Supporting Information

March 23, 2021

Handler S., O. LeDee, C. Hoving, B. Zuckerberg, and C. Swanston. 2021. A menu of climate adaptation actions for terrestrial wildlife management. Wildlife Society Bulletin.

This document includes the following supporting information:

1) A sample agenda from our workshops to test the Wildlife Adaptation Menu (Page 1)
2) A sample questionnaire used to solicit feedback on draft versions of the menu (Page 3)
3) The full narrative version of the Wildlife Adaptation Menu with example tactics to illustrate all 13 strategies and 80 approaches (Page 4)

EXAMPLE WORKSHOP AGENDA FOR TESTING WILDLIFE ADAPTATION MENU

Day 1

9:00 Registration and Coffee

9:30 Welcome and Introduction

Outline objectives of the workshop

10:00 Introduce People and Projects

Describe project locations and goals identified during pre-work (Adaptation Workbook Step #1).

10:30 Assess Climate Change Impacts – Small Groups

Consider climate change impacts and complete ranking activity (Adaptation Workbook Step #2).

12:00 Lunch *(provided)*

12:45 Assess Climate Change Impacts – Large Group

Group activity and discussion.

1:15 Challenges/Opportunities for Meeting Management Objectives – Presentation

Presentation of Adaptation Workbook Step #3.

1:30 Challenges/Opportunities for Meeting Management Objectives – Small Groups

Describe how climate change affects the feasibility of your management objectives (Adaptation Workbook Step #3).

2:15 Break

2:30 Challenges/Opportunities for Meeting Management Objectives – Large Group

Group activity and discussion.

3:00 Climate Adaptation Strategies and Approaches – Presentation

Provide an overview of adaptation concepts and review the Wildlife Adaptation Menu.

3:30 Identifying Climate Adaptation Approaches and Tactics – Small Groups

Select and evaluate adaptation actions from the Wildlife Adaptation Menu (Adaptation Workbook Step #4).

5:00 Adjourn

Day 2

8:30 Welcome and Recap

Discuss Day 1 progress, answer questions, and outline Day 2.

9:00 Identifying Climate Adaptation Approaches and Tactics – Small Groups

Consider new ideas and complete Adaptation Workbook Step #4.

Prepare posters and give summary presentations from individual project teams.

10:15 Adaptation Approaches and Tactics – Large Group Gallery Walk

Project teams share details and ask questions among each other.

10:45 Break

11:00 Identifying Metrics for Monitoring and Evaluating Effectiveness – Presentation

Describe process for completing Adaptation Workbook Step #5.

11:15 Identifying Metrics for Monitoring and Evaluating Effectiveness – Small Groups

Discuss monitoring opportunities and ideas (Adaptation Workbook Step #5).

12:00 Lunch *(provided)*

12:30 Wildlife Adaptation Menu Feedback – Questionnaire and Group Discussion

Consider gaps and possible improvements on the draft Wildlife Adaptation Menu.

1:30 Next Steps and Wrap-up

Describe next steps and expectations for projects post-workshop.

Complete evaluation forms and record Workbook sheets.

2:00 Adjourn

Feedback Questionnaire - Wildlife Adaptation Menu

What did you like about the Wildlife Adaptation Menu? (Not the workshop, but specifically the menu.) Which ideas/statements were described well?

What could use improvement with the menu? Are there terms/ statements that were confusing or misleading? Please list your ideas.

Are there missing topics in the menu? Were you expecting to find something that wasn't there?

In what situations do you think it would be most useful to use this menu?

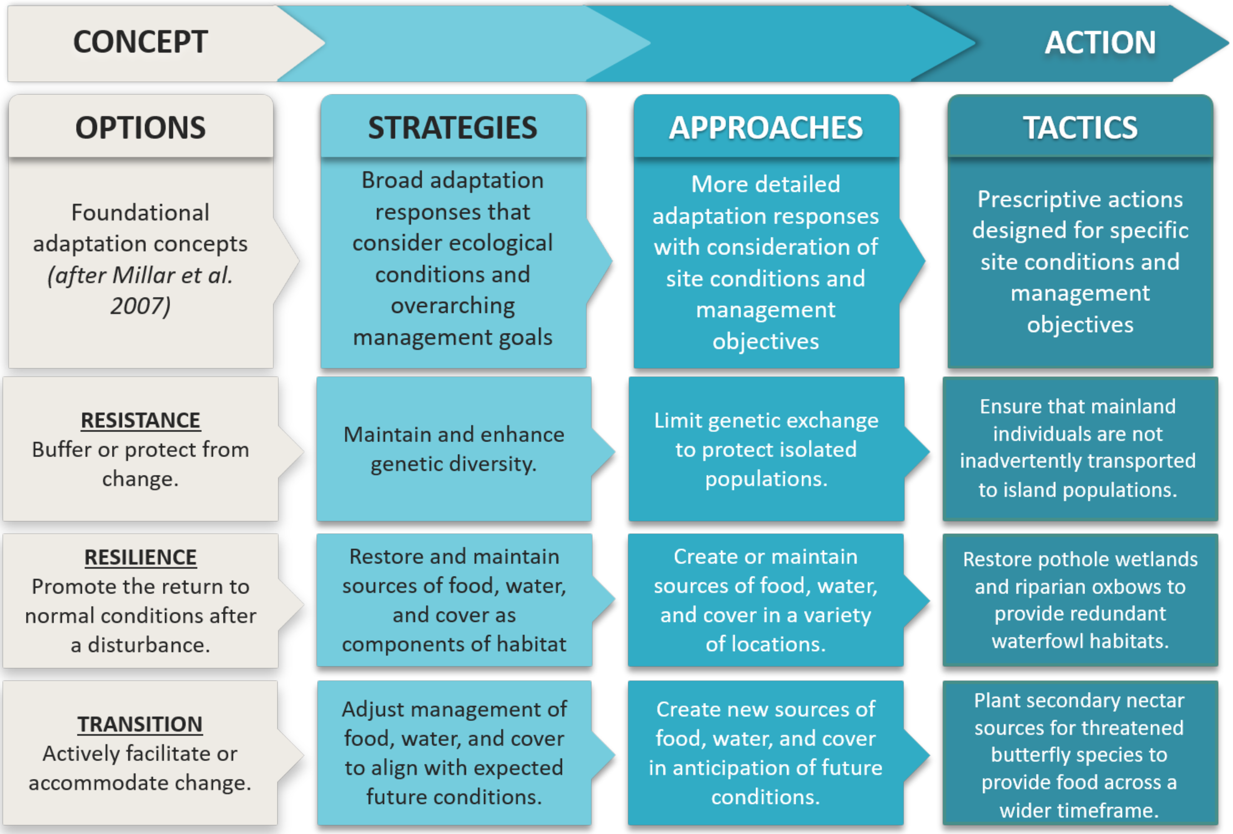
Other notes:

INTRODUCTION TO THE WILDLIFE ADAPTATION MENU

The Wildlife Adaptation Menu is a structured list of adaptation actions for terrestrial wildlife management. It is designed to translate broad concepts into actionable approaches to help managers respond to climate change risks and meet desired management goals. The menu includes actions related to managing wildlife populations as well as managing wildlife habitat. Managers should not treat the menu as a prescriptive list, but rather choose items from the menu based on their specific geographic settings, operational and administrative context, and management goals. Menu items can be applied in various combinations to achieve desired outcomes, but some approaches in the menu are contradictory. Furthermore, actions that work well in one context type may not work in another; it is up to the manager to select appropriate actions for a specific project and specific conditions. This resource was designed to be used with the Adaptation Workbook (Swanston et al. 2016 - *Forest Adaptation Resources: Climate change tools and approaches for land managers and Adaptation Workbook, 2nd edition;* and the corresponding online interactive tool: www.adaptationworkbook.org) or with other existing climate adaptation planning processes. Using the Wildlife Adaptation Menu in conjunction with the Adaptation Workbook will help wildlife managers identify and refine appropriate adaptation actions and also to clearly express the intent of those actions. Learn more at: www.forestadaptation.org/focus/wildlife/

The following table presents the strategies and approaches in the Wildlife Adaptation Menu. Adaptation strategies are broad adaptation responses that consider ecological conditions and overarching management goals. Approaches are more detailed adaptation responses that articulate different ways that a general strategy could be employed. The next section of the Supporting Material contains full narrative descriptions for all strategies and approaches, along with several example tactics to illustrate how each approach might be implemented. Strategies, approaches, and tactics represent a continuum from concepts to actions (Figure 1).

Figure 1. Adaptation options, strategies, approaches, and tactics represent a continuum of increasing specificity from general pathways to specific actions for implementation. Adaptation strategies and approaches represent intermediate tiers in this hierarchy that help managers navigate the multiple ideas in the Wildlife Adaptation Menu (Swanston et al. 2016). Examples are provided to illustrate strategies, approaches, and tactics for each of three general adaptation options (resistance, resilience, and transition (Millar et al. 2007).



OPTIONS	STRATEGIES	APPROACHES	TACTICS
Foundational adaptation concepts *(after Millar et al. 2007)*	Broad adaptation responses that consider ecological conditions and overarching management goals	More detailed adaptation responses with consideration of site conditions and management objectives	Prescriptive actions designed for specific site conditions and management objectives
RESISTANCE Buffer or protect from change.	Maintain and enhance genetic diversity.	Limit genetic exchange to protect isolated populations.	Ensure that mainland individuals are not inadvertently transported to island populations.
RESILIENCE Promote the return to normal conditions after a disturbance.	Restore and maintain sources of food, water, and cover as components of habitat	Create or maintain sources of food, water, and cover in a variety of locations.	Restore pothole wetlands and riparian oxbows to provide redundant waterfowl habitats.
TRANSITION Actively facilitate or accommodate change.	Adjust management of food, water, and cover to align with expected future conditions.	Create new sources of food, water, and cover in anticipation of future conditions.	Plant secondary nectar sources for threatened butterfly species to provide food across a wider timeframe.

Adaptation Strategies	Adaptation Approaches
Adaptation Strategies for Population Management	
1. Maintain and enhance genetic diversity	1.1. Increase genetic exchange between populations 1.2. Maintain and enhance genetic admixture (interbreeding) zones in order to facilitate adaptive genetic exchange 1.3. Limit genetic exchange to protect isolated populations 1.4. Prioritize conservation of trailing edge or leading edge populations 1.5. Maintain populations in disturbed environments because they may contain adaptive traits 1.6. Protect areas of high phylogenetic or phenotypic diversity or endemism 1.7. Translocate individuals with climate-adaptive genetic traits 1.8. Preserve genetic material (gene banks) 1.9. Restore genetic diversity in isolated or inbred populations (genetic rescue)
2. Establish and maintain connectivity between populations	2.1. Translocate individuals or populations to habitat within the existing range that was formerly occupied and remains suitable (reintroduction) 2.2. Identify and protect source sub-populations 2.3. Establish and maintain connectivity between sub-populations through corridors or stepping stones
3. Facilitate shifts in the geographic range of the species in anticipation of future conditions	3.1. Establish corridors and minimize barriers to movement to new suitable habitats 3.2. Prepare suitable habitat in anticipation of future introduction, reintroduction, or natural range shift of a species 3.3. Move and release individuals into a population where conditions are now suitable and are expected to improve 3.4. Reintroduce species where climate is expected to remain suitable 3.5. Conserve leading-edge populations (high altitude, northern, etc.) 3.6. Introduce species to new areas with suitable current and future climate
4. Manage interspecific and biotic interactions	4.1. Increase or protect existing biodiversity, for example species richness, functional diversity, and phylogenetic diversity 4.2. Detect and remove non-native invasive species 4.3. Manage predator populations 4.4. Restore historic trophic linkages 4.5. Maintain functional groups or keystone species that help sustain ecosystem functions 4.6. Reintroduce extirpated species or functional groups

	4.7. Manage extant and emerging diseases
5. Maintain a sustainable population size by managing reproduction, survival, and dispersal	5.1. Move and attract individuals to augment an existing population
	5.2. Increase reproduction and survival rates
	5.3. Use captive breeding programs to increase populations of declining or rare species
	5.4. Manage natural predation to increase populations of declining or rare species
	5.5. Control take, harvest, and illegal harvest
6. Adjust harvest regulations to manipulate populations of harvested species	6.1. Adjust harvest regulations to increase population size for declining species or species anticipated to be impacted by climate change
	6.2. Adjust harvest regulations to decrease population size
	6.3. Adjust harvest regulations to facilitate shifting phenology or species ranges
7. Plan for and reduce human disturbance and human-wildlife conflict	7.1. Anticipate and manage conflict from increasing populations, range expansions, or changing behaviors
	7.2. Manage conflict associated with societal adaptations to climate change
	7.3. Reduce or limit access to sensitive habitats or environments
	7.4. Reduce or remove human disturbance stress during sensitive time periods
	7.5. Implement nonlethal behavioral control methods (barriers and deterrents)

Adaptation Strategies	Adaptation Approaches
Adaptation Strategies for Habitat Management	
8. Restore, and maintain sources of food, water, and cover as components of habitat	8.1. Manage for plant species diversity and complexity 8.2. Promote plant genetic diversity 8.3. Prioritize native vegetation and suitable site conditions for habitat management and restoration 8.4. Manage and create suitable microhabitats and microclimates 8.5. Enhance primary food sources for specialist climate-sensitive species 8.6. Provide supplemental food sources 8.7. Create or maintain sources of food, water, and cover in a variety of locations across the landscape 8.8. Maintain or mimic natural disturbance regimes to enhance habitat quality
9. Adjust management of food, water, and cover to align with expected future conditions	9.1. Use non-local, future-adapted genotypes in habitat management 9.2. Create new sources of food, water, and cover in anticipation of future conditions 9.3. Accommodate altered hydrology, accounting for periods of high water and low water availability 9.4. Maintain or enhance sources of food, water, and cover across the annual cycle and different life stages in response to changing phenology 9.5. Establish or redesign infrastructure to protect habitat from anticipated climate impacts
10. Establish and enhance protected areas or habitat reserves	10.1. Create large, intact, or aggregated protected areas 10.2. Increase representation and replication of protected species and habitats across the portfolio of protected areas 10.3. Select reserves that maximize biodiversity protection for a suite of species 10.4. Orient suites of protected areas in ways that span gradients in climate 10.5. Create protected areas that maximize topographic and geologic variety 10.6. Protect areas at high risk of change due to climate or land use change 10.7. Protect climate refugia across the landscape 10.8. Protect sites that are expected to provide future suitable habitat 10.9. Protect stepping stones, adjacent reserves, and corridors 10.10. Create temporary or dynamic reserves 10.11. Maintain or enhance habitat across the annual cycle and life stages 10.12. Protect current safe havens for climate vulnerable populations to ensure those populations are available for future conservation efforts 10.13. Protect sufficient habitat for viable populations to be self-sustaining and of sufficient quality to create surplus dispersers

11. Promote wildlife habitat conservation on lands outside of protected areas	11.1. Identify and restore degraded landscapes with high potential habitat quality 11.2. Reduce or limit barriers to wildlife movement across private land 11.3. Manage private lands near and between protected lands (buffer zones) 11.4. Enhance green infrastructure and promote sustainable urban landscapes 11.5. Manage public or private agricultural land to provide compatible wildlife use 11.6. Manage forest structure to provide compatible wildlife use
Adaptation Strategies	Adaptation Approaches
Additional Adaptation Strategies	
12. Intentionally choose to take no action	12.1. Take no action in some situations as part of an overall triage strategy 12.2. Designate “no action” areas as a control to compare with management interventions 12.3. Allow for autonomous, or unassisted, adaptation to climate change
13. Engage human communities in wildlife conservation	13.1. Develop outreach and technical assistance programs for the public 13.2. Provide access for wildlife-dependent recreation 13.3. Increase local community involvement in wildlife management 13.4. Promote community-managed conservation lands 13.5. Respect and incorporate landscape values of indigenous communities in management decisions 13.6. Pay for ecosystem services that also benefit wildlife 13.7. Coordinate across landowners and scales to make sure programs are complementary

WILDLIFE ADAPTATION MENU – COMPLETE NARRATIVE WITH EXAMPLE TACTICS

Adaptation Strategies for Population Management

1. **Maintain and enhance genetic diversity**

   Genetic diversity within a population or across an entire species provides the basis for adaptability through time. Maintaining and enhancing genetic diversity in wildlife species may become even more important as a climate adaptation strategy, as populations and species may be required to adapt to novel climatic conditions through time (Greenwood et al. 2016, Razgour et al. 2018). The following Approaches offer different opportunities to incorporate aspects of genetic diversity into management.

   <u>*Approaches and Example Tactics*</u>

   1.1. Increase genetic exchange between populations

   Genetic exchange, or gene flow, between populations occurs when members of one distinct population are able to breed with members of another population. This approach can help ensure that populations receive regular inputs of new genes, which can reduce the potentially harmful effects of inbreeding and the loss of diversity through genetic drift (Wong et al. 2013).

   1.1.1. Establish corridors of interior hardwood forest between existing populations of scarlet tanagers.
   1.1.2. Relocate timber rattlesnakes from one population to another to enhance genetic exchange.

   1.2. Maintain and enhance genetic admixture (interbreeding) zones in order to facilitate adaptive genetic exchange

   In some cases, populations that were previously isolated may be brought into contact as the climate changes or other factors facilitate interbreeding. This genetic admixture could be beneficial in some cases, if the interbreeding allows beneficial traits to spread between populations (Ehrlich and Pringle 2008, Webster et al. 2017, Werneck et al. 2012).

   1.2.1. Place reserves at the convergence of different prairie chicken population areas.
   1.2.2. Allow new admixture zones where changing climate conditions may draw previously isolated dragonfly populations together.
   1.2.3. Identify areas of potential hybridization between species, such as blue-winged and golden-winged warblers or southern and northern flying squirrels.

   1.3. Limit genetic exchange to protect isolated populations

   Isolated populations, such as those that exist on islands, can contain novel traits and may be particularly adapted to their native environments. To maintain distinct populations, it may be necessary to proactively limit genetic exchange by modifying the environment to make migration between populations less likely or limiting intentional genetic manipulation (Russo et al. 2019).

1.3.1. Ensure that mainland individuals are not inadvertently transported to island wildlife populations, such as mainland red squirrels being transported to Isle Royale National Park.
1.3.2. Create dispersal barriers to limit genetic exchange between populations.

1.4. Prioritize conservation of trailing edge or leading edge populations
For species with large native ranges that span environmental gradients, climate change trends may exert different pressures on the "trailing edge" of the range versus the "leading edge." Populations in trailing edge areas may contain traits or behavioral adaptations that allow them to tolerate looming changes (Hampe and Petit 2005). Conversely, populations in leading edge areas may contain traits or behavioral adaptations that allow them to opportunistically take advantage of newly available habitat or changing conditions (Gibson et al. 2009).

1.4.1. Identify and protect "trailing edge" or southerly populations of boreal species such as snowshoe hare, to increase capacity for phenotypic plasticity (color coat change) that may allow them to persist in changing conditions.
1.4.2. Promote or invest in "leading edge" populations of Carolina wren in New York and Massachusetts to promote warm-adapted traits and populations.

1.5. Maintain populations in disturbed environments because they may contain adaptive traits
It may be possible to identify populations that have already endured disturbances that are expected to become more frequent under climate change, such as droughts, wildfires, or floods. Populations and individuals that have previously tolerated such disturbances may have unique traits that will be even more beneficial under climate change (Linksvayer and Janssen 2009, Webster et al. 2017).

1.5.1. Identify wildlife populations that thrive in recently burned areas that may be suited to future conditions with more frequent wildfire (areas of pyrodiversity).
1.5.2. Favor wildlife populations that have survived mega-drought events and may be suited to future conditions with more drought stress.

1.6. Protect areas of high phylogenetic or phenotypic diversity or endemism
Some areas of the landscape are natural "hotspots" of biodiversity, which may include phylogenetic diversity (diversity based on evolutionary history), phenotypic diversity (diversity of expressed characteristics), or endemism (species being unique to only one area). Conserving these locations of high diversity can help ensure that genetic diversity is maintained, which may enhance adaptive capacity as the climate changes (Dawson et al. 2014, Cobben et al. 2011).

1.6.1. Establish new protected areas in areas of high phylogenetic diversity.
1.6.2. Prioritize phylogenetic diversity hotspots when designing fuel breaks for wildfire protection.

1.7. Translocate individuals with climate-adaptive genetic traits

Widely distributed species likely contain populations in areas with vastly different climatic conditions. Certain populations may contain traits that help them tolerate certain climate conditions, such as prolonged dry spells or extreme high temperatures (Weeks et al. 2011, Prober et al. 2012). In this situation, it may be beneficial to move individuals to a new population that is expected to be exposed to future climate conditions that are similar to their "home" population.

1.7.1. Translocate southern black bears to northern areas, because these individuals may be physiologically adapted to shorter periods of torpor during the winter.
1.7.2. Introduce individuals that may have physiological traits that allow them to tolerate greater heat stress during the summer.

1.8. Preserve genetic material (gene banks)
In cases when the rate or magnitude of climate change may overwhelm the ability of a species to adapt, it may be prudent to store genetic material from that species in the event that new opportunities for re-establishment appear in the more distant future (Vicente 2010, Fitak et al. 2013).

1.8.1. Collect tissue samples of critically endangered wildlife for frozen storage, following the example of the Australian Frozen Zoo and other gene banks.
1.8.2. Identify captive populations or museum specimens of critically endangered wildlife and preserve samples of their tissue, such as Karner blue butterfly specimens from Indiana Dunes National Lakeshore.

1.9. Restore genetic diversity in isolated or inbred populations (genetic rescue)
Populations that have already experienced genetic bottlenecks or inbreeding depression may be less able to persist and tolerate novel conditions as the climate changes. In these situations, it may be possible to intentionally introduce new individuals to a population to boost genetic diversity (Weeks et al. 2011, Landa et al. 2017).

1.9.1. Introduce wolves from the mainland from different populations to restore genetic diversity in an inbred island population.
1.9.2. Use individual eastern Massasauga rattlesnakes from zoos to restore genetic diversity in wild populations through captive breeding programs.

2. Establish and maintain connectivity between populations

Connectivity between populations has a critical influence on population dynamics and evolution of a species. Strategically managing connectivity can help ensure that species are in the best position to tolerate future climate change, as well other environmental stressors. The following Approaches offer different opportunities for wildlife managers to influence connectivity.

Approaches and Example Tactics

2.1. Translocate individuals or populations to habitat within the existing range that was formerly occupied and remains suitable (reintroduction)

Habitat loss or other factors have constrained some species to a small portion of their historical range. It may be possible to translocate individuals or populations to remnant suitable habitat. This can help ensure that multiple populations exist across the landscape to reduce overall extinction risk, and it may also be used to establish species in a particular location that may be strategically beneficial for climate adaptation (Kuemmerle et al. 2012, Corlett 2016).

- *2.1.1. Capture antelope from a thriving population and re-introduce them into unoccupied suitable grassland habitat in the former range.*
- *2.1.2. Establish a population of elk in the historic, but unoccupied, range in northeastern Minnesota.*

2.2. Identify and protect source sub-populations

Some wildlife species have sub-populations that act as "sources" of new individuals due to optimal habitat conditions or life-history factors that allow these populations to persist. Strategic conservation of source populations may be critical for facilitating dispersal and connectivity between populations (Hole et al. 2011, Grinde and Niemi 2016).

- *2.2.1. Protect the source population of cougars in the Dakotas to allow for continued emigration to suitable habitat throughout the Midwest.*
- *2.2.2. Protect source American marten populations in New Hampshire to facilitate dispersal to Vermont.*

2.3. Establish and maintain connectivity between sub-populations through corridors or stepping stones

Managers can facilitate connectivity between sub-populations by ensuring that individuals are able to move freely across the landscape (Jones et al. 2016). Depending on the dispersal ability of the species and the particular constraints they face, these actions may be targeted (installing a crossing tunnel under a busy road) or more diffuse (ensuring that suitable forest cover exists between two populations) (Minor and Lookingbill 2010).

- *2.3.1. Establish corridors of interior hardwood forest between existing populations of scarlet tanagers.*
- *2.3.2. Identify and protect stepping stone areas nearby and between existing populations, such as creating islands of savanna habitat with lupine in close proximity to occupied Karner blue butterfly areas.*
- *2.3.3. Construct amphibian tunnels to permit movement across roads.*

3. Facilitate shifts in the geographic range of the species in anticipation of future conditions

The geographic range of a species may shift under climate change, based on key life-history traits or future migration of suitable habitat. Particularly in instances where there is a high degree of confidence in future shifts, it may be appropriate to intentionally facilitate expand a species' range to ensure that newly suitable habitat is occupied. The following Approaches cover several ways for wildlife managers to anticipate and take advantage of shifting conditions.

Approaches and Example Tactics

3.1. Establish corridors and minimize barriers to movement to new suitable habitats

In some cases, managers can facilitate species range expansion by ensuring that individuals can move freely across the landscape. Depending on the dispersal ability of the species and the particular constraints they face, these actions may be discrete or more diffuse. These actions can be taken in strategic locations that will open up access to projected future suitable habitat (Kostyack et al. 2011, Howard and Schlesinger 2013).

3.1.1. Create highway crossing structures that span barriers to northward movement.
3.1.2. Connect mature northern or boreal forest habitats that are oriented north-south across the landscape to facilitate northward migration of northern flying squirrels.
3.1.3. Orient pollinator projects in priority areas to create private land stepping stones through rural and urban landscapes.
3.1.4. Buffer natural cover along north-south trails, like the Pacific Crest Trail, through acquisitions, easements, or private land programs.

3.2. Prepare suitable habitat in anticipation of future introduction, reintroduction, or natural range shift of a species

Suitable habitat may not always exist in locations that are expected to be climatically suitable for a species in the future. In these instances, managers can work ahead of time to establish suitable habitat conditions such that the area is ready for a species when it eventually arrives (Huntley et al. 2006, Adams-Hosking et al. 2012).

3.2.1. Provide technical assistance to enable private landowners to create grassland habitat for quail and other grassland birds.
3.2.2. Identify and improve anticipated future stopover or wintering habitat for migratory birds.

3.3. Move and release individuals into a population where conditions are now suitable and are expected to improve

For species that are distributed across a gradient of climate conditions, it may be clear that some populations occur in areas that will become more suitable as the climate shifts. Other populations may exist in areas that are anticipated to become less suitable. Managers may choose to intentionally move individuals into projected suitable climate conditions to maximize the persistence of these populations ahead of time (Rödder and Schulte 2010).

3.3.1. Move eastern tiger salamanders from populations in south-central Minnesota to populations in north-central Minnesota, where conditions may be more suitable as the prairie-forest border shifts to the northeast.
3.3.2. Release wild turkeys from Mid-Atlantic states into New England.

3.4. Reintroduce species where climate is expected to remain suitable

Many species exist in only a small portion of their historical range. When managers intend to reintroduce individuals or populations to remnant habitat, it may be possible to select areas that are expected to remain suitable over the long-term as the climate changes (Kuemmerle et al. 2012, Sax et al. 2013). This can help ensure that conservation efforts are not "wasted" by reintroducing a species to locations that may not be viable over the long term.

- *3.4.1. Capture bighorn sheep from a thriving population and reintroduce them into areas that are expected to be suitable habitat.*
- *3.4.2. Capture copperbelly water snakes from populations that are not listed, and introduce them in wetland complexes in northern Indiana and Ohio that are geographically isolated from extant endangered populations.*

3.5. Conserve leading-edge populations (high altitude, northern, etc.)

For species with large native ranges that span environmental gradients, it may be appropriate to invest particular conservation effort in "leading edge" populations. These populations may contain traits or behavioral adaptations that allow them to opportunistically take advantage of newly available habitat or changing conditions (Gibson et al. 2009, Thomas et al. 2012).

- *3.5.1. Identify and protect "leading edge" or northerly populations of temperate species, such as red-bellied woodpeckers, in case they are more suited to take advantage of newly available habitat*
- *3.5.2. Identify and protect high-elevation populations, especially along north-south oriented mountain ranges*

3.6. Introduce species to new areas with suitable current and future climate

In some situations, it may possible to move a species to suitable habitat beyond where it might be expected to naturally move, and to locations outside of the historic range (Kostyack et al. 2011, Corlett 2016). This concept, often called "assisted migration" can occur over short distances as well as long distances. It should be pursued with caution and only after consideration of the risks and potential consequences of such an action (Hällfors et al. 2017, Payne and Bro-Jørgensen 2016).

- *3.6.1. Release Karner blue butterfly individuals into established savanna habitat in northern locations in the Lower Peninsula of Michigan, beyond where they would be expected to migrate on their own.*
- *3.6.2. Release quail in agricultural landscapes with suitable food, cover, and structure at both local and landscape scales.*

4. Manage interspecific and biotic interactions

Wildlife species succeed or struggle based on numerous interactions with other species, including other animals that may be predators, prey, or competitors; plants that may be sources of food or cover; and other organisms such as those that cause disease. This Strategy contains a variety of considerations for managing the web of interactions that may influence how a species is able to tolerate continued climate change.

Approaches and Example Tactics

4.1. Increase or protect existing biodiversity, for example species richness, functional diversity, and phylogenetic diversity

Wildlife managers who are focused on maintaining intact ecosystems, as opposed to particular species, may opt to focus conservation actions on increasing or protecting habitats and locations that contain significant biodiversity. These locations may be disproportionately important across the landscape, particularly when considering how to achieve the most positive outcomes with limited resources for management (Zimbres et al. 2012, Leadley et al. 2014, Webster et al. 2017).

4.1.1. Restore areas of tallgrass prairie habitat in landscapes dominated by row crops.
4.1.2. Identify vernal pools in upland forests and protect these areas from disturbance during forest management operations.
4.1.3. Identify viable assemblages of Species of Greatest Conservation Need.
4.1.4. Provide a variety of nectar-producing plants as a food base for many diverse pollinators.

4.2. Detect and remove non-native invasive species

Non-native invasive species may upset the natural balance in some areas by out-competing native flora and fauna. In some cases, non-native invasive species are persistent stressors that may limit the ability of native wildlife to persist under climate change (Reside et al. 2014). Detecting and removing non-native plant and animal species may be a necessary first step toward climate adaptation (Mainka and Howard 2010).

4.2.1. Invest in eradication efforts (trapping, hunting, etc.) to remove non-native feral hogs from protected areas.
4.2.2. Monitor for the presence of non-native constrictor snakes such as Burmese pythons in areas adjacent to known occurrences and remove them.
4.2.3. Remove stinging nettle and other plants that compete with native forbs in grasslands.

4.3. Manage predator populations

Managing the interactions between predator and prey species is one way managers can influence the success of wildlife species. Being intentional about manipulating predator-prey relationships can help promote climate adaptation, but it requires managers to first consider the full implications of management (Beschta et al. 2013, Davis et al. 2016, Galetti et al. 2017).

4.3.1. Manage for higher predator populations to control prey species such as white-tailed deer.
4.3.2. Trap and remove nest predators in turtle recovery areas.

4.4. Restore historic trophic linkages

Biotic food webs have been reduced and simplified in many ecosystems around the world, as species have become extirpated and habitats have been lost or modified by human development and land-use change (Galetti et al. 2017). In some cases, restoring key trophic connections between wildlife and food sources may help a particular species thrive (Beschta et al. 2013).

4.4.1. Reintroduce apex predators such as wolves or lynx in areas where they have been eradicated.
4.4.2. Restore food sources such as wild rice to benefit waterfowl populations.

4.5. Maintain functional groups or keystone species that help sustain ecosystem functions

Certain wildlife species can act as "ecosystem engineers" by actively creating the conditions that favor their persistence. Other wildlife species may benefit when these engineer species or groups of species are maintained or restored to an area (Heller and Zavaleta 2009, Kreyling et al. 2011).

4.5.1. Restore large grazers such as bison in order to sustain savanna and grassland habitats.
4.5.2. Protect prairie dogs in order to provide a prey source and burrows for other species.
4.5.3. Maintain non-native flowering species that are sustaining native insects, such as non-native milkweed being used by monarch butterflies.

4.6. Reintroduce extirpated species or functional groups

The practice of reintroducing lost animal species to natural environments, also known as "rewilding," is contentious but it may be appropriate in some limited situations (Dawson et al. 2011, Corlett 2016). The extirpated species being reintroduced should be expected to tolerate anticipated climate conditions, and the species should fill an ecological role that confers greater adaptive capacity to the entire system.

4.6.1. Reintroduce apex predators such as cougars where they have been extirpated.
4.6.2. Resurrect extinct/extirpated species that fulfill a critical functional role, such as resurrecting the passenger pigeon in eastern North America.

4.7. Manage extant and emerging diseases

Some wildlife species face immediate and dire challenges from diseases, and future climate conditions may promote new diseases or intensify disease transmission among wildlife (Smith et al. 2009). Managers may be able to take action to reduce the effects of disease, such as vaccination campaigns, limiting transmission opportunities, and boosting natural immunity (Walker et al. 2008).

4.7.1. Vaccinate vulnerable individuals or populations against disease, such as vaccinating prairie dogs and black-footed ferrets against the plague bacterium.
4.7.2. Partner with research labs to increase capacity for surveillance, outreach, and management of diseases.

4.7.3. Limit interspecific interactions that can spread disease, such as increasing hunting to reduce white-tailed deer in remnant moose habitats to protect moose from brainworm typically carried by white-tailed deer.
4.7.4. Protect individuals that exhibit natural immunity and resistance, such as bats that appear immune to White-Nose Syndrome.

5. Maintain a sustainable population size by managing reproduction, survival, and dispersal

Wildlife managers are often concerned with adjusting the population size of vulnerable wildlife species. Managers can affect population size through actions that influence reproduction, survival, and dispersal. This Strategy contains Approaches for increasing populations of vulnerable species, whether they are declining, rare, or have specific climate-related vulnerabilities.

Approaches and Example Tactics

5.1. Move and attract individuals to augment an existing population

Some wildlife species may be have particular sub-populations that are declining or vulnerable, and yet have other sub-populations that are thriving. Managers can use thriving sub-populations as "sources" of new individuals to augment declining or vulnerable populations, via active movement or passive techniques (Oliver et al. 2012, Payne and Bro-Jørgensen 2016).

5.1.1. Capture sharp-tailed grouse from a large, stable population in northern Minnesota and release them into a smaller existing population in northern Wisconsin.
5.1.2. Augment declining Canada lynx populations in Colorado with individuals from Alaska.
5.1.3. Capture moose from an expanding population on Isle Royale National Park and release them into suitable habitat areas in the mainland of Minnesota, Wisconsin, and Michigan.
5.1.4. Move turkeys from southern New England to suitable habitat in northern New England in order to provide new hunting opportunities.
5.1.5. Use audio playback to attract male songbirds to establish territories in an area.

5.2. Increase reproduction and survival rates

Managers may support populations of vulnerable species in the wild through actions to increase reproductive success and survival (Poiani et al. 2011, Davis et al. 2016). Careful consideration of a species life-history and population ecology may help managers pinpoint which life stages are most critical to influencing overall population growth.

5.2.1. Install artificial nests or denning sites, such as nest boxes for northern flying squirrels or wood ducks on unoccupied lakes.
5.2.2. Provide supplemental food to improve survival for songbirds in winter.
5.2.3. Create nesting platforms for black terns to reduce nest loss.

  - *5.2.4. Encourage "put and take harvests" toward the northern or upslope range limits for species like pheasants or quail to establish reproductive adults.*
  - *5.2.5. Head-starting juvenile individuals to increase survival, for example capturing and raising juvenile Blanding's turtles in captivity for a short period before releasing them into the wild.*

5.3. Use captive breeding programs to increase populations of declining or rare species

For imperiled populations, it may be necessary to breed and raise juveniles in controlled environments such as laboratories or zoos (Pritchard et al. 2012, Landa et al. 2017). This may be appropriate when reproductive success in the wild is too low to sustain a population, or when the risks to juvenile individuals in the wild is unacceptably high.

  - *5.3.1. Captive breeding programs to increase reproduction of highly threatened species such as black-footed ferrets.*
  - *5.3.2. Use salvage captive rearing to increase productivity of Great Lakes piping plover.*

5.4. Manage natural predation to increase populations of declining or rare species

In some instances, vulnerable species are able to successfully reproduce and raise juveniles in the wild, as long as natural predation is reduced (Berton C. Harris et al. 2012, Bradley and Neufeld 2012). Managers may opt to reduce predation by physically removing or deterring predators.

  - *5.4.1. Trap and remove nest predators in turtle recovery areas.*
  - *5.4.2. Install predator guards on nest boxes to protect eggs and juveniles from owls, raccoons, cats, and snakes.*
  - *5.4.3. Reduce populations of feral cats to protect songbird populations.*
  - *5.4.4. Trap and relocate fishers out of areas where pine marten populations are struggling to establish.*

5.5. Control take, harvest, and illegal harvest

Managers can protect some species that are particularly affected by human threats such as take, harvest, and illegal harvest (Kingsford et al. 2009, Struebig et al. 2015). It may be necessary to enact new regulations or more consistently enforce existing regulations, depending on the species and the nature of the risk.

  - *5.5.1. Implement no-wake zones on lakes around active loon nests.*
  - *5.5.2. Enforce regulations against illegal harvest of wildlife species.*

6. Adjust harvest regulations to manipulate populations of harvested species

Harvested species are often the focus of wildlife management agencies, and modifying harvest regulations for these species is a direct way to influence population sizes. As managers consider risks and opportunities from continued climate change, it may be necessary to intentionally adjust harvest regulations to continue to support appropriate population sizes.

<u>*Approaches and Example Tactics*</u>

6.1. Adjust harvest regulations to increase population size for declining species or species anticipated to be impacted by climate change

For species that are already declining or anticipated to experience climate change impacts, managers may opt to decrease or cease harvest pressure (Struebig et al. 2015, Hole et al. 2011). This could be employed in a variety of ways depending on the context, such as reducing hunting season length, reducing bag limits in particular locations, restricting particular hunting methods, or closing the season.

6.1.1. Decrease harvest (through season length, bag limits, refuge, etc.) to encourage dispersal by surplus individuals along northern or high elevation range limits.
6.1.2. Reduce bag limits for declining furbearer species.
6.1.3. Set harvest regulations more conservatively (relative to theoretical optimal harvest levels) to allow for direct and indirect impacts of climate change to harvestable surpluses.
6.1.4. Adjust harvest levels for waterfowl species anticipated to decline, such as redhead ducks.

6.2. Adjust harvest regulations to decrease population size

In some cases, reducing the population of a particular species may be appropriate in order to reduce climate change vulnerability for another species in the system or avert other negative consequences of climate change (Davis et al. 2016, Withey and van Kooten 2011). Managers can adjust hunting season length, harvest levels in particular areas, or allowable hunting methods.

6.2.1. Increase harvest of white-tailed deer in moose habitat areas to reduce the transmission of brainworm from deer to moose.
6.2.2. Increase harvest of elk to reduce agricultural damage from increased overwinter browsing.

6.3. Adjust harvest regulations to facilitate shifting phenology or species ranges

In many cases, hunting opportunities coincide with particular life-history events such as mating or seasonal events such as migration. As climate change shifts the phenology of species behaviors and the geographic ranges that species occupy, wildlife managers may opt to adjust harvest regulations accordingly (Taillon et al. 2012).

6.3.1. Revise wildlife harvest regulations to track changes in timing, such as changing migration dates for waterfowl.
6.3.2. Set population goals high enough to encourage evolution or dispersal, such as setting high population goals for reintroduced elk in Wisconsin to allow for gradual dispersal to new areas.

7. Plan for and reduce human disturbance and human-wildlife conflict

Human communities and wildlife will respond to climate change in ways that bring them together in new places or new levels of abundance. Wildlife managers will need to anticipate and address conflicts that are driven by climate change. This Strategy contains Approaches for reducing different potential conflicts.

Approaches and Example Tactics

7.1. Anticipate and manage conflict from increasing populations, range expansions, or changing behaviors

Climate change will help increase populations of some wildlife species and result in range shifts to new areas. New wildlife species in areas without the cultural knowledge or physical infrastructure to cope with new or newly abundant wildlife populations will require intervention to avert or reduce wildlife-human conflict (White and Ward 2011).

7.1.1. Implement chemical or hormonal contraception in white-tailed deer to reduce populations in urban areas.

7.1.2. Increase trapping on orchards to reduce crop damage from expanding opossum populations in northern states.

7.1.3. Provide subsidies for income losses, such as subsidizing farmers and ranchers for lost income due to increased wildlife predation or harassment of livestock from expanding coyote populations.

7.2. Manage conflict associated with societal adaptations to climate change

Human communities will respond to climate change in unique ways across the country. These adaptations may include land-use changes for energy development, agriculture, housing, coastline management, and new energy infrastructure, along with different approaches to ecosystem management. Any of these changes also has the potential to affect wildlife communities, so wildlife managers can help evaluate and avert negative consequences of societal adaptation actions (Bradley et al. 2012, Jones et al. 2016).

7.2.1. Avoid the conversion of natural grasslands or woodlands to agricultural uses as land-use pressure increases.

7.2.2. Locate utility corridors around critical habitats and use wildlife-friendly options when possible, such as planting native pollinator species in powerline right-of-ways.

7.2.3. Develop siting plans for wind and solar energy development that ensure habitat connectivity for wildlife and that avoid critical habitats such as calving grounds for native ungulates.

7.3. Reduce or limit access to sensitive habitats or environments

Wildlife species may have particular portions of their habitat that are particularly vulnerable to disturbance and disruption. Wildlife managers can help ensure that critical areas are not compromised as species attempt to adapt to a changing climate (Raymond and Brown 2011, Schlacher et al. 2013, Gollan et al. 2014).

7.3.1. Route recreational trails around or away from occupied piping plover nests.

7.3.2. Alter timing of forest management operations or recreational activities to avoid compacting below-the-snow environments.

7.4. Reduce or remove human disturbance stress during sensitive time periods
Wildlife species may have particular seasons or time periods that are critical to overall population success, such as nesting or calving seasons or long-distance migrations. Wildlife managers can help ensure that vulnerable time periods are especially avoided as adaptation occurs (Schlacher et al. 2013, Farhadinia et al. 2015).

7.4.1. Limit recreational trail access to areas that might be critical for nesting birds.
7.4.2. Implement temporary road closures to restrict access to elk populations during calving season.
7.4.3. Restrict dog access on beaches to reduce disturbance and stress to beach-nesting birds.

7.5. Implement nonlethal behavioral control methods (barriers and deterrents)
Non-lethal methods to influence wildlife behavior may become more necessary as climate change and societal adaptation bring humans and wildlife into closer proximity. Barriers, deterrents, and other non-lethal methods may be particularly necessary if the wildlife species in question is also a climate-vulnerable species or otherwise protected (McClelland 2009).

7.5.1. Use trained animals such as dogs to "haze" large carnivores away from livestock, crops, and other areas that may attract them.
7.5.2. Use electric fencing to keep wildlife away from areas where they aren't desired.

Adaptation Strategies for Habitat Management

8. Restore, and maintain sources of food, water, and cover as components of habitat

Many managers deal with wildlife habitat more than directly managing wildlife populations. Ensuring that quality habitat exists may be a "no regrets" form of climate change adaptation. This Strategy contains several Approaches related to restoring and maintaining the different components of habitat: food, water, and cover.

Approaches and Example Tactics

8.1. Manage for plant species diversity and complexity
Terrestrial ecosystems often exist in a relatively simplified state compared to pre-settlement conditions. Managing for diverse plant communities, including species as well as structural diversity, can help ensure that wildlife have a variety of food sources and opportunities for cover (Tilman 1999, Chazdon 2008).

8.1.1. Promote a diversity of species and age classes with forest management, such as implementing variable-density thinning in a red pine plantation to create diverse canopy cover and light environments for tree regeneration.

8.1.2. Seed a diversity of aquatic vegetation in wetland restoration projects to create a variety of food sources at different times for migratory waterfowl.

8.2. Promote plant genetic diversity

Greater genetic diversity may help species adjust to new conditions or sites by increasing the likelihood that some individuals within a species will be able to withstand climate-induced stressors. A changing climate may require new guidelines that accommodate shifting seed zones and promote more options for increasing genetic diversity (Millar et al. 2007).

8.2.1. Use seed from multiple seed zones during grassland restoration efforts.
8.2.2. Use seed from southerly populations or areas that have experienced drought in recent past.

8.3. Prioritize native vegetation and suitable site conditions for habitat management and restoration

Habitat loss and degradation is one of the major challenges currently facing many wildlife species, and restoring degraded habitat can give species a better chance to cope with changing conditions. Managers can emphasize native vegetation and based on local site conditions to ensure that restored habitat is most suited to a project location (Millar et al. 2007, Chazdon 2008).

8.3.1. Use native tree species to reforest former agricultural land.
8.3.2. Use seed mixtures with native drought-tolerant species in grassland restoration projects.
8.3.3. Manage for habitats according to suitable soil associations, such as managing for northern white-cedar in areas with mesic, calcium-rich soils.

8.4. Manage and create suitable microhabitats and microclimates

Many wildlife species depend on suitable conditions at very small spatial scales, such as vernal pools within forests or caves that serve as hibernacula. Wildlife managers can focus on creating suitable microhabitats and microclimates that will help wildlife species thrive and tolerate change (Lagarde et al. 2012, Earl and Semlitsch 2015, Ellis 2015).

8.4.1. Protect and create small vernal pools in mesic forests.
8.4.2. Implement forest management actions that promote diverse canopy cover, light environments, down woody habitat, and diversity of tree sizes.
8.4.3. Retain snags of large-diameter trees that can be used as cavity nesting habitat.
8.4.4. Modify the temperature and humidity regime in a cave or hibernaculum to optimize conditions for bats.

8.5. Enhance primary food sources for specialist climate-sensitive species

Dietary and habitat specialists are particularly vulnerable to climate change. A single-species focus on their needs may be necessary to complement more broad community or ecosystem management objectives (Adams-Hosking et al. 2012, Regos et al. 2016).

8.5.1. Protect milkweed along roadsides, utility corridors, and grasslands for monarch butterfly habitat.
8.5.2. Plant nutrient-dense native grass species and seed sources as winter food sources for threatened grassland bird species such as greater prairie chickens.

8.6. Provide supplemental food sources

When food sources are impacted by climate change, habitat can be managed to favor food sources, or native vegetation can be planted for herbivores and pollinators (Memmott et al. 2010, Maron et al. 2015).

8.6.1. Promote a diversity of mast-producing species through forest management, such as planting soft mast species to supplement hard mast species in oak forests.
8.6.2. Provide supplemental forage for a reintroduced elk herd during especially harsh winters.
8.6.3. Create mixed plantings of forbs, legumes and grasses to produce insects at critical periods for birds.

8.7. Create or maintain sources of food, water, and cover in a variety of locations across the landscape

Wildlife managers working across large landscape will have to contend with diverse site conditions and unpredictable climate impacts at local scales. One viable action to reduce risk across the landscape is to create and maintain multiple, replicated sources of food, water, and cover in order to help ensure that wildlife will resilient to disruptions at any single location (Kalda et al. 2015).

8.7.1. Manage for early-successional aspen forests in multiple locations adjacent to winter deer yards.
8.7.2. Restore pothole wetlands and riparian oxbows in agricultural landscapes to provide redundant waterfowl habitats.

8.8. Maintain or mimic natural disturbance regimes to enhance habitat quality

Native terrestrial ecosystems are shaped by a variety of factors, including disturbances such as floods, fires, and wind events that historically governed vegetation succession and habitat patterns at small and large scales. Land managers can help maintain wildlife habitat by mimicking the natural shape, size, timing, intensity, and variability of disturbance processes (Corlett 2016, Wiederholt et al. 2015).

8.8.1. Restore fire to fire-adapted ecosystems through prescribed burning.
8.8.2. Design management practices that mimic natural disturbance in terms of size, shape, timing, and intensity, such as creating small harvest gaps in northern hardwoods forests to mimic a small windthrow event.
8.8.3. Match historic variability in size, shape, timing, and intensity of disturbances.
8.8.4. Use water control infrastructure to replicate flooding regimes in wetlands.

9. Adjust management of food, water, and cover to align with expected future conditions

Providing quality habitat for wildlife into the future may require managers to evaluate how sources of food, water, and cover may shift under climate change. Adaptation may involve supplementing or even re-designing habitat to account for changing conditions. This Strategy contains several Approaches that involve being proactive about managing food, water, and cover based on anticipated future conditions.

Approaches and Example Tactics

9.1. Use non-local, future-adapted genotypes in habitat management

As climate change continues, some genotypes may be better adapted to future conditions or changing conditions because of pest resistance, broad physiological tolerances, short regeneration times, or other characteristics (Spittlehouse and Stewart 2003, Millar et al. 2007). Wildlife managers can identify and manage for these future-adapted genotypes as a way to help ensure that vegetation communities are better equipped to cope with change.

9.1.1. In habitat restoration projects, select seed sources based on anticipated future climate conditions, such as selecting seed zones from central or southern Minnesota when planting trees in northern Minnesota.

9.1.2. Establish grain food plots with cultivars that are expected to be tolerant of future climate conditions.

9.2. Create new sources of food, water, and cover in anticipation of future conditions

Future climate conditions may reduce the availability of currently available sources of food, water, and cover, or a wildlife population may be forced to migrate to new areas where some habitat elements are less available (Johnson et al. 2005, Garden et al. 2015). In these instances, managers may opt to create new sources of food, water, and cover that are designed to persist under future expected climates.

9.2.1. Promote a new suite of conifer species such as eastern white pine to provide thermal cover in order to replace declining boreal conifers.

9.2.2. Encourage hickory species as a new source of hard mast in northern states.

9.2.3. Plant secondary nectar sources for threatened butterfly species to provide food across a wider timeframe.

9.2.4. Invest in water control structures to allow for controlled wetland management in new areas.

9.2.5. Prioritize jack pine on deep, sandy soils north of the current distribution for Kirtland's warbler.

9.3. Accommodate altered hydrology, accounting for periods of high water and low water availability

The timing, form, and spatial distribution of precipitation is changing, with cascading effects on hydrologic cycles and water availability. Anticipating potential impacts to water levels, including periods of high and low water availability, may help managers reduce risks and sustain wildlife habitat (Furniss et al. 2010). Considering climate-related alterations to the hydrologic cycle along with site-level responses and potential land-use changes is likely to provide the most complete picture of risks and opportunities (Kostyack et al. 2011, Sun and Vose 2016).

9.3.1. Restore historic floodplains and oxbows to retain floodwaters.
9.3.2. Divert excess water into temporary holding structures during floods.
9.3.3. Develop water control infrastructure to manage wetland water levels for waterfowl.
9.3.4. Pump water to accessible tanks for ungulates and other wildlife during droughts.
9.3.5. Favor xeric habitats, such as fire-adapted oak woodlands or shortgrass prairies, in areas expected to experience increased drought stress.

9.4. Maintain or enhance sources of food, water, and cover across the annual cycle and different life stages in response to changing phenology

Wildlife managers will need to consider the altered timing of habitat availability, particularly for species that depend on crucial sources of food, water, or cover at particular life stages or seasons of the year. Climate change will likely lead to altered needs and behaviors across the annual cycle, and managers can attempt to account for these changes (Memmott et al. 2010, Hoglander et al. 2015).

9.4.1. Plant flowering species that provide nectar for pollinators during early, middle, and late phases of the growing season to account for unpredictable phenology.
9.4.2. Create scrapes to retain potential water sources for amphibians.
9.4.3. In northern areas, adjust wetland drawdown periods to promote forage plants across a longer season to provide food sources for ducks that may reside for longer periods of time or eventually remain over winter.

9.5. Establish or redesign infrastructure to protect habitat from anticipated climate impacts

Climate change may require managers to redesign infrastructure in and around wildlife habitat, such as roads, trails, road-stream crossings, and water-control structures (Rasmussen et al. 2018). In some cases, managers may need to establish new infrastructure to avert climate impacts. These actions may be especially important near high-risk areas and where the consequences of lost infrastructure or damaged habitat are unacceptable (Furniss et al. 2010).

9.5.1. Plant native vegetation along stream banks to reduce erosion and sedimentation of downstream wetlands.
9.5.2. Reroute infrastructure to accommodate future conditions, such as re-routing a hiking trail around future nesting habitat for piping plover.
9.5.3. Remove infrastructure that may damage wildlife habitat, such as decommissioning a road that is expected to disrupt landward migration as sea levels rise.

10. Establish and enhance protected areas or habitat reserves

Protected areas have been a fundamental tool to help sustain wildlife species in the face of widespread habitat loss and degradation. The scientific literature on wildlife management and climate adaptation contains an abundance of suggestions for modifying and establishing protected areas so they can more effectively support climate adaptation. This Approach contains several Approaches that describe related but different ideas of protected area management.

<u>*Approaches and Example Tactics*</u>

10.1. Create large, intact, or aggregated protected areas

Extensive areas of habitat are particularly important for species with large ranges. To help ensure that the needs of these species can be met as conditions change, wildlife managers can emphasize creating aggregated protected areas by expanding currently existing protected areas with easements and additional protected areas, or by intentionally consolidating fragmented protected lands into cohesive bocks (Kostyack et al. 2011, Mokany et al. 2013, Fischman et al. 2014).

- *10.1.1. Establish conservation easements adjacent to protected Federal or State lands.*
- *10.1.2. Pursue land swaps to consolidate protected lands into larger consolidated blocks.*

10.2. Increase representation and replication of protected species and habitats across the portfolio of protected areas

Wildlife managers can take a "portfolio management" approach to protected area design across a landscape, to ensure that certain landforms or ecosystems are not over-represented or under-represented within the collection of protected lands (Huntley et al. 2006, Mawdsley et al. 2009, Mokany et al. 2013). Additionally, it is a prudent risk-management approach to ensure that species and habitats are represented in multiple areas if possible.

- *10.2.1. Establish protected areas along multiple stretches of Great Lakes shoreline.*
- *10.2.2. Ensure that protected areas within a region account for a minimum percentage of all native ecosystem types.*
- *10.2.3. Prioritize acquisitions of protected lands in under-represented settings, such as fertile soils, low elevations, or level ground.*
- *10.2.4. Use landscape protection analyses, such as USGS's GAP or TNC's Resilient and Connected Lands, to strategically prioritize future conservation acquisitions.*

10.3. Select reserves that maximize biodiversity protection for a suite of species

Some areas of the landscape are natural "hotspots" of biodiversity, which may include phylogenetic diversity (diversity based on evolutionary history), phenotypic diversity (diversity of expressed characteristics), or endemism (species being unique to only one area). Managers can identify these locations of high diversity and ensure that they are contained within a protected area ensure they are protected from land-use change or human-disturbance (Barrows and Fisher 2014, Webster et al. 2017).

- *10.3.1. Protect prairie remnants with high diversity of grasses and forbs.*
- *10.3.2. Protect forested areas that also contain an intact, native ground flora.*
- *10.3.3. Focus land acquisition for hunting or fishing on lands that provide habitat to multiple Species of Greatest Conservation Need or other climate-vulnerable species.*

10.4. Orient suites of protected areas in ways that span gradients in climate

It may be possible to arrange protected areas to cross gradients in climate, such as dry-to-wet biome boundaries, low-to-high elevation gradients, or consistently cool-to-warm locations on the landscape. This kind of orientation may better enable wildlife species and vegetation communities to naturally migrate to suitable habitat as conditions change (Hole et al. 2011, Townsend and Masters 2015).

10.4.1. Design protected areas to run north-south to allow for species movement, such as northerly-shifting white-throated sparrows.
10.4.2. Design protected areas to run perpendicular to coastlines where maritime or lake effect create narrow growing zones.
10.4.3. Design protected areas to run up and down slope to cut across narrow climate zones associated with elevation.
10.4.4. Prioritize protected area conservation where elevation, latitude, and lake/maritime effects work synergistically, such as the Appalachian Mountains.

10.5. Create protected areas that maximize topographic and geologic variety

Geophysical factors such as elevation, slope, aspect, soil type, and landform can drive biological diversity in a region, because areas with complex and diverse geophysical attributes will naturally have high diversity of habitat types and therefore many niches for species to occupy (Anderson and Ferree 2010, Beier and Brost 2010). Wildlife managers can strategically establish protected areas in areas that will conserve areas with diverse geophysical settings in order to protect diversity under both current and future climates (Beier et al. 2015).

10.5.1. Create protected areas that contain numerous wetlands in an otherwise uniform landscape.
10.5.2. Use landscape analyses and associated maps, such as TNC Resilient and Connected Lands analysis, to identify areas with relatively high topographic (slope, aspect, elevation) and geologic variety.

10.6. Protect areas at high risk of change due to climate or land use change

As ecosystem modeling and land-use modeling becomes more sophisticated, it is becoming possible to identify areas on the landscape that may be most vulnerable to change, whether from climate-induced change or land-use change. If these areas are also immediately critical for wildlife, it may be necessary to emphasize these high-risk areas when establishing or designing protected areas (Raymond and Brown 2011, Booth et al. 2013, Leach et al. 2013).

10.6.1. Protect peatland ecosystems in central Minnesota for declining bird communities.
10.6.2. Restore high-elevation spruce-fir forests in the Allegheny Mountains of West Virginia.

10.7. Protect climate refugia across the landscape

Certain areas of the landscape serve as refugia for species because they have remained consistently cooler or wetter than the surrounding landscape. Wildlife managers may opt to emphasize protecting climate refugia to help ensure that such specialists can persist as long as possible under climate change (Gollan et al. 2014, Morelli et al. 2016). Managers should consider the range size and dispersal ability of a species in order to make informed decisions about climate refugia (Ashcroft 2010).

10.7.1. Design protected areas to include cool spots on the landscape that may be slower to change.
10.7.2. Protect areas that contain disjunct or relict ecosystems, because they have withstood previous periods of environmental change.

10.8. Protect sites that are expected to provide future suitable habitat

The geographic range of a species may shift under climate change, and suitable habitat may also shift. To the extent that wildlife managers can anticipate these shifts, it may be possible to proactively establish protected areas in locations that are expected to provide habitat in the future (Poiani et al. 2011, Booth et al. 2013, Fischman et al. 2014, Jones et al. 2016). This approach may be most appropriate in situations with high confidence regarding future projections or in concert with assisted migration of wildlife species that are critically vulnerable.

10.8.1. Identify and protect areas with expected future climate conditions that are similar to local current conditions.
10.8.2. Protect areas that are geophysically similar (soils, hydrology, etc.) to areas to the south or lower elevation that have habitats valued in that region.
10.8.3. Work with partners to change levels of protection on public land as valued wildlife species move in our out of an area (e.g., critical habitat for endangered species).

10.9. Protect stepping stones, adjacent reserves, and corridors

Protected areas can facilitate population connectivity and migration to areas of new suitable habitat. Managers can use smaller protected areas in between or adjacent to larger protected areas to facilitate species movement, as well as protected corridors along riparian corridors or other natural routes of movement (Hannah et al. 2007, Kostyack et al. 2011, Mokany et al. 2013).

10.9.1. Establish long recreational trails in a north-south orientation and buffer them with natural cover to facilitate dispersal.
10.9.2. Establish trails or other linear conservation areas that run perpendicular to coastlines to facilitate movement across lake/marine climate zones or retreat from sea-level rise.
10.9.3. Encourage private conservation easements adjacent to existing protected areas through favorable tax incentives or agricultural set-aside programs.

10.10. Create temporary or dynamic reserves

In some landscapes it may be impractical to establish permanent protected areas. Additionally, the habitat needs of some species may shift year-to-year and may migrate beyond the current network of protected areas. In these instances, wildlife managers may opt to establish dynamic or temporary reserves on private land that can provide value only so long as they are necessary (Leach et al. 2013, Rissman et al. 2015, Reynolds et al. 2017).

10.10.1. Establish "rolling" conservation easements perpendicular to shorelines that are anticipated to experience increased inundation.
10.10.2. Revise land acquisition plans to acquire/divest of lands as species shift out of protected lands and into unprotected lands.
10.10.3. Incentivize landowners to create temporary wetlands on their property to provide seasonal habitat for migratory waterfowl.

10.11. Maintain or enhance habitat across the annual cycle and life stages

Wildlife managers will need to consider the altered timing of habitat availability, particularly for species that depend on crucial sources of food, water, or cover at particular life stages or seasons of the year (Minor and Lookingbill 2010, Higuchi 2012). Protected areas can be designed to encompass new crucial areas as conditions change.

10.11.1. Maintain winter habitat complexes for white-tailed deer as well as spring foraging areas in adjacent uplands.
10.11.2. Maintain both breeding and wintering habitat for Kirtland's warbler in the upper Great Lakes and Bahamas.

10.12. Protect current safe havens for climate vulnerable populations to ensure those populations are available for future conservation efforts

Species that are vulnerable to climate change may also be currently rare, threatened, or endangered. It may be necessary to establish protected areas around existing populations of these species in order to ensure that they are available to supplement intensive future adaptation efforts such as captive breeding, head-starting, or assisted migration (Simmons et al. 2004, Asner et al. 2009, Fischman et al. 2014).

10.12.1. Protect critical habitat for threatened or endangered species, such as groundwater-fed wetlands with adjacent uplands for eastern Massasauga rattlesnakes.
10.12.2. Protect important stopover habitat for migratory birds in the western Lake Erie watershed.

10.13. Protect sufficient habitat for viable populations to be self-sustaining and of sufficient quality to create surplus dispersers

Many adaptation strategies assume dispersal will follow suitable climate niches, but dispersal usually depends on having surplus individuals in a population. Populations that are in decline are less likely to motivate dispersal. Protecting viable populations may therefore be necessary for dispersal to occur (Pontes et al. 2012, Rao et al. 2013, Reside et al. 2014).

10.13.1. Create large complexes of interior forest habitat for birds like scarlet tanagers.
10.13.2. Increase habitat quality along northern or high elevation edges of a species' geographic range.

11. Promote wildlife habitat conservation on lands outside of protected areas

Most wildlife habitat is not under formal protected status, and many wildlife species depend on ecosystems that are intermingled or entirely converted to agricultural, residential, or urban land-uses. Ensuring that wildlife can adapt to climate change will depend on management actions outside of protected areas. This Strategy contains several Approaches that suggest how wildlife managers can work in "the matrix" of ownerships across the landscape.

Approaches and Example Tactics

11.1. Identify and restore degraded landscapes with high potential habitat quality

Wildlife managers can help address the challenges of habitat loss and degradation by restoring habitat outside of protected areas. It may be possible to strategically choose restoration projects that will offer many benefits and sustained value as the climate changes (Booth et al. 2013, Fischman et al. 2014, Corlett 2016).

11.1.1. Remove marginal agricultural land from production and restore to native vegetation.
11.1.2. Implement prescribed fire in longleaf pine stands to restore open habitats and reduce encroachment of woody species to improve habitat for red-cockaded woodpeckers.

11.2. Reduce or limit barriers to wildlife movement across private land

Managers can facilitate connectivity and migration as the climate shifts by identifying barriers to wildlife movement and addressing these through infrastructure changes or ecosystem management practices (Hamilton et al. 2015, Lister et al. 2015).

11.2.1. Promote wildlife-friendly fencing, such as incorporating gaps or "lay-down" areas when livestock are not present.
11.2.2. Restore wetlands on private lands to provide stopover areas for migratory waterfowl.
11.2.3. Develop wildlife crossing structures across major impediments like highways.

11.3. Manage private lands near and between protected lands (buffer zones)

Private lands that occur near or between protected lands can effectively extend the size of a protected area if they are managed in a compatible fashion. Private lands managers can recommend practices that integrate well with habitat values on nearby protected lands (Oliver et al. 2012, Hamilton et al. 2015).

- *11.3.1. Manage for young forest cover on private land next to protected conifer swamps to provide a continuous complex for deer forage.*
- *11.3.2. Promote mature forest characteristics on private land next to protected old-growth forests.*

11.4. Enhance green infrastructure and promote sustainable urban landscapes

Urban and residential lands are habitat to a surprising array of wildlife species. These areas often have high capacity to manage or restore wildlife habitat, and they can promote connection between humans and wildlife in surprising and unexpected ways (Oliver et al. 2012, Fischman et al. 2014, Vogiatzakis et al. 2016).

- *11.4.1. Plant a diversity of pollinator species in urban and developed landscapes.*
- *11.4.2. Connect urban parks and other open spaces to provide greenways for wildlife movement.*
- *11.4.3. Establish incentives to promote infill development in metropolitan areas rather than suburban and exurban development.*

11.5. Manage public or private agricultural land to provide compatible wildlife use

In rural areas, agriculture is often the dominant land use. Wildlife managers and agricultural producers can find solutions that meet food production and wildlife habitat goals (Kostyack et al. 2011). This might include filter strips, planting native cover in unproductive parts of fields, or reducing pesticides and herbicides during certain ties of the year (Gebbers and Adamchuk 2010, Driscoll et al. 2012, Hamilton et al. 2015).

- *11.5.1. Establish or maintain grazing rates on public grasslands that also allow for wildlife use.*
- *11.5.2. Establish prairie vegetation strips in the midst or on the perimeter of row crop fields to provide pollinator habitat.*
- *11.5.3. Follow "precision agriculture" principles to reduce application rates of herbicides and insecticides.*
- *11.5.4. Follow wildlife-friendly certification standards, such as the Audubon Society "Conservation Ranching" practices.*

11.6. Manage forest structure to provide compatible wildlife use

The majority of forest land, including managed forest land owned by federal, state, and local agencies, is still subject to timber management. Working forests can be an opportunity to provide habitat values for wildlife, in addition to sustained supplies of wood fiber and timber, and thoughtful silvicultural practices are being demonstrated in many forest types (Felton et al. 2010, Fassnacht et al. 2015).

- *11.6.1. Retain and encourage large woody habitat in managed forest land (standing snags and down logs).*
- *11.6.2. Manage forests to provide young regeneration of browse species adjacent to deer wintering complexes.*

Additional Adaptation Strategies

12. Intentionally choose to take no action

Addressing all the threats related to climate change in all places will be beyond the capacity of wildlife management agencies and professional staff. Wildlife managers will need to be strategic and intentional about interventions, including deciding when it is appropriate not to intervene. This Strategy describes three different Approaches to intentionally taking no action.

Approaches and Example Tactics

12.1. Take no action in some situations as part of an overall triage strategy

Triage is the concept of focusing interventions away from those that do not need interventions and those for whom intervention is unlikely to be successful. Under this approach, some species and locations will not receive management interventions because adaptation options are too expensive or unlikely to be successful (Hagerman and Satterfield 2014).

12.1.1. Elect to focus resources on threatened, but viable, Species of Greatest Conservation Need populations.
12.1.2. Divert resources from high-cost, low conservation value wildlife management areas or reserves.
12.1.3. Elect not to pursue high-cost, socially unacceptable conservation measures in order to focus on more viable actions.

12.2. Designate "no action" areas as a control to compare with management interventions

Climate change adaptation will provide numerous opportunities for studying the effectiveness of management techniques. In situations where scientific rigor is appropriate or necessary to determine management outcomes, it will be necessary to leave some areas as "no action" controls, perhaps for extended periods of time or in perpetuity (Zellmer 2012).

12.2.1. Select areas to monitor bird species in managed versus unmanaged forests.
12.2.2. Compare reproduction for waterfowl where shallow lakes are managed differently.

12.3. Allow for autonomous, or unassisted, adaptation to climate change

Managers may opt to allow some wildlife species to evolve to cope with changing conditions. In these situations it may be appropriate to opt for a "wait and see" outlook to observe how adaptation proceeds without human intervention (Oliver et al. 2012, Corlett 2016).

12.3.1. Monitor changes in arrival dates and productivity of short-distance migratory birds in response to changing temperature and food sources.
12.3.2. Plant diverse suites of grassland plants and monitor changes in phenotype and genotype in response to changing climate.

13. Engage human communities in wildlife conservation

Climate change adaptation, especially situations that call for new styles of management, wildlife population changes, or wildlife range shifts may be suitable opportunities to engage or re-engage the public and communicate the intent of adaptation. Encouraging public engagement with wildlife can be an important aspect of climate change response, because a society that is more invested in the success of wildlife may be more likely to support new or more intensive measures for adaptation. This Strategy contains several Approaches that each deal with the human side of wildlife management.

Approaches and Example Tactics

13.1. Develop outreach and technical assistance programs for the public

Existing outreach and technical assistance programs can be an asset to climate change adaptation, because they reach private landowners and the general public (Yaffee 2011, Blaustein 2013, Hamilton et al. 2015). It may be necessary to modify the typical content as well as the target audiences of these programs in order to make them more effective.

13.1.1. Work with stakeholders ahead of time to communicate why climate change will result in noticeable change that adaptation actions may not be able to address, as in the case of declining moose populations in Minnesota.
13.1.2. Facilitate the expected expansion of bighorn sheep in Colorado by establishing technical assistance programs for private landowners to construct wildlife-friendly fencing and enhance open, fire-dependent habitat.
13.1.3. Target outreach programs to reach diverse audiences, including urban and underserved communities.

13.2. Provide access for wildlife-dependent recreation

Recreation that depends on wildlife, such as viewing and hunting, can be useful means to encourage engagement with wildlife and generating support and revenue for adaptation actions (Shafer 1999, Schlacher et al. 2013). Different forms of recreation can happen across the spectrum of public and private lands.

13.2.1. Diversify use categories in protected areas to allow for compatible forms of recreation.
13.2.2. Develop recreational opportunities outside of protected areas, such as birdwatching tours in metro parks or agricultural landscapes.

13.3. Increase local community involvement in wildlife management

Climate change is a global phenomenon, but the impacts will be felt locally. When communicating the potential impacts of climate change, or the potential consequences of adaptation, it will be necessary for managers to reach local communities and people who will be most directly affected (Kingsford et al. 2009, Rao et al. 2013). This can include soliciting input and ideas for adaptation actions, rather than a strict one-way communication from managers to the public.

- *13.3.1. Develop citizen-science programs to monitor wildlife use or changing phenology in protected areas.*
- *13.3.2. Respectfully solicit input from local indigenous communities regarding the management of wildlife and wildlife habitat in homelands or ceded territories.*
- *13.3.3. Work with stakeholders ahead of time when climate adaptation will result in noticeable change, such as "no action" responses to climate change.*

13.4. Promote community-managed conservation lands

There may be situations where the public can play a role in directly managing wildlife, such as community forest management, cooperative agreements between public agencies and private landowners, and funding organizations (Asare et al. 2013, Brito et al. 2014). Community-based management can build support for, and extend the reach of, climate adaptation strategies.

- *13.4.1. Identify private forest lands adjacent to rural communities that may be viable candidates for municipal ownership and funding through the USDA Forest Service Community Forest Program.*
- *13.4.2. Establish cooperative agreements among ranchers to restore and manage wildlife habitat for nature-based tourism and hunting opportunities.*
- *13.4.3. Establish landowner cooperatives to restore and manage wildlife habitat, such as the Nebraska Prescribed Fire Council.*
- *13.4.4. Create endowments for management of community-managed reserves or private lands.*

13.5. Respect and incorporate landscape values of indigenous communities in management decisions

Indigenous communities have a long history and deep relationships with the species and places in their homelands. Not only will they be most profoundly affected by climate change impacts to wildlife and natural ecosystems, but they may have unique perspectives on appropriate ways to respond and prepare for change (Walter and Hamilton 2014, Tribal Adaptation Menu Team 2019). Wildlife managers should take every opportunity engage indigenous communities in the process of climate change adaptation.

- *13.5.1. Consult with Tribal Historic Preservation Officers, elders, and other knowledge holders to learn about the historical and present community relationships with an area.*
- *13.5.2. Design management actions that also enhance and sustain indigenous community values, such as coordinating prescribed fires in areas and during seasons that will enhance blueberry-picking opportunities.*

13.6. Pay for ecosystem services that also benefit wildlife

Payment for ecosystem services (PES) frameworks include a variety of arrangements where landowners receive benefits in exchange for managing their land to provide some sort of ecological service, such as water provision or carbon sequestration. PES arrangements can be utilized to benefit wildlife, by stipulating that management practices promote wildlife habitat or targeting lands that have significant wildlife value (Poiani et al. 2011, Rao et al. 2013, Wiederholt et al. 2015).

13.6.1. Subsidize the cost of wildfire mitigation actions upstream from municipal water sources through payments from the water utility, based on the avoided cost of water treatment from maintaining a forested watershed.
13.6.2. Promote conservation easements through tax incentive programs.

13.7. Coordinate across landowners and scales to make sure programs are complementary Wildlife management may involve a complex network of private landowners and agencies, each working at different scales and with different authorities. Effective adaptation will require coordination across landowner and organizational boundaries, particularly to implement landscape-scale adaptation projects or to coordinate complex projects such as assisted migration or identifying and preserving climate refugia (Shafer 1999, Marini et al. 2009, Groves et al. 2012).

13.7.1. Coordinate with upstream and downstream land owners and agencies while designing habitat restoration projects along river corridors.
13.7.2. Work with local agencies and local communities to plan supporting management actions and outreach programs when planning species movements such as translocations or range expansions.
13.7.3. Identify "boundary organizations" that can facilitate collaboration across organizations and help with landscape-scale adaptation projects.

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