areas to restore should therefore be assessed for inundation potential, and whether restoration or natural infrastructure projects are viable. At least 8% of priority coastal wetland areas to restore are threatened by near-term sea level rise (Figure 18).

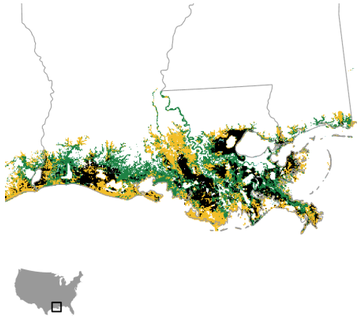


Figure 18. Priority coastal wetlands to restore with predicted habitat transitions due to near-term sea level rise (>50% change in cover by 2030 under an intermediate high scenario) along the Gulf coast in black.

Interior Wetlands

Wetlands can improve water quality by filtering out pollutants from surface water; however, an overabundance of pollutants can lead to wetland impairment. The application of phosphorous fertilizers to crops and subsequent run-off contributes to pollution and nutrient loading in wetlands, which in turn could lead to eutrophication and degradation of freshwater wetland ecosystems. At least 50% of priority interior wetland areas to restore are located in areas with above average phosphorus fertilizer application to crops, which may contribute to eutrophication and degradation of these wetlands (Figure 19).

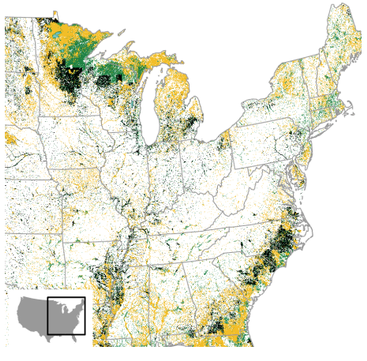


Figure 19. Priority wetlands to restore located in areas with above average phosphorus fertilizer application in black.

Urban/Suburban

Continued development of urban areas reduces their mitigation potential through loss of trees, which intensifies heat effects from impervious surfaces and eliminates a principal absorber of carbon dioxide. Less than 1% of priority areas to restore in urban and suburban environments are threatened by impervious surface heat effects (Figure 20).

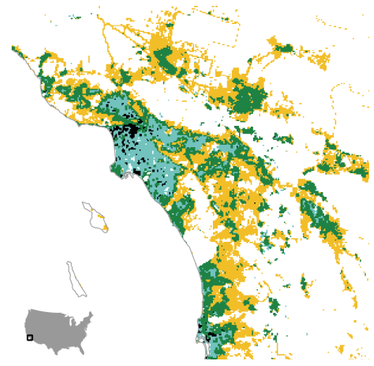


Figure 20. Priority urban and suburban areas to restore with areas of projected impervious surface expansion (>50% impervious cover in 2030) in Southern California in black to demonstrate heat effects.

Alaska

Conventional energy development and mining of resources threatens both the resilience of Alaska's natural ecosystems and avian biodiversity. Up to 86% of priority areas to maintain in Alaska are threatened by mining and conventional energy development (Figure 21).

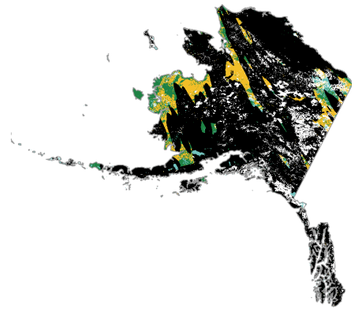


Figure 21. Priority Alaskan habitats to maintain with the potential areas of conventional energy development and resource mining (i.e., coal, gas, oil, metallic and nonmetallic mining) in black.

Summary Findings

THE DIVERSITY OF NATURAL ECOSYSTEMS in the US offers ample opportunities to store and sequester carbon, helping to address climate change. Across forests, grasslands and rangelands, aridlands and shrublands, and coastal and interior wetlands (excluding urban/suburban which includes a variety of habitat types), a total of 71.3 billion tons of carbon across 795+ million acres are stored in priority areas to maintain and an additional 31.7 billion tons of carbon across 435+ million acres are stored in priority areas to restore. That is a total area across all priority areas of more than 1.23 billion acres (or about the size of the 10 largest US states put together) and storage of 103 billion tons of carbon. Over time, these priority areas have acted as net carbon sinks, sequestering more carbon than they emit. The priority areas to maintain sequester, on average, 106.8 million tons of carbon per year, and have the potential to sequester up to 146.3 million tons of carbon per year if human disturbance is minimized. Placing this in units of greenhouse gasses, these priority areas to maintain have the potential to sequester 391.5–536.3 million tons of carbon dioxide, or 17.0–23.2% of the US

Priority areas are not only prime for carbon storage and sequestration, they provide key habitat for birds today and in the future

2016 commitment to the Paris Agreement.[10,66] Similarly, the priority areas to restore sequester, on average, 32.6 million tons of carbon per year, and have a potential sequestration of up to 71 million additional tons of carbon per year if human disturbance is minimized. Placing this in units of greenhouse gasses, these priority areas to restore have the potential to sequester 119.4–290.5 million tons of carbon dioxide, or 5.2–11.3% of the 2016 commitment. The high and low estimates are the difference between carbon sequestration continuing at average historical rates from 1980–2015 versus maximum historical rates. However, the full future potential could be higher still if restoration and management actions are implemented to reduce anthropogenic disturbance. Up to an additional 536.3 million tons of carbon dioxide per year—or 23% of the 2016 commitment—is possible under a scenario of low natural and anthropogenic disturbance, but many ecosystems require disturbance to maintain ecological integrity making this maximum scenario less attainable.

The greatest total carbon storage capacity, defined as a percentage of total storage per priority type across ecosystems, occurred in forests (34% in priority areas to maintain, 38% in priority areas to restore), Alaska (29% for maintain), and grasslands (19% and 27% for maintain and restore, respectively; Figure 23). Forests are also the largest active carbon sinks per acre, on average, across both areas to maintain and restore, and, along with grasslands (largest potential sinks per acre in priority areas to restore), present the greatest opportunity to sequester more carbon through restoration and management efforts. Further, forests actively sequester more than two times the amount of carbon compared to other ecosystems at their maximum (Figure 24a). Because of this, forests offer the greatest benefits from a carbon perspective, as they can sequester carbon rapidly, have a large amount of area that could be restored, and are a relatively stable, long-term storage solution given that carbon stored in living plant materials is well-buffered from carbon loss due to warming temperatures. However, per unit area, many ecosystems provide substantial carbon value; the greatest per-acre carbon storage capacity occurred in priority areas to maintain in coastal wetlands, Alaska, and interior wetlands (Figure 22a). Forest priority areas to maintain are the largest active carbon sinks per acre (Figure 22b), and both forests and coastal wetlands have the largest maximum potential carbon sinks per acre, regardless of priority area type (Figure 22c). Despite the low carbon storage capacity per acre in aridlands and grasslands (Figure 22a), both ecosystems offer some climate change mitigation potential. Aridlands have relatively high potential carbon sink value per acre (Figure 22c), regardless of priority area type, and grasslands also offer valuable sequestration potential via active and potential carbon sequestration (Figures 22b and c). However, in periods of high disturbance, both grasslands and aridlands also act as carbon sources, and can take decades to sequester carbon into their soils. Thus, to maximize the carbon sequestration value, NCS should focus on minimizing disturbances in these ecosystems.

CARBON STORAGE AND SINKS ACROSS ECOSYSTEMS

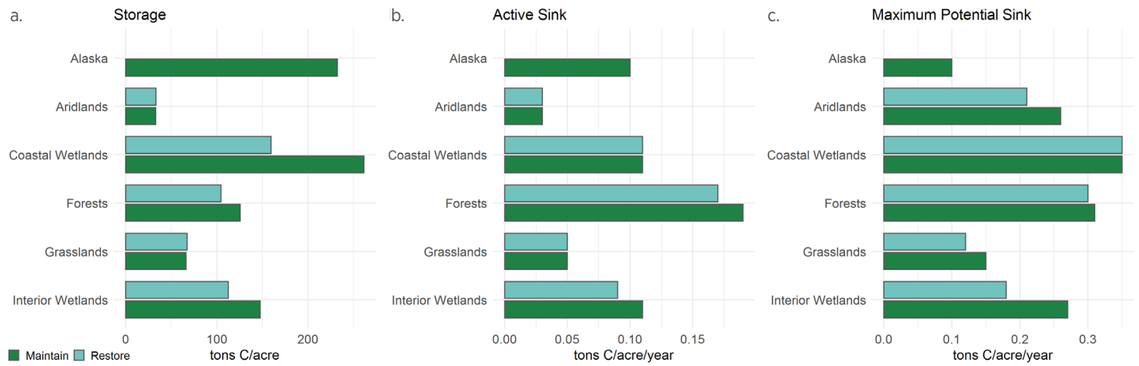


Figure 22. Per unit area carbon values in priorities to maintain (green) and restore (blue), across ecosystems (A) Carbon storage (tons C) per acre; (B) Active carbon sinks (tons C) per acre per year; and (C) maximum potential carbon sinks (tons C) per acre per year. Note that we do not present priority areas to restore for Alaska, given data limitations and the low human footprint. We do not present urban/suburban systems because of their overlap with the other ecosystems shown.

Figure 23. Percent total carbon storage per ecosystem in priority areas to maintain (A) and priority areas to restore (B). Note that we do not present priority areas to restore for Alaska (dark blue). Total carbon storage is 71,285 million tons of carbon stored across 795+ million acres in priority areas to maintain and 31,723 million tons of carbon stored across 435+ million acres in priority areas to restore.

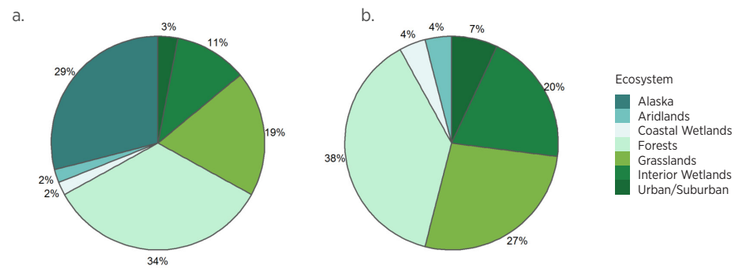
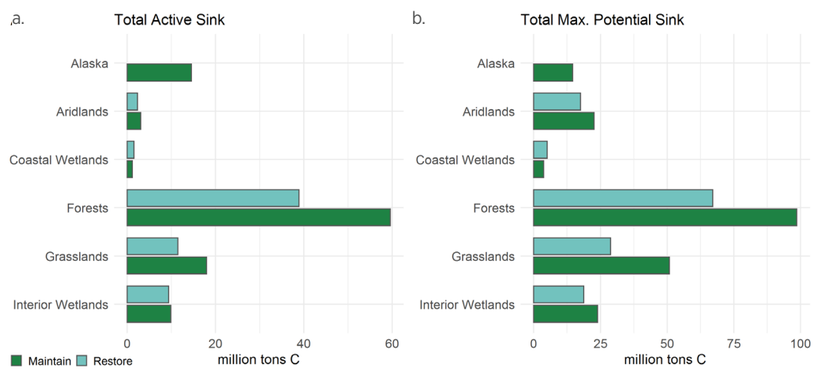


Figure 24. Total carbon (million tons) actively sequestered (A) and total maximum potential carbon to be sequestered (B) by ecosystem in priority areas to maintain (green) and restore (blue). Note that we do not present priority areas to restore for Alaska. We do not present urban/suburban system sink values because of their overlap with the other systems shown.



Maintenance and restoration of natural habitats provide co-benefits to birds. Priority areas are not only prime for carbon storage and sequestration, they provide key habitat for birds today and in the future within Climate Strongholds. In some habitats, these benefits extend to a large number of species, including those vulnerable to range loss under climate change. Grasslands and coastal wetlands have the greatest species richness in identified priority areas (both maintenance and restoration), and Alaska has the greatest climate-vulnerable species richness in priority areas to maintain. Co-benefits for birds and carbon storage are particularly high in forests, grasslands, wetlands, and natural habitats within urban/suburban ecosystems, which all include overlap between priority carbon areas and ranges of 50 (out of 61) Audubon priority birds. Thus, NCS implemented across these ecosystems represent "no-regret" options because they combine climate change mitigation, adaptation, biodiversity conservation (in this case, birds), and sustainable resource management. Audubon is already leading on initiatives and conservation plans that are aligned with this no-regrets NCS framework (see Translating Science into Action section), serving to provide a clear path forward for conserving natural habitats that benefit birds and people.

We know that harnessing the power of NCS to improve decision-making related to land use can help keep climate change under the 2°C climate tipping point.

The majority of priority areas across ecosystems are privately owned (Figure 25). Priority areas in Alaska and aridlands are afforded the most protection, while priority areas in grasslands and urban/suburban areas are the least protected. Additional protection designations in these areas could contribute to climate stabilization and help biodiversity adapt to a changing world. In addition to enhancing protections of natural areas, this report highlights other NCS (Tables 1–7) that will further improve carbon storage while increasing habitat availability for birds. We know that harnessing the power of NCS to improve decision-making related to land use can help keep climate change under the 2°C climate tipping point. Given the recommendations and results provided here, we can further refine these decisions to consider bird habitat needs, ensuring that future efforts are aimed at conserving and restoring natural ecosystems for the benefit of humanity and Earth's biodiversity.

LAND OWNERSHIP FOR PRIORITY AREAS TO MAINTAIN

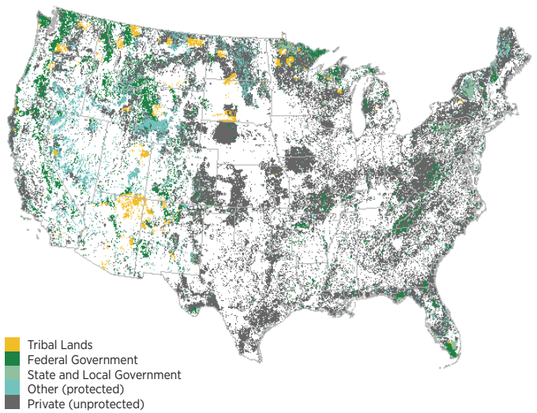


Figure 25a. Land ownership for priorities to maintain across all ecosystems.

LAND OWNERSHIP FOR PRIORITY AREAS TO RESTORE

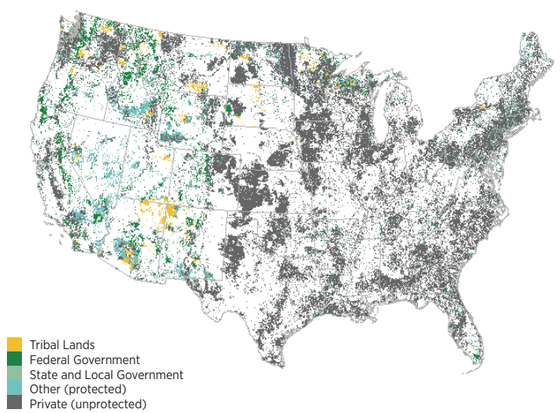


Figure 25b. Land ownership for priorities to restore across all ecosystems.

Relevant Federal and Audubon NCS Initiatives

FORESTS: Forests are crucial to carbon sequestration, and each type of forest has unique benefits. For instance, bottomland hardwood forests are forest wetlands in areas that are seasonally flooded or covered with water for most of the year, and provide flood control, water filtration, and unique bird habitat. The Conservation Reserve Program (CRP) should devote additional resources to the program to restore these forests, which are critical carbon sinks.

GRASSLANDS: Federally, the USDA's Sodsaver program prevents grassland conversion by reducing crop insurance premiums by 50% for lands where native sod is tilled, in effect reducing incentives to convert native grasslands. Currently, Sodsaver only applies to six Midwestern states, but the program should be expanded nationwide. Audubon has developed the Conservation Ranching Initiative to enhance grassland bird conservation and wildlife habitats in the western US by incentivizing good grassland stewardship through a certification label on beef products.

INTERIOR WETLANDS: Wetlands are often drained to accommodate commercial, residential, and agricultural development, but they are critical for carbon sequestration, flood control, and wildlife. It is critical to preserve strong protections for wetlands under the Clean Water Act and state wetlands regulations. At the federal level, the Wetland Reserve Easement (WRE) program should be expanded to help restore, protect, and enhance wetlands through the purchase of conservation easements and cost-share agreements for restoration costs. At Audubon, we have developed an ambitious conservation action plan in the Great Lakes region, *Audubon's Vision: Restoring the Great Lakes for Birds and People*, which offers a blueprint or how best to conserve indispensable coastal areas to address the threats facing the Great Lakes ecosystems.

COASTAL WETLANDS: The damming and diversion of our river systems has led to the depletion of coastal marshes that help protect against storm surges and sequester carbon. Restoration projects, like the Mid-Barataria Sediment Diversion on the Mississippi River, are crucial to replenishing the sediment needed to build up these ecosystems and fortify remaining wetlands against sea level rise. At Audubon, we are working to restore critical coastal habitats with comprehensive plans like our *Gulf Restoration Plan* and *Blueprint for Resilient Coastal Communities in San Francisco Bay*, which describes projects and programs that will benefit key coastal bird species while setting the region on a path to long-term environmental health and resilience.

ARIDLANDS/SHRUBLANDS: The sagebrush steppe ecosystem has been severely degraded, reducing the ability of these habitats to sustain wildlife and sequester carbon, and increasing the severity of wildfires. Bigger investments must be made in on-the-ground projects to restore degraded sagebrush steppe habitat and can be directed through USDA and BLM's existing fire, wildlife management and conservation programs. At Audubon, we are working on enhancing conservation of sagebrush steppe birds like the Greater Sage-Grouse and prairie chicken species, which have suffered serious declines since the 1960s.

Birmingham, Alabama

URBAN/SUBURBAN: Programs like the Urban and Community Forestry Program help local governments, non-profits, and associations plant and care for trees in parks or along streets, and could do even more with expanded funding. At Audubon, the Native Plants for Birds Initiative helps landowners identify appropriate native plants for their gardens, which can help restore urban habitats for birds and pollinators like bees, moths, and butterflies.

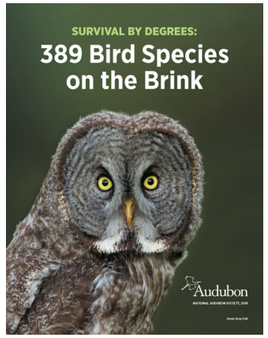
ALASKA: It is estimated that Alaska's Tongass National Forest holds 44% of all the carbon stored in the US National Forest system. The Tongass National Forest contains some of the nation's oldest forests, and it is important to prevent logging within these mature and old growth forests. The Tongass National Forest also contains over 18,000 miles of coastline, more than the rest of the US combined. Important Bird Areas (IBAs) of global significance include some of the nation's most important wetlands for migratory birds, such as the Stikine River Flats and the Chilkat River estuary. Audubon is working to protect both the old growth forests and coastal estuaries of the Tongass National Forest, as well as the last, undeveloped stretch of Arctic Coastal Plain in the Arctic National Wildlife Refuge and the National Petroleum Reserve-Alaska. This coastal landscape includes one of the largest wetland regions in the circumpolar Arctic, the Teshekpuk Lake Wetlands Complex.

Translating Science into Action

BIRDS WE LOVE FACE AN EXTINCTION crisis fueled by disappearing natural spaces, environmental destruction, and climate change. Habitat loss and degradation are key drivers of this looming threat, but by maintaining and restoring the places birds need, we can simultaneously address the twin crises of biodiversity loss and climate change.

Audubon's 2019 *Survival by Degrees* report shows that climate change is the biggest threat to North American birds, with nearly two-thirds of species vulnerable to extinction if we continue emitting greenhouse gases at current rates. However, if we can limit warming to 1.5°C, outcomes could improve for 76% of those imperiled species.

We know what's good for birds is good for people, and through our efforts to save the species we love, we will create a world with cleaner air and water, more resilient cities, and more equitable access to green spaces.



According to the Intergovernmental Panel on Climate Change (IPCC), reaching this goal would require transforming our economy and the way we manage lands and waters to achieve net-zero greenhouse gas emissions by 2050, and encouraging and helping other countries to do the same. Though daunting, this call to action gives us the opportunity to reimagine our energy and transportation systems, our manufacturing industry, and the way we manage our natural and working lands, all while creating good paying jobs. We know what's good for birds is good for people, and through our efforts to save the species we love, we will create a world with cleaner air and water, more resilient cities, and more equitable access to green spaces.

One of our greatest opportunities to address the intersection of climate change and disappearing habitat is through NCS. NCS are actions aimed at conserving, restoring, and sustainably managing natural and human-altered ecosystems to mitigate climate change and enhance biological carbon sinks. In other words, investment in the health and resilience of our farms, fields, and forests could deliver significant emissions reductions, while also improving the places that are becoming increasingly important for the survival of birds. In addition, widespread use of these tactics could protect drinking water sources, increase the resilience of food systems, reduce the heat island effect in cities, and drive investment into rural, urban, and suburban communities across the country. It is critical that policies are designed so that the benefits are felt equitably—from cleaner air across different communities within a city, to equal access to programs for private landowners, to ensuring that traditional and Indigenous land stewards have a say in the decision-making process.

Restoring degraded landscapes or maintaining healthy ecosystems could help achieve a goal of conserving 30% of the nation's lands and waters by 2030, which would help combat both the climate and biodiversity crises. Climate-smart management of both our recreation areas and working lands can help reach this objective.

Audubon is working to promote a slate of policy ideas that will drive the adoption of NCS at the federal, state, and local levels.

Understanding Land Ownership Across the US

Lands and waters in the US are managed through a patchwork of entities, which changes what policies are needed to implement or incentivize NCS in any given area. Government agencies impact both public and private lands through management decisions, funding opportunities, and technical assistance, so it is critical that they have adequate funding, staff, and resources needed to do this important work effectively.

PUBLIC LANDS: The federal government owns and manages about 28% of the country's total land area—approximately


Sandhill Cranes in Nebraska

640 million acres primarily in the western US and Alaska—and other public lands are owned and managed by local, state, and Tribal governments across the country. A large part of that acreage is used for cattle grazing, coal and mineral mining, and oil and gas development, all of which have associated carbon emissions; in fact, about one quarter of all US emissions come from the production and combustion of fossil fuels from federal lands.[67] These lands also boast a wealth of trees, native grasses, tidal marshes, and deep soils that naturally soak up carbon dioxide. There is ample opportunity to better manage and restore these landscapes—especially those held by the US Forest Service (USFS) and the Bureau of Land Management (BLM)—so that they sequester more carbon, support more birds, and provide more places for people to recreate.

PRIVATE LANDS: The majority of US farms, ranches, and forests are privately owned, including over 2 million farms spread across almost 900 million acres. Most of these landowners receive financial and technical assistance from programs at the US Department of Agriculture (USDA), or from state and local agencies related to natural resources, wildlife, and agriculture. Working with private landowners to implement climate-smart agriculture, forestry, and land management practices can reduce emissions, sequester carbon, increase resilience, drive investment into local communities, and help protect some of the country's most important habitats for birds.

Audubon's Policy Priorities

Working Lands

Forests

Increase Funding and Resources for Farm Bill Conservation Programs

The largest source of federal funding for conservation of private lands is directed through the conservation title of the Farm Bill. The Farm Bill programs provide financial and technical assistance, cost-share agreements, easements, and land retirement options for landowners to protect and enhance natural spaces on their property, and may be focused on specific practices or projects, or on improving entire conservation systems. These programs—like the Conservation Stewardship Program (CSP), Environmental Quality Incentives Program (EQIP), Conservation Reserve Program (CRP), Agricultural Conservation Easement Program (ACEP), and Regional Conservation Partnership Program (RCPP)—have caps on funding or acreage enrolled, but remain popular and oversubscribed. Audubon supports significantly increasing resources for Farm Bill conservation programs, as well as prioritizing projects that increase bird habitat, benefit underserved farmers and ranchers, and result in high carbon sequestration, increased resilience, or multiple benefits.

Create New Incentives for Climate-Smart Agriculture and Forestry Practices

In order to adopt new climate-smart practices, landowners often need access to upfront capital and some protection from financial risk. While existing conservation programs play an important role, they may not fit the needs of all landowners. Congress and state agencies have the opportunity to think outside the box with new programs that provide direct payments or tax incentives to reward landowners for implementing climate-smart management practices, or make it easier for private landowners to access voluntary carbon markets that can supplement the cost of management changes that sequester or store additional carbon. New programs could also incentivize sustainably-sourced wood products such as cross-laminated timber, which could also serve as replacements for energy-intensive construction materials such as steel and concrete. All programs put in place must ensure the 'additionality' of the carbon saving, meaning that the actions taken resulted in sequestration that would not have happened without the program intervention. Programs must also guarantee permanence of the emissions reductions, protect against 'leakage' of harmful activities to areas outside of the project boundary, and have systems in place for monitoring, reporting, and verification of emissions reductions, as well as accounting for data uncertainties that still exist for these systems. Programs should be required to put in place safeguards that account for the health of the entire ecosystem over activities that result in short-term gains—including through preserving old-growth trees—and should disqualify actions that result in clearcutting or illegal deforestation.

Restore and Expand Our Forests

Approximately one-third of the United States is forested, which means that the US has an opportunity to substantially increase domestic carbon sequestration, as well as improve bird habitat and water quality. Much of this potential comes from improved forest management, reforestation, mitigation of fire risk, and reduction in land conversion. Management changes, including increasing species and structural diversity and lengthening timber harvest schedules, lead to enhanced natural forest regrowth, which results in forests that store more carbon and support more biodiversity than manually planted tree farms. Many landscapes are also in need of reforestation due to damage from wildfires, disease, and pests—all of which are worsening with climate change and threatening the ability of forests to naturally regenerate. For instance, the US Forest Service (USFS) has a backlog of at least 1.3 million acres that must be addressed. In order to efficiently restock our forests, we must also invest in nursery capacity to ensure there are enough saplings of native and ecologically appropriate tree species on hand. Protection of old-growth forests, like the Tongass National Forest in Alaska, is especially important because they hold massive amounts of carbon, especially in their deep soils, and have larger trees that are more resistant to fires. It is also crucial to invest in urban forestry because of trees' capacity to reduce the heat island effect in cities, create important stopover sites for migratory birds, and make the distribution of green spaces more equitable across neighborhoods.

Create a National Strategy to Protect and Restore Grasslands and Sagebrush

Native grasslands and rangelands have become some of the most reliable and resilient carbon sinks because of their ability to store carbon in their extensive root structures,[30] but have dwindled to just 40% of their historic range. Grassland conservation presents an opportunity to both protect existing carbon storage and maximize additional carbon sequestration, in addition to providing habitat for birds and pollinators. Despite their ecological importance, there is still no national strategy to combat grassland conversion, decline, and encroachment of invasive species like cheatgrass. Audubon supports a national prioritization of native grassland conservation, efforts to avoid conversion (e.g., easements, USDA Sodsaver program), financial and technical support for innovative projects that test new management strategies, and management for ecosystem health on public grasslands used for grazing. Sustainable ranching can be also part of the solution, and Audubon supports the creation of market signals that reward ranchers who adopt regenerative grazing approaches and manage their rangelands to improve bird habitat, such as through Audubon's Conservation Ranching Initiative.

Deploy Natural Infrastructure to Sequester Carbon and Increase Resilience

Our built environment is increasingly at risk of flooding and other natural disasters as a result of sea-level rise, increasingly heavy rainfall events, more severe and prolonged drought, and development patterns that have paved over natural floodplains. Threats from rising seas and rivers, and efforts to protect existing development using seawalls and levees are squeezing coastal and riverine habitats that are important for birds and degrading the natural flood protections provided by these ecosystems. Natural infrastructure—including wetlands, natural oyster beds, sea grasses, reactivated floodplains, and mangrove forests—can reduce flood risks, provide natural water storage in arid landscapes, reduce stormwater pollution and run-off, and sequester carbon in urban and suburban environments. Audubon supports efforts to fund and create incentives for using natural infrastructure approaches for building climate resilient communities, especially when rebuilding or preparing for natural disasters. Federal programs should provide funding for natural infrastructure projects, discourage development in flood-prone areas, and invest in efforts to restore blue carbon ecosystems along our coasts—including the Great Lakes—that both sequester carbon and provide important natural flood protections.

Expand Research, Development, and Innovation of NCS

Though we know that policies supporting NCS will bring numerous benefits, there is still a lot of scientific research needed to accurately quantify current and potential carbon sequestration, understand the capacity of different landscapes and projects to meet environmental and climate goals, and determine which practices are most effective for preserving and restoring carbon sinks. The federal government plays a critical role in funding research and development in a number of sectors, including agriculture, forestry, and coasts. Audubon supports increasing funding for relevant government research arms—including the Forest Inventory and Analysis (FIA), the US Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA)—as well as for programs that provide funding for independent entities to drive on-site research, such as the Conservation Innovation Grants program. Without a comprehensive national program, many states have created their own innovative programs that improve landowner access to financial and technical assistance to implement NCS. Where possible, the federal government should support this innovation and help successful programs become more widespread.

Wetlands

Sagebrush

Key Terms and Additional Resources

Climate Strongholds: areas that are predicted to have high climate suitability and low human modification for bird species at present, and under contemporary climate change scenarios in both breeding and non-breeding seasons[1]. These areas balance the representation of all included species and capture critically important habitat for every bird species assessed for each ecosystem today and under climate change.

Vulnerable Climate Strongholds: climate strongholds that have been exposed to high amounts of human modification.

Carbon stores: areas of high carbon storage. Carbon storage totals within urban/suburban areas exclude overlap with natural areas already accounted for in other systems (e.g., forests, wetlands, grasslands) to prevent double counting. Although we include the carbon storage and sequestration capacity of coastal ecosystems in this report, these did not include the substantial nearshore and offshore carbon stores, such as submerged aquatic vegetation (e.g., eelgrass), marine seabed sediments (e.g., mudflats), or mangroves.

Active carbon sink: areas that, on average, are actively sequestering more carbon than they emit annually; this is derived from the mean annual sequestration rate for each ecosystem between 1980 and 2015.

Potential carbon sink: areas that have the potential to sequester more carbon than they currently do, on average, if anthropogenic disturbance is minimized; this is derived from the maximum annual sequestration rate for each ecosystem between 1980 and 2015 and is a high-end estimate of sequestration capacity under no or low disturbance.

Carbon source: areas that, on average, are emitting more carbon than they sequester annually.

Priority areas to maintain: Climate Strongholds for birds that align with high carbon stores or active carbon sinks. Recommended for maintaining current ecosystem function via conservation or management within a NCS framework. These areas are prioritized because they represent an overlap between (i) areas that are suitable for birds now and that will remain suitable under climate change, and (ii) areas that are effective carbon stores or active carbon sinks currently; thus, maintaining their current conditions and function is critical for both climate change adaptation (for birds) and climate change mitigation (for carbon sequestration).

Priority areas to restore: vulnerable Climate Strongholds that have potential to increase their value to birds if restored, and align with potential carbon sinks. Recommended for restoration or active management efforts within a NCS framework. These areas are prioritized because they represent overlap between (i) areas that could be suitable for birds now and may remain or become suitable under climate change if likely land conversion is avoided, and (ii) areas that could be more effective carbon sinks if disturbance is reduced. Thus, restoring their ecosystem functioning is critical for both climate change adaptation (for birds) and climate change mitigation (for people). Note that we do not present priority areas to restore for Alaska, given data limitations and the relatively low human footprint.

Gap status code: areas designated as GAP Statuses 1 and 2 are primarily managed for biodiversity, GAP 3 areas are managed for multiple uses including conservation and extraction, and GAP 4 has no known mandate for biodiversity protection.

Audubon Priority Birds: birds of significant conservation need, for which our actions, over time, can lead to measurable improvements in status or are birds that are representative of priority habitats.[68] See Supplementary Information for full list of species.

Climate-vulnerable species: the 389 North American bird species that are at risk from climate change related range loss[8] (https://www.audubon.org/climate/survivalbydegrees)

Species at risk from climate-related threats: bird species that face multiple coincident climate change-related threats.[9] For the lower 48 states, species that face 3 or more coincident threats (https://www.audubon.org/climate/survivalbydegrees) and for Alaska, it is 5 or more coincident threats (https://ak.audubon.org/node4186/survival-degrees-storymap).

Interpreting the Maps

High value areas for birds: bird priorities to maintain are defined as areas with high climate suitability for birds and high landscape condition. Bird priorities to restore, also referred to as Vulnerable Climate Strongholds, are defined as areas with high value for birds but low to moderate landscape condition or areas with the greatest potential to increase their value to birds if restored.

High value areas for carbon: carbon priorities to maintain are defined as areas of high carbon stores (i.e., the top 40% of carbon storage capacity) or active carbon sinks (i.e., areas that sequester more carbon than they emit). Carbon priorities to restore are defined as areas with the capacity to sequester substantially more carbon under the hypothetical absence of disturbance.

High value areas for both: the areas of overlap between high value areas for birds and high value areas for carbon.

See Data and Methods in our Supplementary Information document for more information on how we analyzed the data in this report.

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